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Microbial Activities in the Mangrove (Rhizophora mangle)

Leaf Detrital System

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INTRODUCTION

The red mangrove (Rhizophora mangle L.) detrital system is a basic energy source for certain food webs in estuarine environments (Odum, 1970). The degrading leaves are converted by microorganisms to a high protein material that is consumed by small invertebrates which, in turn, are consumed by commercially important fishes and crustaceans. Similar leaf degradation systems have been observed in terrestrial (Hudson, 1968; Clark and Paul, 1970; Preece and Dickinson, 1971) and freshwater (Cairns, 1969; Odum, 1971; Kaushik and Hynes, 1971; Hynes, 1970) communities. Freshwater community structures are dependent, to a large extent, on the import of degradable organic materials (Chapman, 1966; Nelson and Scott, 1962; Cummins et al., 1973; Minshall, 1967). During leaf decay there is an absolute increase in nitrogen that is 2 to 3 times the original (Kaushik and Hynes, 1971). Fungi, rather than bacteria, have been considered to be the principal source of this nitrogen increase, and Kaushik and Hynes (1971) found that animals feed preferentially on microbially infested leaves. A microbial decay process also takes place in Spartina salt marsh communities (Burkholder and Bornside, 1957); these marshes have a twofold importance to the adjacent estuary, as a nursery ground for a variety of animals and for the production of organic materials (Teal, 1962).

The only mangrove detrital system that has been studied in any detail is R. mangle. Heald (1969) observed, during the degradation of mangrove leaves, a significant increase in the relative amount of protein similar to that observed in freshwater systems due to fungal activities. Heald conjectured that fungal protein might be an important food source for the detrital consumers.

Casagrande (1970) examined some of the chemical changes during leaf

decay. He analyzed the amino acids in living and dead plant material (R. mangle and Cladium) in the Everglades (Florida) and found considerable increases in amounts of protein and non-protein acids in the surface litter. While it was difficult to distinguish the added proteins in the surface litter from those originally present in the protoplasm, most of the non-protein acids were either not present in the plant or were in much higher concentrations in the litter than in the living plant. Some of the non-protein acids such as γ -aminobutyric acid, α - γ -diaminobutyric acid and α - ϵ -diaminopimelic acid are constituents of bacterial cell walls, whereas α -aminobutyric acid, citrulline, ornithine and cysteic acid are metabolic breakdown products of microbial protein amino acids. Casagrande assumed that fungi were involved in the conversion process; however, it was not possible to prove this biochemically due to the lack of amino acids that are specific to fungal cells.

There have not been any extensive studies of fungi from mangrove leaves. The available reports (Creager, 1962; McMillian, 1964; Ciferri and Fragaso, 1927; Batista et al., 1955; Guba, 1961; Stevens, 1920; Vizioli, 1923) have been examinations of parasites and saprophytes on living leaves. Additional mycological studies in mangrove habitats include the extensive research of Kehlmeier (1969) of the woody parts; Lee and Baker (1973) of roots; and Lee and Baker (1972a,b), Rai et al. (1969), Swart (1958, 1963), Cribb and Cribb (1955, 1956, 1960) and Ulker (1970, 1972) in soils. This research has been reviewed by Newell (1975) who studied the fungal successions on red mangrove seedlings.

As far as we are aware, the meiofauna associated with degrading mangrove leaves have not been studied, although certain mangrove sediment groups such as the foraminifera (Bronniman and Zaninetti, 1948; Saunders, 1958), nematodes

(Gerlach, 1957; Timm, 1966) and polychaetes (Hartmann-Schroder, 1959) have been investigated.

The purpose of the present program is to study the degradation processes in mangrove leaves; in this paper we will discuss the fungi that are associated with various stages of leaf degradation, the alterations in nitrogen levels that take place, and some of the population responses of the primary consumers (meiofauna).

METHODS

Rhizophora mangle leaves were collected from the following locations:

1) Stations from the north to south ends of Biscayne Bay (Miami, Fla.) including Turkey Point, Mangrove Point, West Point, Matheson Hammock, Bear Cut; 2) Card Sound, which is south of Biscayne Bay; 3) Several other locations in Florida including Windy Key in the Florida Keys, Ten Thousand Islands and Flamingo Key on the west coast, and Ft. Pierce on the east coast; 4) Bahamas including Andros Island, Conception Island, Long Island, Great Exuma and Man-O-War at Abaco Island; 5) The Caribbean including Gonave Island (Haiti), Jamaica, Grand Cayman, Curacao and Bonaire (Netherlands Antilles), Columbia, Costa Rica, Trinidad; 6) Viet Nam; 7) Selangor, Malaysia; 8) Seychelles in the Indian Ocean. The leaves from the Indian and Pacific Oceans were not identified but they were from mangrove species other than R. mangle.

At all of the stations, random samples of leaves were obtained that usually included those that were pre-senescent, senescent and post-senescent as estimated by color (green, yellow, brown). Samples were transported to the laboratory in sterile plastic bags with enough water from the field to keep the material moist. Some of the Caribbean and all of the

Pacific and Indian Ocean samples were sent to us by cooperating investigators (see acknowledgments).

For the succession studies, collections were made of senescent yellow leaves that easily detached from the tree and were considered ready to fall. The leaves were placed in nylon mesh bags with a 2.5^{sq. mm} mesh size. The bags, with 50 leaves/bag, were tied to mangrove roots so that they were continuously submerged and lay on the bottom in the leaf litter. Leaves were removed from the bags weekly or bi-weekly for 3 months. At each sampling period, two leaves were removed from each bag and placed in sterile plastic containers for transportation to the laboratory. Succession studies were in the Miami area at Card Sound, Matheson Hammock, Mangrove Point, Turkey Point in July 1970 and at Turkey Point in April 1971. A study was made at Andros Island, Bahamas in August 1973. This was a 5-day study of 2 stations, 5 miles apart; samples were collected every 24 hours.

Fungal isolation techniques (Fell and Master, 1973) employed incubation of 4 mm dia. leaf discs on corn meal agar (Difco, prepared with 15 ppt (parts per thousand) seawater and 0.02% chloromycetin) with and without prior leaf surface sterilization with a mercuric chloride-alcohol wash. A water culture technique was used for some of the lower fungi. This consisted of placing leaf discs in 100 x 15 mm dishes containing 25 ml of 15 ppt seawater with 0.05% streptomycin sulfate and 0.05% penicillin G. Temperature tolerances were tested by measuring the daily radial colony growth on corn meal agar at 15 ppt salinity.

For meiofaunal studies, the leaves were placed in clean glass petri plates and then gently scraped with a rubber policeman, using a washbottle of seawater for rinsing to remove all of the detrital coating. The rinsing and detritus were brought to a 50 ml volume. Ten ml aliquots were

examined in a counting chamber. The number and types of meiofauna were recorded and the results extrapolated to the total volume. The numbers of meiofauna per square centimeter of leaf surface were calculated. The mangrove leaf surface area was approximated by determining the area of an oval (2Hab), to include the two leaf surfaces. The animals were cultured by placing the leaves on the surface of half-strength Difco corn meal agar plates prepared with 15 ppt seawater (Hopper et al., 1973). Most of the meiofaunal species migrated into the agar, carrying with them the microorganisms which they utilized as a food source. The microbes, mostly bacteria, proliferated on the corn meal agar. This particular medium was chosen because of its transparency which facilitated microscopic viewing of the meiofauna with a dissecting microscope and in many cases permitted the elucidation of their life histories. Temperature tolerances (12-37 C) were carried out by the establishment of monospecific meiofaunal cultures on separate 15 ppt corn meal agar plates (Hopper et al., 1973).

In a separate study the habitat range of the mangrove associated meiofauna, within an estuary, was examined on two diverse substrates: sublittoral sediments of Card Sound and marsh grasses (*Juncus* and *Cladium*) on the adjacent coast. Sediment collections were obtained October 1968 at 4 stations in Card Sound, varying from 500 to 1800 meters offshore at water depths of 1 to 3 m. Eight surface sediment cores (10 cc each) were collected at each station. Nematodes were extracted from the sediment by differential centrifugation and sieving techniques, then preserved in 4% seawater formalin for later identification. Marsh grasses were examined by the same litter bag techniques as used for mangrove leaves.

Relative carbon and nitrogen values were determined from leaves collected from a sequential litter bag study, November 1973 - March 1974, in

Card Sound. The leaves were washed to eliminate surface debris and animals, and then oven dried at 105 C for one week or until a constant weight was reached. The samples were ground in a Wiley mill and the powder stored in a vacuum desiccator until processing in a Perkin-Elmer 240 Elemental Analyzer. The results were recorded on a per weight basis. Absolute values required the additional step of a constant volume throughout the series which was obtained by cutting 21 mm diameter discs with a cork borer. These discs were dried, weighed and the percent of carbon and nitrogen determined. This percentage was multiplied by the weight of the disc. Thirty to forty leaves were tested from each of 0, 15, 24, 50, and 115 days. The results of each sampling period were subjected to an analysis of variance test followed by the Student-Newman-Keuls test ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Mycoflora

The initial studies of mangrove leaf degradation were designed to obtain a general picture of the decay process and to ascertain the associated fungi. These results were published by Fell and Master (1973), who isolated 66 genera of fungi and observed a sequence of infestation. Senescent leaves, prior to leaf fall, harbored several parasitic and saprophytic fungi. Pestalotia and Phyllosticta were readily discernable due to their large fruiting bodies that were visible as small dark spots in the upper epidermis of the leaf. Some of the other fungi, particularly Aureobasidium and Myrothecium, were adventitious or leaf surface colonizers. Many of the fungi, e.g., Cladosporium, Cylindrocephalum and Nigrospora, penetrated the internal layers of the leaf. These fungi varied in their ability to survive

when the leaves fell in the water. Pestalotia, the most prevalent genus, persisted throughout the decay process whereas Phyllosticta disappeared after the first week in the water, and the remaining genera diminished in prevalence at differing rates. A variety of fungi invaded the leaves as they decayed. Within the first week of submergence the most abundant initial invaders were the Phycomycetes Thraustochytrium, Schizochytrium, Phytophthora vesicula and several undescribed species of Phytophthora. In some instances these were the only fungi isolated from the leaves. Other primary invaders were Aspergillus, Penicillium, Trichoderma, Fusarium, Curvularia and Drechslera. In the Fell and Master report (1973), Drechslera was mis-identified as Dendryphiella, also Fusarium was listed as a Cephalosporium-Fusarium-Verticillium complex. Subsequently, we incubated that complex of organisms at 37 C and found that they all produced typical Fusarium macroconidia. The only significant invader that appeared after the second week of submergence was Lulworthia, a cellulolytic marine Ascomycete. The enrichment technique that we used is preferential for several of the ubiquitous hyphomycetes. The water culture technique, which was designed for phycomycetes, uses a low nutrient medium and therefore was also of value for observing slow growing marine forms. Of particular interest was Zalerion varium, which was found on the majority of the leaves after the second and third weeks of submergence in the litter bag studies. Another incubation technique that should be considered, in future studies, is the Keyworth (1951) damp chamber.

The majority of the genera isolated from the mangrove leaves are ubiquitous saprophytes that are often associated with the breakdown of plant material. Many of these genera have been isolated from a variety of substrates including terrestrial soils (Barron, 1968), terrestrial leaf

litter in terrestrial soils (Hering, 1965), in freshwater (Kaushik and Hynes, 1968) and in seawater (Anastasiou and Churchland, 1969), the marine grass Thalassia (Meyers et al., 1965), mangrove muds (Rai et al., 1969; Swart, 1958) and salt marshes (Dickinson, 1965). In contrast, the fungal populations reported from mangrove wood (Kohlmeyer, 1969) are quite distinct from the populations in leaves. Only Phoma and Lulworthia were found in both substrates.

As indicated, the phycomycetes were prevalent during the initial phases of decay. Very little is known about the role of phycomycetes in marine detrital systems. Perkins (1973) suggested that labyrinthulids and thraustochytrids might be significant in the detrital formation of non-marine sporophyte material. Anastasiou and Churchland (1969) described Phytophthora vesicula from arbutus (Arbutus mensiesii) and laurel (Prunus laurocerasus) leaves that were submerged at brackish and marine sites near Vancouver, B.C. The incidence of P. vesicula was high, 71% of the 750 leaves examined contained the fungus. Volz and Jerger (1972) reported Schizochytrium and Thraustochytrium from marine soils, mangrove wood and algae at Abaco Island, Bahamas. Ulken (1970, 1972) also observed those two genera in marine soils in Brazil. The genus Phytophthora has not been reported from mangroves, in fact, Lee and Baker (1973) remarked about the absence of phycomycetes on mangrove roots in Hawaii, but suggested it might be due to the isolation techniques. Methodology is important; using the water culture technique we found P. vesicula and an undescribed Phytophthora species to be prevalent in leaves from a variety of locations (Table 1). Phytophthora sp. has a spiny globose sporangium (Fig. 1), a characteristic that has not been described in the genus. As indicated in Table 1, this species appears to have a

TABLE 1

Filamentous Phycomycetes from decaying mangrove (Rhizophora mangle) leaves.

SPECIES	Miami, Fla.						Florida			Bahamas				Caribbean						Pacific-Indian					
	Bear Cut	Card Sound	Mangrove Point	Matheson Hammock	Turkey Point	West Point	Flamingo	10,000 Islands	Windy Key	Abaco	Andros Island	Conception Island	Long Island	Bonaire	Columbia	Costa Rica	Curacao	Gonave	Grand Cayman	Jamaica	Trinidad	Malaysia ¹	Viet Nam	Seychelles ¹	
<u>Phytophthora vesicula</u>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<u>Phytophthora</u> sp. A (Globose spiny sporangium)	X		X	X	X	X	X	X	X	X	X	X		X	X		X	X	X		X				
<u>Phytophthora</u> sp. A (Lobate spiny sporangium)																						X	X	X	
<u>Phytophthora</u> spp (Fungal parasites)	X			X		X										X						2			

1. Mangrove species not identified.

2. Morphologically, the Malaysian isolates are distinct from those isolated elsewhere.

distinct geographical distribution as it has not been isolated from Asian or Indian Ocean samples. Those areas have a similar species or variety with a spiny but lobate sporangium (Fig. 2).

The 24-hr sequential studies at Andros Island, Bahamas demonstrated that the two species of Phytophthora inhabit 75 to 100% of the leaves within the first 24 hrs of submergence and retained this level for the entire 5-day test period. The results of the long-term experiments in Florida were variable. The 1970 study indicated a 20% infestation after 7 days of submergence, whereas the 1971 testing at the same time period indicated a 100% infestation by the Phytophthora spp. In all cases the phycomycetes were rare or not present after four weeks of submergence. Our sampling program is not sufficiently extensive at present to ascertain the environmental conditions that affect phycomycete colonization. The specific role of these phycomycetes is not known; they are probably saprophytes that utilize the readily available carbon compounds.

Phytophthora may have an additional role in the mangrove degradation system. We found a species at several locations in Florida waters that is parasitic on other fungi, particularly Pestalotia, Americosporium and Fusarium. The hyphae of the parasitized fungi are attacked by appressoria, twining and hyphal invasion (Fig. 3). Formal descriptions of these and other mangrove associated phytophthoras are being prepared.

Phycomycetes are also parasitic on the animal populations. During our study of nematodes associated with mangrove leaves, Newell and Cefalu (unpublished) found a lagenideaceous species, Myzocyttium (vermicolum?) (Fig. 4) that was pathogenic on marine rhabditid nematodes. Zoospores of Myzocyttium attach by an adhesive process to the cuticle of the nematode, Rhabditis marina. The zoospore penetrates the cuticle and grows as a hypha

throughout the nematode's pseudocoelom. The hyphae digest the nematode's internal organs and eventually convert entirely to zoosporangia; tubes form through the cuticle and the motile zoospore stage is released.

In addition to the phycomycete, Newell and Cefalu encountered two hyphomycetous fungi, Harposporium that destroyed nematodes of the genus Diplolaimelloides and Paecilomyces (Fig. 5) that attacked a tylenchid nematode. The hyphae infect the animals internally and develop external conidia. Also, Zalerion varium, a common mangrove fungus, has been observed "trapping" nematodes of the genus Monhystera. Most of these nematode destroying fungi can be readily observed in culture and will destroy an entire nematode culture population. However, their role in controlling nematode populations in nature is unknown.

Carbon-Nitrogen Analyses

The alterations in nitrogen content, as an indication of protein concentrations and the potential food value of degrading leaves, have been examined for several litter systems. Kaushik and Hynes (1971) observed absolute increases in nitrogen with various leaves in freshwater streams. In their review, they noted that in woodland litter studies, absolute nitrogen levels varied; it was suggested that the available phosphorous and nitrogen was the determining factor. In Spartina, Odum and de la Cruz (1967) reported a relative increase in nitrogen during the decay process, as did Heald (1969) in studies of red mangroves.

As there is some question as to the meaning of an increase in the relative amount of nitrogen, we compared relative and absolute nitrogen and carbon values (Figs. 6 and 7) as well as dry weight loss and C:N levels (Fig. 8) from leaves in Card Sound. The results of dry weight loss and

relative nitrogen changes are essentially the same as those presented by Heald (1969) for the Everglades. The mean values in Figs. 6-8 are given with 95% confidence intervals. Within the first 15 days there was a 36% dry weight loss which gradually increased to a 59% loss at 115 days. Paralleling this loss was a decrease in C:N from 109 at day 0 to 55 at day 115. In terms of relative nitrogen there was a 58% increase during the 115-day period, suggesting enrichment. In contrast, significance was not detected between mean absolute nitrogen values at day 0 and day 115, although there was a 16% increase from day 15 to day 50. The relative amount of carbon (Fig. 6) increased by 17% from 0 to 115 days; however, absolute carbon values (Fig. 7) indicated a 51% loss for the 115-day study period. Thirty-two percent of this loss took place during the first 15 days.

It would appear that there was a rapid loss of materials due to leaching, followed by microbial colonization which increased the nitrogen content of the leaf. This increase was considerably smaller than previously indicated by relative nitrogen. These results demonstrate nitrogen standing crop and do not take into account the constant and rapid turnover that is taking place in and on the leaf due to the activities of large populations of microbes and meiofauna.

Assuming a rapid production and utilization of protein, the question is presented as to the origin of the nitrogen. Nitrogen concentrations in the mangrove intertidal waters have not been measured. The only available information is from surface waters in Card Sound (Segar et al., 1971) which demonstrated that nitrates ranged from 6 to 93 $\mu\text{g/liter}$ and nitrites from 4 to 8 $\mu\text{g/liter}$. These figures suggest that ambient nitrogen levels are low, as they are in most marine areas. Therefore, Taylor (personal communication) considered another source of nitrogen, specifically, nitrogen

fixation by bacteria on the mangrove leaves. In preliminary field degradation studies of 2 to 28 days, Taylor found that the rate of nitrogen fixation ranged from 24 to 96 $\mu\text{g/day/gm}$ dry wt of mangrove leaf. The nitrogen values in degrading leaves reported in Fig. 8 for the days 15-50 are equivalent to 54 $\mu\text{g/day/gm}$. This would suggest that bacteria are capable of contributing a considerable portion of the required nitrogen.

Meiofauna

Within the first 24 hrs of submergence there is an accumulation of detritus and sediment particles as well as fungal spores, meiofauna and unicellular algae on the leaves. In many cases, a bacterial slime will coat the leaves and act as a matrix for adhesion of these particles and organisms. Studies at Andros Island (Table 2) indicated that during the first six days there was a gradual increase in the numbers of animals to approximately 2 to 13 animals/sq cm of leaf (a sq cm averages 1.4% of the leaf surface area). Longer term studies in Florida (Table 3) demonstrated peaks at 3 to 7 weeks in the range of 34 to 71 animals/sq cm of leaf. These data are insufficient to withstand statistical scrutiny; however, they indicate a trend of increasing population densities during the decay process. The majority of the animals were nematodes and copepods. In an examination of 30 samples (3 leaves/sample) over a year in Florida, 29 to 95% of the meiofaunal populations were nematodes (average 73%), 1 to 58% were copepods (average 21%) and 1 to 21% (average 6%) were a variety of other animals. There is considerable variation, quantitatively and qualitatively, in the meiofaunal populations on the leaves at any particular site. This has not been statistically evaluated. As an indication of the observed community structure, a "typical" degrading mangrove leaf usually

TABLE 2

Total number of meiofauna per cm² surface area of leaf with time of submergence, Andros Island, Bahamas (average of 3 leaves/sample).

	Number of Days Submerged					
	1	2	3	4	5	6
STATION 1						
Exp. 1	0.1	0.4	4.6	-	5.2	7.0
Exp. 2	0.5	1.9	0.9	-	1.6	3.6
STATION 2						
Exp. 1	1.3	1.0	3.2	-	7.1	13.2
Exp. 2	0	0.2	1.2	-	0.9	1.5

TABLE 3

Total number of meiofauna per cm^2 surface area of leaf with time of submergence, West Point, Biscayne Bay, Florida (average of 3 leaves/sample).

	Number of Days Submerged								
	11-12	17-20	23-25	28-34	38-42	47-48	50-53	59	64
STATION 1	<1	2	6	2	34	11			
STATION 2									
Exp. 1	7	15	61	71	43	57			
Exp. 2	4	16		42	15	17	20	11	

includes 10 species of nematodes, 1 to 3 copepod species, 1 to 2 polychaete species, several species of foraminifera and large ciliates, and one species each of flatworms, insect larvae, mites, oligochaetes, ostracods, tardigrades and testacids. Ecological studies of this type are particularly difficult due to the lack of taxonomic information on the various meiofaunal groups. Many of the species that we have examined appear to be undescribed. The lack of in-depth taxonomic studies has resulted in a compromise that is useful in the laboratory but unsatisfactory for reporting purposes. We have maintained permanent slide mounts and drawings for the majority of the unidentified species in order to recognize and compare animals from different locations. These comparative studies have indicated that certain populations are cosmopolitan in distribution, whereas the occurrence of other populations will vary with location and environmental conditions. Species that appear to be ubiquitous components of the leaf habitat (Tables 4 and 5) include the nematode Diplolaimelloides sp. 1, the copepod Leptocaris trisetosa, the polychaete Capitellides giardi, and the foraminifera Trichohyalis sp. and Quinqueloculina sp.. Many of the geographical restrictions observed in Tables 4 and 5 may be due to sampling error, for example there was considerably more sampling in Florida than in Viet Nam, which makes it difficult to confidently distinguish specific geographical groups. Possible exceptions are Diplolaimelloides spp. 3 and 4, Mononchoides sp. and Oncholaimus spp. 5 and 7 from Malaysia. This particular difference in meiofaunal populations may be host dependent as R. mangle does not occur in Malaysia.

Table 6 indicates the basic results of meiofaunal distribution studies in mangrove leaves, sublittoral sediments and marsh grasses. These lists are restricted to the more abundant species, for example, over 100 spp. were

TABLE 4

Nematodes found on decaying mangrove (*Rhizophora mangle*) leaves at various locations.

	Miami, Fla.	Florida	Bahamas	Caribbean	Asia
<i>Diplolaimelloides</i> sp. 1	X	X	X	X	X
<i>Monhystera parelegantula</i>	X	X	X	X	X
<i>Cyatholaiminae</i>	X	X	X	X	X
<i>Dichromadora scandula</i>	X	X	X	X	X
<i>Halipllectus dorsalis</i>	X	X	X	X	X
<i>Oncholaimus</i> sp. 8	X	X	X	X	X
<i>Diplolaimella ocellata</i>	X	X	X	X	X
<i>Theristus</i>	X	X	X	X	X
<i>Eurystominae</i>	X	X	X	X	X
<i>Viscosia</i>	X	X	X	X	X
<i>Chromadorinae</i>	X	X	X	X	X
<i>Halticoanolaimus</i>	X	X	X	X	X
<i>Linhomoeinae</i>	X	X	X	X	X
<i>Syringolaimus striatocaudata</i>	X	X	X	X	X
<i>Theristus</i> sp. 1	X	X	X	X	X
<i>Actinonema</i>	X	X	X	X	X
<i>Chromaspirina</i>	X	X	X	X	X
<i>Desmodorinae</i>	X	X	X	X	X
<i>Epsilonematinae</i>	X	X	X	X	X
<i>Halalaimus</i>	X	X	X	X	X
<i>Neochromadora bonita</i>	X	X	X	X	X
<i>Oncholaimus</i> sp. 1	X	X	X	X	X
<i>Rhabditis marina</i>	X	X	X	X	X
<i>Spilophorella paradoxa</i>	X	X	X	X	X
<i>Tylenchidae</i>	X	X	X	X	X
<i>Anticomma</i>	X	X	X	X	X
<i>Axonolaimus</i>	X	X	X	X	X
<i>Cephalobidae</i>	X	X	X	X	X
<i>Diplolaimelloides</i> sp. 3	X	X	X	X	X
<i>Diplolaimelloides</i> sp. 4	X	X	X	X	X
<i>Enoplus parafittoralis</i>	X	X	X	X	X
<i>Euboeotrichus dianeae</i>	X	X	X	X	X
<i>Euboeotrichus parasitiferus</i>	X	X	X	X	X
<i>Meversia major</i>	X	X	X	X	X
<i>Mononchooides</i>	X	X	X	X	X
<i>Microlaimus</i>	X	X	X	X	X
<i>Odontopharynx</i>	X	X	X	X	X
<i>Odontophora</i>	X	X	X	X	X
<i>Oncholaimus</i> sp. 5	X	X	X	X	X
<i>Oncholaimus</i> sp. 7	X	X	X	X	X
<i>Parodontophora</i>	X	X	X	X	X
<i>Ptycholaimellus</i>	X	X	X	X	X
<i>Symplecostoma</i>	X	X	X	X	X
<i>Terschellingia</i>	X	X	X	X	X

* Mangrove species not identified

TABLE 5

Meiofauna, other than nematodes, found on decaying mangrove (Rhizophora mangle) leaves at various locations.

Meiofauna	Miami, Fla.					Florida			Bahamas			Caribbean				Asia		
	Card Sound	Mangrove Point	Matheson Hammock	Turkey Point	West Point	Fort Pierce	Sanibel Island	Windy Key	Andros Island	Exumas	Long Island	Bonaire	Curacao	Gonave	Grand Cayman	Jamaica	Malaysia *	Viet Nam *
COPEPODS																		
<u>Leptocaris trisetosa</u>	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
<u>Leptocaris vermicularis</u>	X	X							X			X	X					
<u>Nitocra & Nitocrella</u> spp.	X	X	X	X	X	X		X		X			X	X			X	X
<u>Paramphiascella robinsoni?</u>			X						X	X		X	X	X			X	X
<u>Microlaophonte</u> sp.	X	X							X			X						
POLYCHAETES																		
<u>Capitellides giardi</u>	X	X				X	X		X	X		X	X	X	X		X	X
unidentified with spines	X	X	X						X					X			X	X
unidentified with tentacles	X	X																
FORAMS																		
<u>Trichohyalis</u> sp.	X	X	X	X	X	X			X	X	X	X	X	X	X		X	X
<u>Quinqueloculina</u> sp.	X	X	X	X	X	X	X		X	X		X		X	X		X	X
CILIATES																		
<u>Keronopsis rubra</u>	X	X	X	X						X		X			X		X	X
OLIGOCHAETES																		
<u>Marionina</u> sp.		X	X	X		X	X		X	X			X	X			X	X
TURBELLARIANS																		
2 unidentified spp.	X	X	X	X		X	X		X	X		X		X	X	X	X	X
HYDRACARINES																		
several unidentified spp.	X	X	X			X			X			X	X					

* Mangrove species not identified.

TABLE 6

Nematodes found on shoreline decaying mangrove leaves (Rhizophora mangle) and grasses (Juncus roemerianus and Cladium jamaicensis) and in sublittoral sediments of Card Sound.

Nematode Taxa ¹	Sediments (36‰) ²	Decaying Mangrove Leaves (18-44‰)	Decaying Grasses (0-28‰)
<u>Cyatholaiminae</u>	X	X	X
<u>Dichromadora scandula</u>	X	X	X
<u>Epsilonematinae</u>	X	X	X
<u>Halalaimus</u>	X	X	X
<u>Monhystera parelegantula</u>	X ³	X	X
<u>Oncholaiminae</u>	X	X	X
<u>Oncholaimus</u>	X	X	X
<u>Ptycholaimellus</u>	X	X	X
<u>Syringolaimus striatocaudata</u>	X	X	X
<u>Theristus</u>	X	X	X
<u>Actinonema</u>	X	X	
<u>Anticoma</u>	X	X	
<u>Axonolaimus</u>	X	X	
<u>Chromadorinae</u>	X	X	
<u>Chromaspirina</u>	X	X	
<u>Desmodorinae</u>	X	X	
<u>Eubostrichus diancae</u>	X	X	
<u>Eubostrichus parasitiferus</u>	X	X	
<u>Euchromadora</u>	X	X	
<u>Halicoanolaimus</u>	X	X	
<u>Linhomoeinae</u>	X	X	
<u>Monhystera sp. 1</u>	X ³	X	
<u>Odontophora</u>	X	X	
<u>Parodontophora</u>	X	X	
<u>Spilophorella paradoxa</u>	X	X	
<u>Terschellingia</u>	X	X	
<u>Viscosia</u>	X	X	
<u>Diplolaimelloides sp. 1</u>		X	X
<u>Haliplectus dorsalis</u>		X	X
<u>Microlaimus</u>		X	X
<u>Neochromadora bonita</u>		X	X
<u>Tylenchidae</u>		X	X
<u>Diplolaimella ocellata</u>		X	
<u>Eurystomininae</u>		X	
<u>Aphelenchidae</u>			X
<u>Cephalobidae</u>			X
<u>Dorylaimidae</u>			X
<u>Ethmolaimus</u>			X
<u>Plectus</u>			X
<u>Rhabditinae</u>			X
<u>Ceramonema</u>	X		
<u>Cheironchus</u>	X		
<u>Croconema</u>	X		
<u>Epacanthion</u>	X		
<u>Metonyx</u>	X		
<u>Meyersia minor</u>	X		
<u>Monhysterinae</u>	X		
<u>Neotonchus</u>	X		
<u>Phanodermopsis</u>	X		
<u>Pselionema</u>	X		
<u>Richtersia</u>	X		
<u>Sphaerolaimus</u>	X		
<u>Tricoma</u>	X		

1. Taxa listed only as family, subfamily, or genus may contain more than one species.

2. Salinities recorded at sample collections.

3. In sediment samples specimens of Monhystera were found but not identified to species.

found in the sediment samples. Also additional sampling could alter some of the apparent habitat limitations of some of the species. However, the study established that the mangrove leaves do not have a specific nematode fauna. Some of the mangrove associated nematodes were ubiquitous to all of the habitats, others (in sediments and mangrove leaves) were restricted to the more saline environments and some, such as *Diplolaimelloides* sp. 1, may be specific constituents of decaying plant material. This species is particularly significant due to its widespread geographical distribution (Table 4).

One of the main environmental concerns in the study of food webs is the potential disruption of one or more of the links due to natural or man induced perturbations. As a preliminary indication of tolerance levels, we examined the temperature effects on two of the components of the leaf degradation system in the laboratory. Figure 9 indicates that the optimal growth temperature for strains of Phytophthora are at or below 33 C and that most strains are incapable of reproducing at 37 to 39 C. Similarly, the mangrove associated nematodes (Fig. 10) studied by Hopper et al. (1973) do not reproduce above 35 C. Although laboratory experimentation of this type requires confirmation in the field, it is suggested that high temperature, as occurs normally in the summer in some areas, and abnormally as a result of industrial effluents, may disrupt the entire food web.

SUMMARY AND CONCLUSIONS

Fungal invasion of R. mangle leaves initiates while the leaves are on the tree. Several species of fungi inhabit the leaves; some penetrate the epidermal layers, others are leaf surface inhabitants. Their survival and continued activity in the water vary with the individual species.

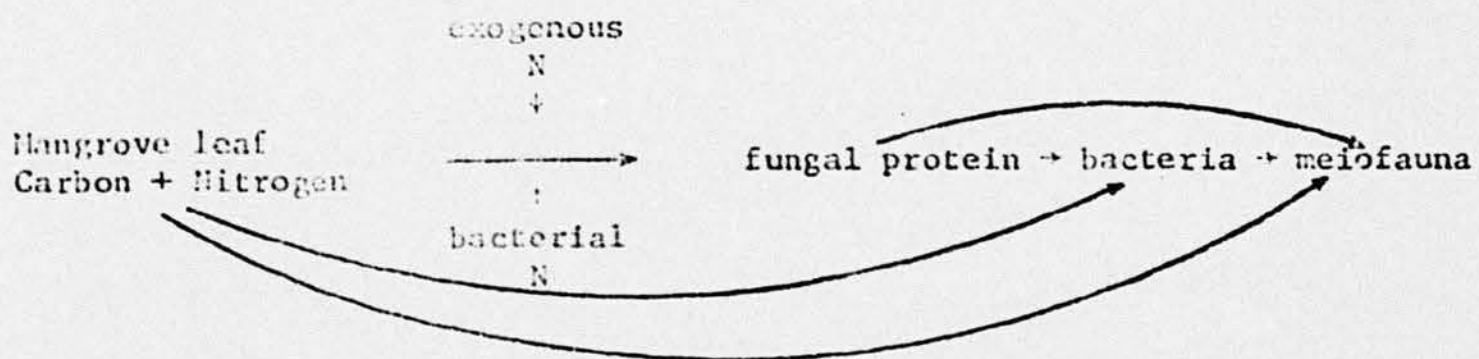
Within the first 24 hrs of submergence, the leaves are attacked by phycomycetes of the genus Phytophthora; subsequently they are infested by a variety of other saprophytes such as Fusarium and Penicillium. In the second and third weeks the cellulolytic fungi (Zalerion, Lulworthia) appear and by the end of the third week the majority of the phycomycetes have disappeared. The sequence is probably a reflection of the availability of carbon compounds initiating with the utilization of simple carbon compounds by the phycomycetes through to the consumption of the more complex compounds by the other saprophytic fungi. Eventually, cellulose and lignin are the major remaining components.

During the first two weeks of submergence there is considerable leaching of water soluble materials, during which time the carbon level drops by 32%. Absolute nitrogen values then increase by 16% during the next 5 weeks of submergence. This nitrogen increase reflects standing crop of microorganisms and does not take into account the rapid utilization of energy sources. Under optimal conditions fungi and bacteria can replicate within minutes and some of the nematodes can reproduce in 1 to 2 days. The agents responsible for the nitrogen increase are probably fungi, but this has not been proven experimentally. The inference is based on analogous roles in terrestrial and aquatic litter systems. Nitrogen levels in the water probably are not sufficient to account for the entire increase. It is suggested that bacterial nitrogen fixation on the leaves contribute to the nitrogen pool.

The major meiofaunal constituents are nematodes and copepods, although a variety of other invertebrates are present. These animals inhabit the surface layers of the leaves within the first 24 hrs of leaf submergence. Generally, the animals are interstitial within a detrital layer that

accumulates on the leaf surface. Animal nutrition may be dependent to some extent, upon degradation of detrital material that accumulated on the leaf from external sources as well as decay of the leaf. Peak meiofaunal population densities are reached after three weeks of leaf submergence, which coincides with the leaf nitrogen increases.

Bacteria undoubtedly are important in the detrital system. In many instances, they produce a heavy slime layer on the leaf during the first week of submergence. This slime acts as a matrix for accumulation of detritus, algae, meiofauna and fungal spores. Bacteria are also a primary food source for many of the meiofauna. While some animals, such as the amphipods and polychaetes, consume leaf particles and appear to derive their energy from leaf and fungal material, the majority of the animals, particularly the nematodes, are bacterial feeders. This suggests an additional step in the food chain, i.e., bacterial utilization of breakdown products of fungal and plant degradation. The postulated food chain is depicted as follows:



Distributional studies of fungi and meiofauna indicate that community structures are similar throughout the world. Some populations are ubiquitous, whereas the occurrence of other populations may be dependent on a variety of factors including environmental conditions, host substrates or geography. Because of this basic similarity in microbial communities,

the mangrove leaf degradation food webs are probably similar in all red mangrove regions. Certain normal and induced environmental perturbations potentially can alter these food webs. The only parameter that we have studied is temperature. The results indicate that individual components (phycomycetes and nematodes) are unable to reproduce at temperatures of 35 to 39°C. Temperature is only one of many possible stresses; also of concern are effects of changes in salinity, and additions of insecticides, fungicides, industrial and domestic wastes, etc. These effects must be taken into account when considering future uses of estuarine regions which can range from annihilation of mangroves, to dumping of industrial and domestic wastes. This is particularly critical as the studies of Odum (1970) and Austin & Austin (1971) have shown a dependence upon the mangrove detrital system by a large variety of fishes and invertebrates.

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Figure 1

Phytophthora sp. with a globose spiny sporangium. The species is abundant in decaying mangrove leaves in the Western Hemisphere.

Figure 2

Phytophthora sp. with a lobate spiny sporangium. This species is found in decaying mangrove leaves in the Indian-Pacific region.

Figure 3

Phytophthora sp., a fungal parasite that is twining about the hyphae of Pestalotia sp.

Figure 4

Phycomycete, Nyctocyclus (vermicolum?), in the nematode Rhabditis marina:
a) nematode cuticle, b) zoospores penetrating cuticle, c) sporangium,
d) exit tube.

Figure 5

Paecilomyces sp. parasitizing a tylenchid nematode.

Figure 6

Mean relative amounts (per weight) of carbon and nitrogen in decaying Rhizophora mangle leaf discs. Percent carbon confidence intervals ± 1.2 .

Figure 7

Mean absolute amounts of carbon and nitrogen in decaying Rhizophora mangle leaf discs.

Figure 8

Dry weight and carbon:nitrogen determination in decaying Rhizophora mangle leaf discs. Dry weight confidence intervals ± 2.8 mg.

Figure 9

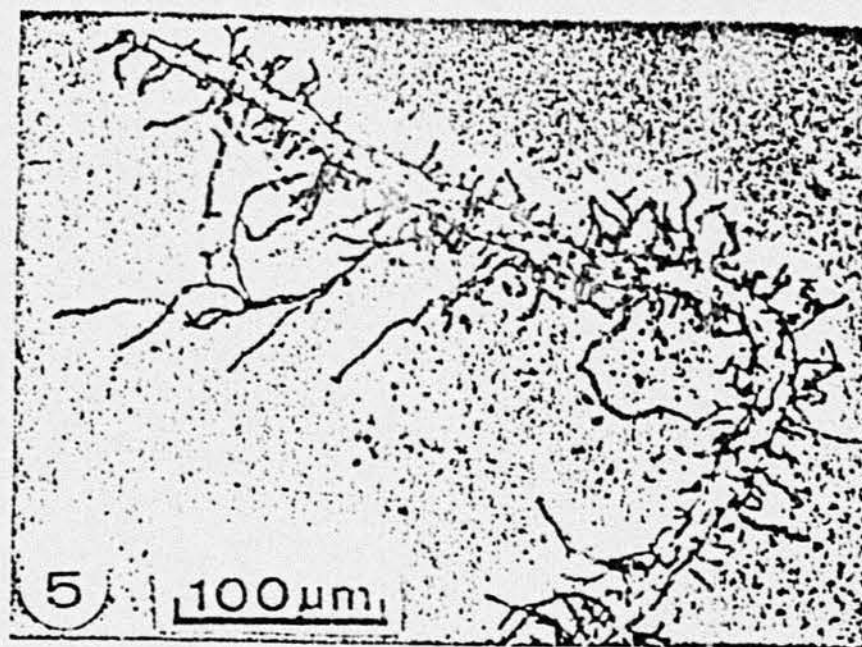
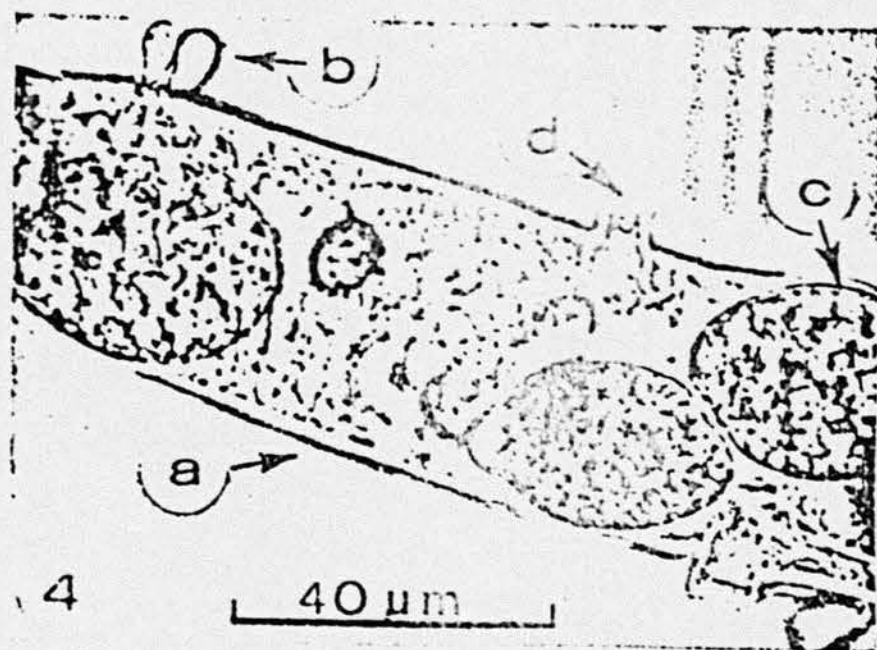
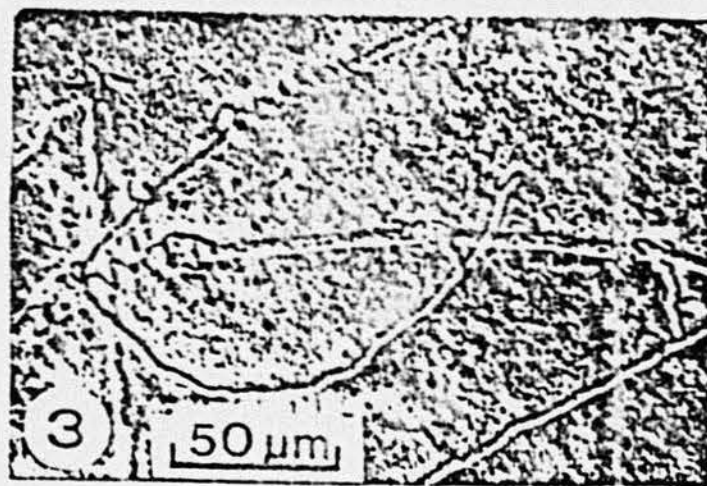
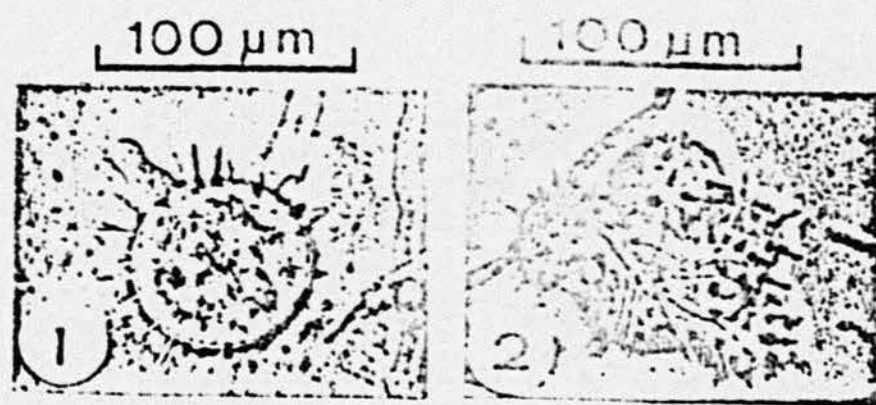
Colony size of Phytophthora spp. after seven days on corn meal agar.

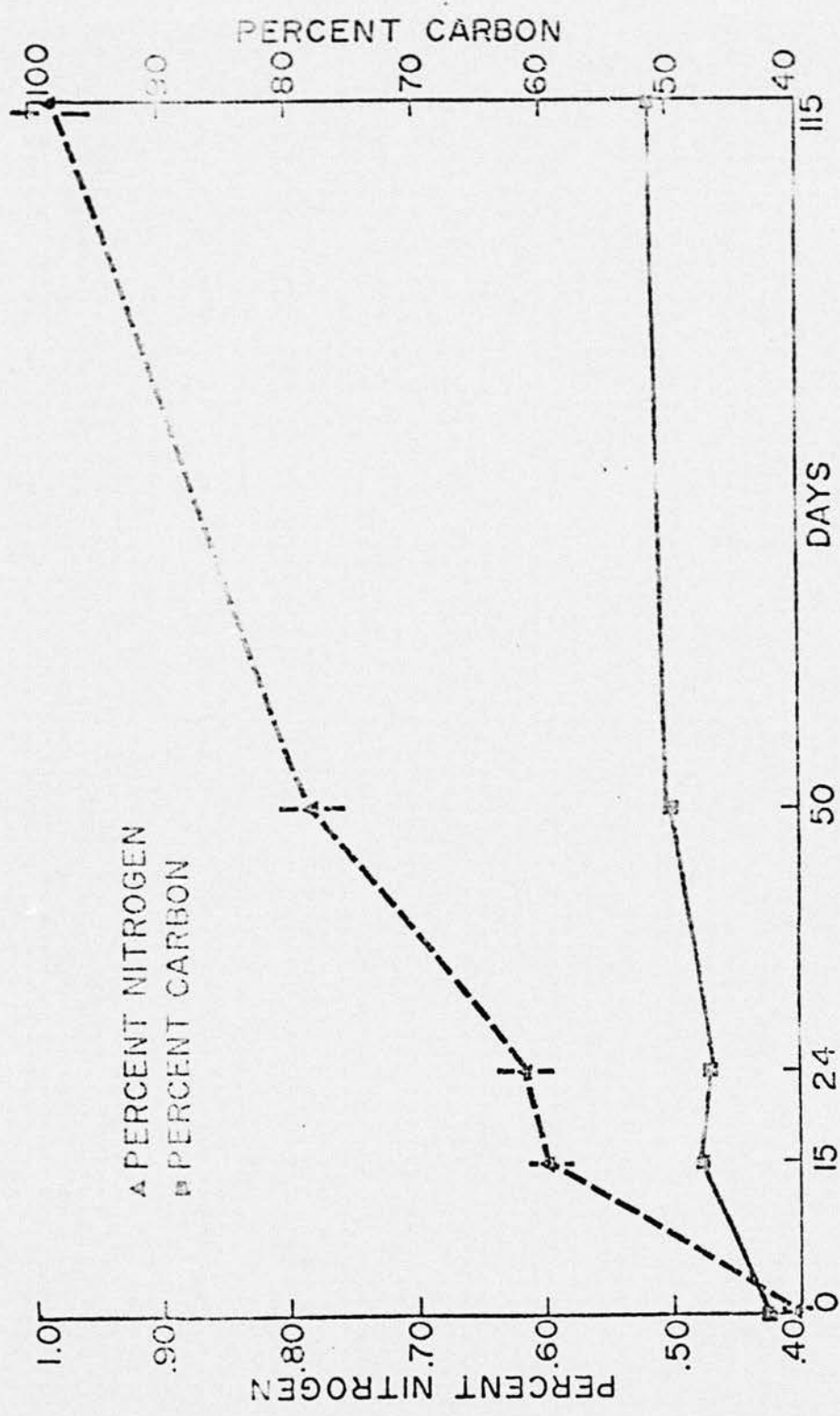
LIST OF FIGURES (continued)

Figure 10

Durations of life cycles of marine nematodes at various temperatures in laboratory culture, 15‰ salinity (From Hopper et al., 1973).

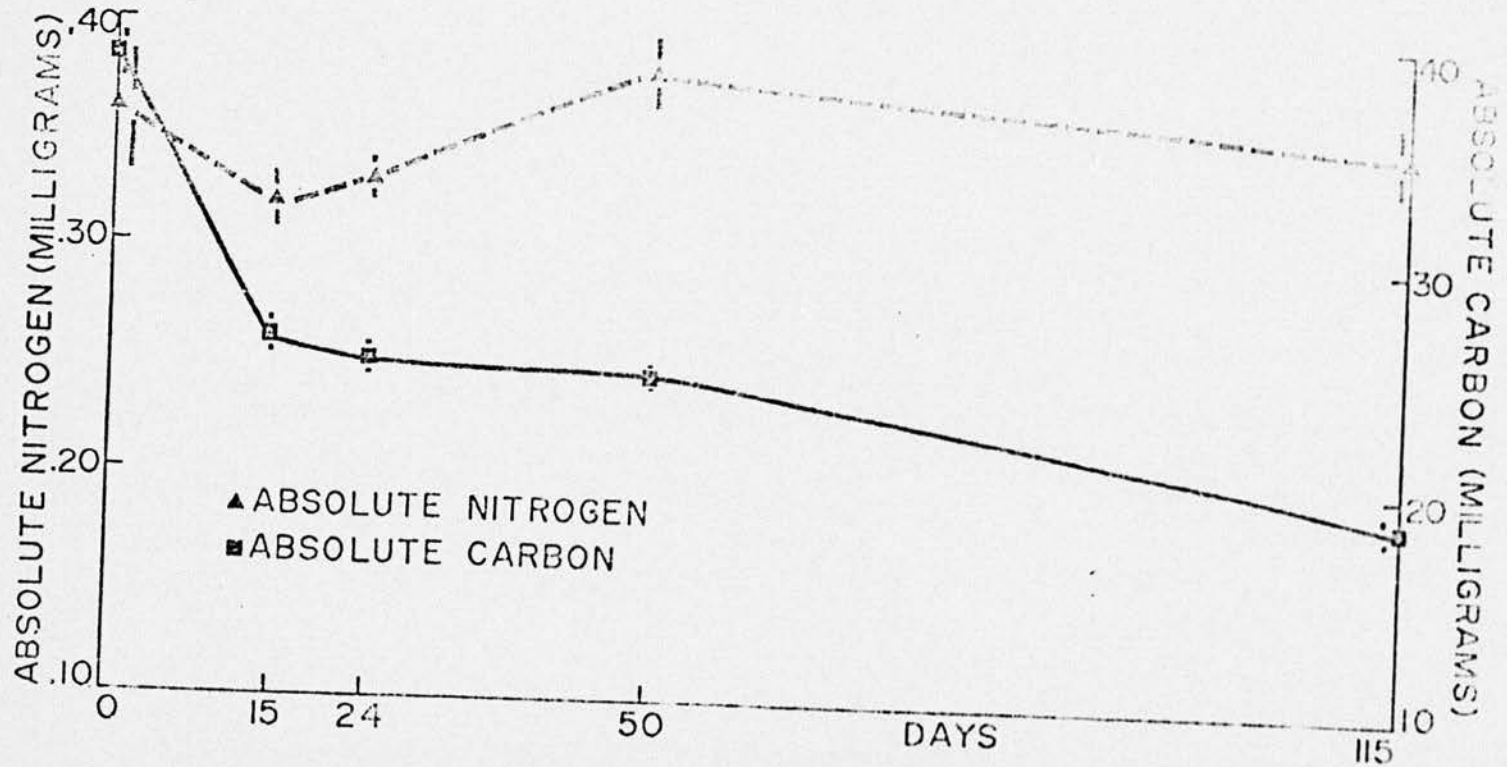
Figure 1

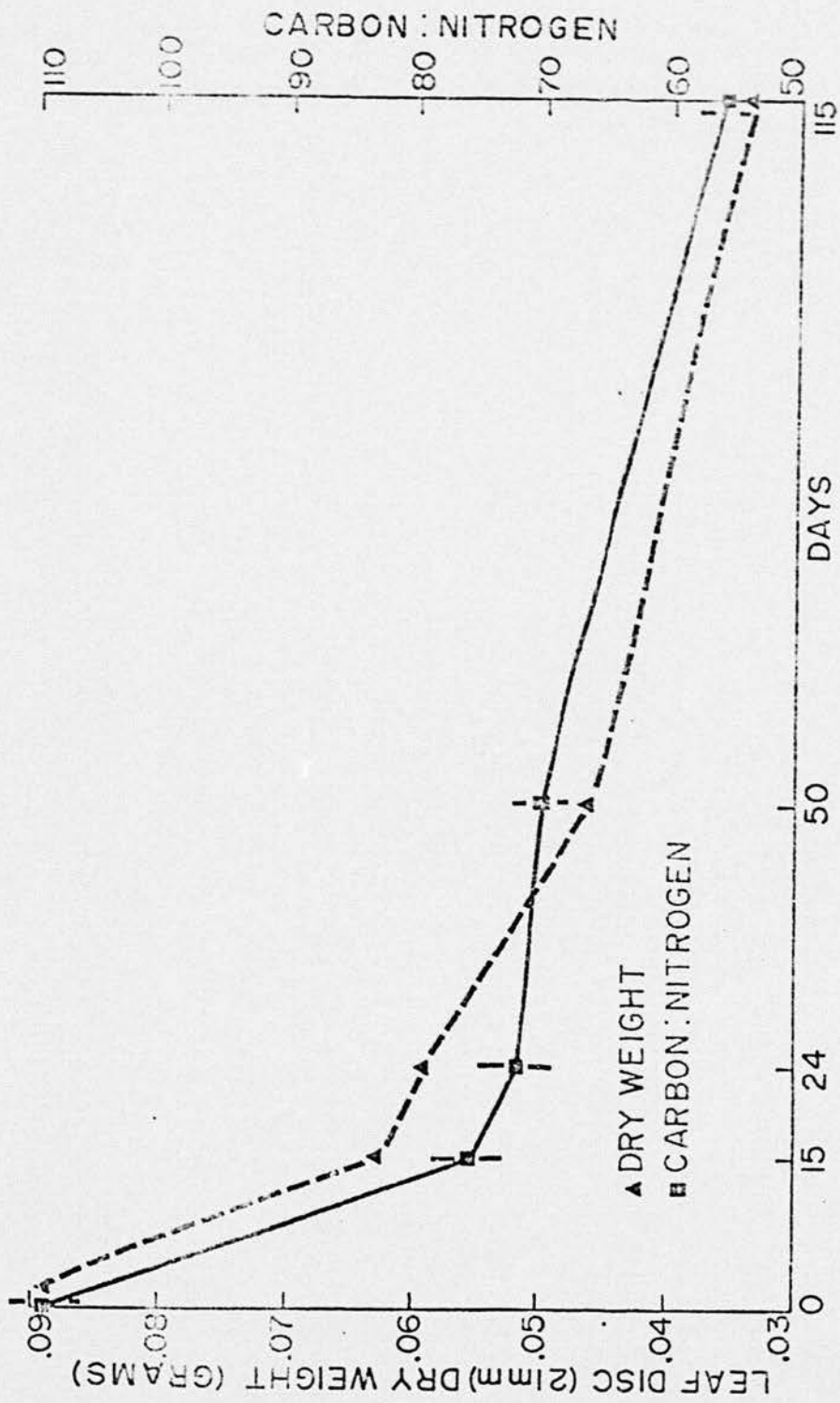


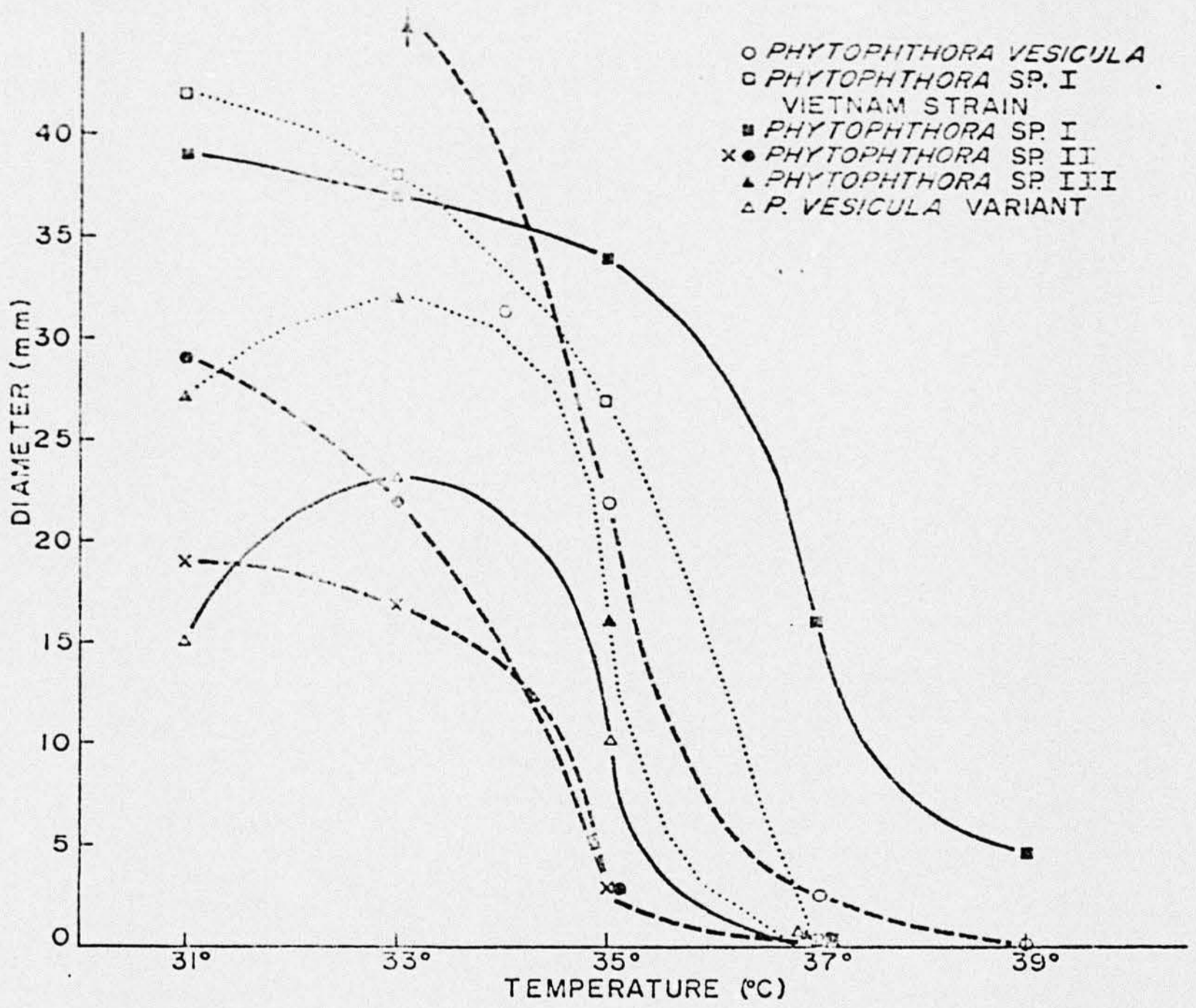


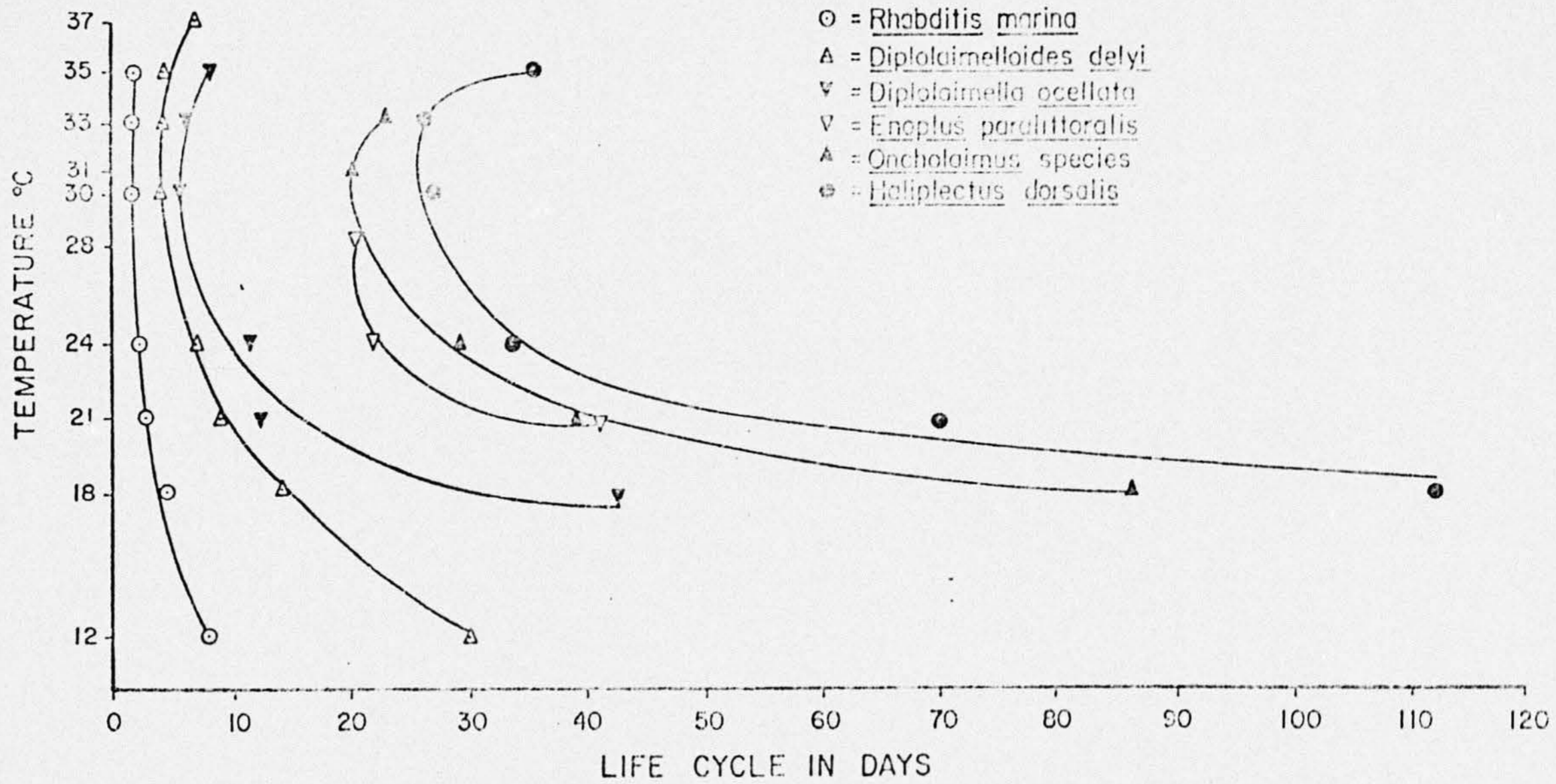
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 DAYS
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 0 15 24 50

F 22 X 1









Phycomycetes (Phytophthora spp.n. and Pythium sp.n.)
associated with degrading mangrove (Rhizophora mangle L.) leaves¹

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Abstract

Fungi of the genus Phytophthora were found to be associated with the initial stages of leaf litter decay of Rhizophora mangle L. and other Rhizophora species in estuarine and coastal marine waters. Phytophthora appears to be an important component of red mangrove litter degradation systems throughout the tropics including the Atlantic, Pacific and Indian Oceans. The distributions of Phytophthora vesicula Anastasiou et Churchland, and four new species of Phytophthora are discussed, as well as their occurrence in other tropical marine allochthonous spermatophytic leaf litter. The descriptions of the new species and varieties, Phytophthora bahamensis, P. epistomium, P. mycoparasitica, P. spinosa var. spinosa and P. spinosa var. lobata, are presented.

Pythium was rarely observed in the mangrove litter system, although one species, Pythium grandisporangium sp.n., is described.

Introduction

Terrestrial plant materials, such as Juncus, Spartina and mangroves, contribute a major portion of the organic material that drives certain estuarine food chains. In the case of the red mangrove (Rhizophora mangle L.), it has been estimated (Odum et al. 1973) that the leaves contribute approximately 730 gms dry wt/m²/year of organic material to the estuary. Heald (1969) reported that this material is converted to microbial protein which is consumed by small invertebrates, which, in turn, are eaten by commercially important crustaceans and fish.

In freshwater leaf detrital systems, fungi are considered to be of primary importance in degrading plant materials (Kaushik and Hynes 1971). The association of fungi with the mangrove detrital system was reported by Fell and Master (1973). They noted that phycomycetes, including Phytophthora, Schizochytrium and Thraustochytrium, were members of the degradation flora. Similarly, Perkins (1977) suggested that labyrinthulids and thraustochytrids might be significant in the detrital formation of non-marine spermatophyte material. Our present studies indicate that the genus Phytophthora may be important in these detrital systems. Previous studies have not indicated the presence of these fungi in the mangrove ecosystem. Lee and Baker (1973) noted the absence of phycomycetes on mangrove roots in Hawaii, but suggested it might be due to the methods they used. Volz and Jerger (1972) specifically examined the marine soils, mangrove wood and algae at Abaco Island, Bahamas for phycomycetes. They found populations of Thraustochytrium and Schizochytrium, but did not report Phytophthora. Rai et al. (1969) in India, and Swart (1958, 1963) in Africa, examined mangrove soils and indicated that phycomycetes were not important members of the soil mycoflora. In contrast, Ulken

(1970, 1972) reported Thraustochytrium and Schizochytrium from mangrove soils of Brazil; in addition, she described a new species, Phlyctochytrium mangrovii.

There is relatively little known about the marine occurrence of the genus Phytophthora; several reports (Fuller and Poyton 1964; Høhnk 1956; Siepmann 1959) have cited the presence of Phytophthora sp. in brackish or marine waters and sediments. According to Goodman (1959), Austwick (unpublished) observed a Phytophthora sp. on Spartina townsendii. The first report of a potential role for Phytophthora in the marine environment was by Anastasiou and Cherdland (1969). They isolated a species, which they described as P. vesicula, from arbutus (Arbutus menziesii) and laurel (Prunus laurocerasus) leaves that were submerged at brackish and marine sites near Vancouver, B.C. The incidence of P. vesicula was high: 71% of the 750 leaves examined contained the fungus.

In contrast, the genus Pythium is prevalent in marine environments and has been isolated from waters, sediments and algae, and as a parasite of invertebrate ova (reviewed by Johnson and Sparrow 1961).

The purpose of the present report is to indicate the presence of the Pythiaceae in mangrove and other allochthonous tropical detrital systems. Because the species that have been observed in these detrital systems are unique among their respective genera, descriptions of four new species of Phytophthora and one species of Pythium are presented.

Materials and Methods

Collection Sites

Mangrove (Rhizophora mangle) leaves were collected from the following locations: 1) stations in Miami, Florida area from the north to

south end of Biscayne Bay, including Bear Cut, West Point, Matheson Hammock, Turkey Point, Mangrove Point; 2) Card Sound, which is south of Biscayne Bay; 3) Windy Key in the Florida Keys; 4) 10,000 Islands, on the west coast of Florida; 5) Flamingo, Florida; 6) Costa Rica; 7) the Bahamas, including Andros Island, Conception Island, Long Island and Abaco; 8) Conaves Island, Haiti; 9) Jamaica; 10) Curacao and Bonaire, Netherlands Antilles; 11) Colombia; 12) Trinidad; 13) Hawaiian Islands at Kaneohe Bay, Oahu and Kona, Hawaii; 14) Vietnam; 15) Selangor, Malaysia; and 16) Seychelles, Indian Ocean. Leaves from the Indian and Pacific Oceans, except for Hawaii, were from unidentified Rhizophora species other than R. mangle.

Collection Techniques

At all the stations, random samples of mangrove leaves were obtained that usually included those that were presenescent, senescent and postsenescent as estimated by color (green, yellow, brown). Submerged samples were transported to the laboratory in sterile plastic bags with enough water from the field to keep the material moist. Some of the Caribbean and the majority of the Pacific and Indian Ocean samples were sent to us by cooperating investigators (see Acknowledgments).

For the fungal succession studies, collections were made of senescent yellow leaves that easily detached from the tree and were considered ready to fall. The leaves were placed in nylon bags with a mesh size of 2.5 sq mm. The bags, with 50 leaves/bag, were tied to mangrove roots so that they were continuously submerged and lay on the bottom in the leaf litter. Leaves were removed from the bags weekly or biweekly for periods up to 3 months. At each sampling period, two leaves were removed from each bag and placed in sterile plastic containers for transportation to the laboratory.

Succession studies were made at three locations in the Miami area: Card Sound, Mangrove Point and Turkey Point in July 1970, and Turkey Point in April 1971. A study was made at Andros Island, Bahamas, August 1973. This was a 5-day study of 2 stations, 5 miles apart; samples were collected every 24 hours.

Other plant leaf material was sampled using the litter bag technique. Plants included tropical shoreline trees: black mangrove (Avicennia germinans), buttonwood (Conocarpus erecta), Australian pine (Casuarina equisetifolia), coconut palm (Cocos nucifera) and sea grape (Coccoloba uvifera); shoreline herbs: Juncus roemerianus, Sakile fusiformis, Distichlis spicata, Phloxerus vermicularis, Sesuvium portulacastrum, Salicornia virginica and Sporobolus sp.; marine grasses: Thalassia testudinum and Syringodium filiformis; and a marine alga: Sargassum sp.

Sampling Techniques

Plant material was usually sampled within a few hours but could be stored up to a week at 5 C. Any detritus or mud was rinsed off with sterile water. All sample handling was performed with alcohol-flame sterilized instruments. Samples were removed from the leaves with a 4 mm (I.D.) cork borer. Eight samples were taken from each leaf and treated with two techniques: four discs were placed on an isolation agar medium and four in an isolation water culture (see below).

All water used for rinses, media, water cultures, slide preparations, etc., was seawater diluted to 15‰ with deionized water and autoclaved. Fresh or aged seawater was used with equal results. With the exception of agar media, the water had to be used within a few days after autoclaving; water stored for over a week usually did not permit sporangial production

with even the most prolific isolates. For practical reasons, filter-sterilized water was not generally used; however, it did not appear to have the time limitations.

Plastic petri dishes (100 x 15 mm) containing 25 ml of media were used for water cultures and agar plates. The agar isolation medium (CMA+) consisted of Difco corn meal agar enriched with 0.01% Difco yeast extract, 0.001% NBC liver extract, 0.001% Difco cholesterol, 0.0002% ferrous sulfate, and 0.002% chloromycetin. The cultures were maintained on this medium (CMA+), but without chloromycetin, unless "normal" growth was obtained on corn meal agar lacking additives (CMA). Isolation water cultures consisted of 15‰ seawater with 0.05% streptomycin sulfate and 0.05% penicillin G, added aseptically after autoclaving. The observation water culture, which consisted of 15‰ seawater without any additive, was used for subculturing, measurements and other observations.

Isolation water cultures were examined the first and second days after sampling, with a stereoscope with substage lighting. Sporangia and sporangio-phores were visible radiating from leaf discs. When only one type of phycomycete was present in a dish, subcultures were made by baiting with a sterile crushed sesame seed, which, after 1-2 days of incubation, was transferred to the isolation medium. When more than one type of phycomycete was present, the fungus was isolated by dissection of the sporangia or hyphae with fine-tip forceps which was then transferred to the isolation medium.

Isolation agar plates were observed for the fast-growing saprophytes 2 and 3 days after sampling. Observations employed a stereoscope with substage and suprastage lighting. The distinctive hyphae and sporangia were visible around or on the leaf discs, growing slightly faster than the higher fungi. Subcultures were made with agar cuts at the colony periphery or by removing

sporangia and sporangiophores with forceps. The isolation plates were inspected at 10-15 days for parasitic phycomycetes. Their sporangia were observed mixed with the hyphae of the host fungi. These phycomycetes were subcultured axenically by transferring agar blocks of the mix to a water culture and baiting the zoospores with sterile crushed sesame seeds, or by micromanipulating a sporangium free from the host and plating it on CMA+ for direct germination rather than zoosporulation.

The majority of the observations and measurements for descriptions were made from inoculated sesame seeds in observation water cultures 24 hours after inoculation using Nomarski differential interference contrast microscopy. An exception was Phycomyces spinosa which was described from CMA plates. All hyphal measurements were from CMA for P. spinosa and CMA+ for the other species.

Attempts to observe sexual reproduction involved the classical methods of Emerson (1958), Sparrow (1960) and Waterhouse (1963); and the biochemical stimulation of Brassier (1971), Reeves and Jackson (1972) and Hendrix (1964, 1965, 1970).

Temperature and salinity tolerances were tested on 47-mm tightly sealed plastic petri dishes (Millepore Corp.) utilizing CMA+ prepared with distilled water, 15‰, 30‰ and 45‰. The latter was prepared by the addition of artificial seawater salts (Triton Marine Salts). Plates were incubated in the dark at 31, 33, 35, 37 and 39 C. Radial growth was measured daily for one week. All cultures were then tested for viability at room temperature.

Results and Discussion

Random sampling from a variety of locations including Florida, the Bahamas, the Caribbean, Malaysia, Vietnam, Hawaii and the Seychelles has

shown a widespread occurrence of filamentous phycomycetes (Table 1). The results indicate that the phycomycetes were associated with freshly fallen leaves, i.e., those that were yellow to yellow-brown, and not with leaves picked directly from the trees or those that had been submerged for a considerable period and had become dark brown to black. The 24-hr sequential studies at Andros Island indicated that two species, Phytophthora vesicula and P. spinosa, could inhabit 75-100% of the leaves within the first 24 hrs of leaf submergence and retain this level for the entire 5-day test period. The results of experiments in Florida were variable. The 1970 study indicated a 20% infestation at the first sampling, which was after 7 days of submergence, whereas the 1971 testing indicated a 100% infestation by the Phytophthora spp., also after 7 days. In all cases the phycomycetes were rare or not present after four weeks of leaf submergence. This sampling program was not sufficiently extensive to ascertain the environmental conditions that affect phycomycete colonization.

Sampling of other plant materials indicated that the phycomycetes were not restricted to mangroves. Phytophthoras were isolated from decaying leaves of sea grapes, Australian pine, buttonwood, white mangrove, coconut palm and salt grass. Phytophthoras may not inhabit all plant materials, as we did not isolate them from Sargassum, Syringodium, Salicornia, Cakile, Phloxerus, Sporobolus or Sesuvium. As this was a limited sampling program, additional collections are required of these and other plant materials to determine the substrate range of these fungi.

Phytophthora vesicula was the most prevalent species; it was found at all locales (Table 1) on a variety of allochthonous plant materials including: sea grape, Australian pine, buttonwood, white mangrove, black mangrove, coconut palm and Distichilis, and the meristem of diseased Thalassia seedlings

maintained in artificial culture. The majority of the isolates were similar to the description of Anastasio and Churchland, although, as will be discussed in the descriptive section of this report, some morphological differences were observed.

P. spinosa var. spinosa is another prevalent species particularly in Florida, the Bahamas, the Caribbean and the Hawaiian Islands. In addition to R. mangle leaves, P. spinosa has been observed on other allochthonous materials such as Microtheca mangle seedlings, and decaying leaves of sea grape, Australian pine, white mangrove, coconut palm and buttonwood. The species is unique in the genus because of the characteristically spiny sporangium (Figs. 20 & 21). These spines are elongate ($\bar{x} = 20 \times 4 \mu\text{m}$) with a hollow base, and the sporangial protoplasm extends into the spines. There is some variability in the degree of spine formation; sporangia in agar cultures were usually abundantly spined, whereas in water cultures the spines were restricted to the distal end or were completely lacking. The presence of spines on the sporangium is a unique characteristic within the genus, but has been reported among other biflagellated and uniflagellated species such as Pythium spinosum, Arthrospora spinosa and Rhizophydium keratinophilum (Waterhouse 1968; Sparrow 1960).

P. spinosa var. lobata appears to have a distinct geographical distribution from the variety spinosa. Isolations of var. lobata were from Vietnam, Malaysia and the Seychelles, an area that is inhabited by Rhizophora mucronata, R. apiculata and R. stylosa, but not R. mangle. The sporangia of the var. lobata are spiny; however, the basic difference from the var. spinosa is the multilobate characteristic of the sporangia (Fig. 25). The sporangia initiate as a single unit, then develop lateral lobes which increase in size and number until a single sporangium resembles a botryose group of fused

sporangia. This complex still functions as a single sporangium as only one papilla per sporangium develops.

While P. vesicula and P. spinosa were the most abundant species on the decaying mangrove leaves, three other Phytophthora species were encountered. These species, P. bahamensis, P. epistomium and P. mycoparasitica, differ from other members of the genus by the presence of plugged dehiscence tubes. These dehiscence tubes and the plugs form as the sporangium develops. The plug of P. bahamensis (Fig. 7) is hyaline, gelatinous and nearly cylindrical. The distal end of the plug extends slightly beyond the dehiscence tube. At zoospore release the plug is forcefully ejected and appears to expand to approximately three times the original length. The plug dissolves within an hour of ejection. P. mycoparasitica has a similar type of plug (Fig. 12). Within the dehiscence tube there appears to be some initial dissolution at either end of the plug, followed by ejection of the remainder of the plug. Another distinct characteristic of P. mycoparasitica is the denticulate sporangium; the spines are short ($\bar{x} = 2.5 \mu\text{m}$) as compared to the spines of P. spinosa ($\bar{x} = 20 \mu\text{m}$).

In contrast to P. spinosa and P. bahamensis, which appear to be saprophytes on decaying plant material, P. mycoparasitica is a facultative parasite of other fungi, particularly Pestalotia and Penicillium. The hyphae of the parasitized fungi are attacked by appressoria, twining and hyphal invasion. P. epistomium is also a facultative fungal parasite; however, the sporangium is smooth and the dehiscence plug (Fig. 12) is distinct from that of the two other species. The dehiscence tube is elongate ($\bar{x} = 27 \mu\text{m}$) compared to the tubes of P. bahamensis ($\bar{x} = 5 \mu\text{m}$) and P. mycoparasitica ($\bar{x} = 8 \mu\text{m}$). The dehiscence plug of P. epistomium is elongate ($\bar{x} = 41 \mu\text{m}$), cylindrical and extends well beyond the end of the dehiscence tube. There is a

constriction at the end of the tube where it appears to grip the plug. All three species have a small gelatinous mass that separates the zoospores from the dehiscence plug. The plug is forcefully ejected from the tube and is followed by the gelatinous mass. The latter rapidly evanesces or is swept away. The dehiscence plugs usually evanesce within an hour, an exception is the plug of P. epistomium which persists for several days. Dehiscence tubes and plugs have not been reported in Phytophthora, nor have we seen any reports of their presence in other phycomycetes.

P. bahamensis, P. epistomium and P. mycoparasitica were not abundant in our collections. P. bahamensis was isolated at Conception Island in the Bahamas and at Grand Cayman Island. P. epistomium was obtained at three locations in Biscayne Bay and from Costa Rica. P. mycoparasitica was collected in Malaysia (Table 1).

During a study of degrading plant materials in Card Sound we found a species of Pythium associated with Rhizophora mangle, Rustichilis spicata and Cladium jamaicense. This species, Pythium grandisporangium sp.n., is distinguished by the size and shape of the sporangium (Fig. 27), which is bursiform to ventricose in shape (35-130 x 22-74 μ m, \bar{x} = 85 x 51 μ m) with a tapering neck (22-139 μ m, \bar{x} = 62 μ m long). The total sporangial length ranges from 91-235 μ m. Other taxonomically important characteristics include the large (\bar{x} = 41 μ m) smooth oogonia, the pleurotic thick-walled (\bar{x} = 4 μ m) oospores and the lack of internal proliferation.

Waterhouse (1967) places considerable reliance on sporangial size as a species criterion. The sporangia within the genus generally range from 6-80 μ m, with the majority less than 50 μ m (Waterhouse 1968). Only two species have sporangia over 100 μ m. Phytophthora stellata (= Pythium helicandrum) was described with sporangia of 81-116 μ m; however, this species

proliferates internally and has a spiny oogonium. Pythium uncinatum var. littorale Höhnk has sporangia measuring 49-162 μ m and the sporangia are lobate.

In using the Waterhouse (1967) key, the closest species to P. grandisporangium are P. salinum Höhnk, P. tracheiphilum Matto and P. pleroticum Ito. In addition to the differences in size of the sporangium, oogonium and oospore wall, the sporangium of P. pleroticum produces hyphae rather than zoospores, P. salinum sporangia are globose to subglobose, while P. tracheiphilum produces chlamydespores and has globose to subglobose sporangia. The sexual structures of P. grandisporangium are similar to P. iwayamai Ito in that they are yellowish in color and plerotic, and that the antheridia are never hypogynous. P. iwayamai differs by terminal or intercalary oogonia, the presence of chlamydespores and smaller, generally spherical, sporangia.

Species descriptions

Phytophthora bahamensis sp.n.

Hyphae - branched, smooth-walled, 1-3 μ m, \bar{x} = 2.2 μ m diameter; develops lunate or umbonate septa with age; vacuoles and oil droplets are present. The colony is rosette in appearance, superimposed with concentric growth rings in some isolates. Growth rates of the isolates vary, 1.6-2.5 mm/day on CMA+, 1.5-1.9 mm/day on CMA.

Sporangiophores - indistinct from vegetative hyphae, intra- or extra-matrical, simple; proliferation or branching is rare. Length up to 1 mm, width 1-6 μ m, \bar{x} = 3.4 μ m.

Sporangia - hyaline to subhyaline, thin-walled, smooth, terminal, non-deciduous; prior to zoospore differentiation the sporangia are filled with prominent irregular vacuoles. The sporangium is separated from the

sporangiophore by a hyaline plug or septum which is variable in diameter, thickness, shape and location. Usually the plugs are about twice the thickness of the cell walls and are at the base of the sporangium, although they may protrude into the sporangium. The shape of the sporangium is highly variable. In some isolates (Fig. 1) the sporangia are bursiform, single to multilobed (26-119 x 19-43 μm , \bar{x} = 61 x 28 μm), often with one or more septate or aseptate setiform appendages, up to 102 μm long. There is one dehiscence tube, even in the multilobed sporangia, which is distal or lateral to the long axis of the sporangium. Other isolates (Fig. 2) have obpyriform to obclavate sporangia (39-97 x 14-31 μm , \bar{x} = 68 x 23 μm) that lack appendages and have the dehiscence tube at the tapered distal end of the sporangium. Zoospores are released through a short (3-7 μm , \bar{x} = 5.1 μm) plugged dehiscence tube. The dehiscence plug is hyaline, gelatinous, nearly cylindrical and fills the dehiscence tube. The dehiscence tube and plug form during early stages of sporangial development. In the initial stages the plug is undifferentiated (Fig. 3), but later becomes distinct from the protoplasm (Fig. 4). A split develops distally (Fig. 5) and the outer wall of the tip ruptures as the plug becomes extended (Fig. 6). At this point the protoplasm contains numerous vacuoles and the protruded end of the plug is ragged in appearance (Fig. 7). Prior to zoospore release the vacuoles disappear and the protoplasm cleaves into zoospores. A small mass of semisolid material separates the zoospores from the dehiscence plug. This plug is forced out of the dehiscence tube at zoospore release (Fig. 8). The plug approximately triples in length after release and sometimes has a banded appearance; it then dissolves in less than one hour.

Zoospores - reniform, laterally biflagellate, diameter 1-6 μm , \bar{x} = 2.6 μm when encysted, germination usually by one germ tube, occasionally 2-3.

Sexual reproduction - not observed.

Salinity tolerances - (at 31 C) growth in distilled water media, weak; optimal growth varied with isolate, 15-45 ‰; growth at highest salinity tested (45 ‰) strong or weak.

Temperature tolerances - (at 15 ‰) growth at 33 C, positive; at 35 C, weak.

Bait dish studies - sesame seeds and agar blocks are readily colonized, with abundant sporangial formation.

Habitat - isolates were collected from yellow leaves of Rhizophora mangle submerged in seawater at Conception Island, Bahamas, October 1972. Another isolate was observed on yellow R. mangle leaves from Grand Cayman, April 1974.

Type culture - a bursiform culture isolated from R. mangle leaves submerged in seawater at Conception Island, Bahamas, October 1972, was selected as the type and deposited at ATCC No. 28296. Also deposited, ATCC No. 28297, was an obpyriform to obclavate culture collected at Conception Island.

P. bahamensis is distinct in the genus by the presence of smooth-walled, variable-shaped sporangia with a short congenital dehiscence tube and a cylindrical evanescent dehiscence plug.

Phytophthora epistomium sp.n.

Hyphae - in axenic culture the growth is slow (0.8 mm/day on CMA+, 0.7 mm/day on CMA), hyphae are irregular, smooth-walled, 2-4 μ m, \bar{x} = 3.1 μ m in diameter, infrequently septate with age; frequently branch and form intercalary sclerotia. When mixed with a fungus (Pestalotia, Fusarium and Americosporium) that P. epistomium is capable of parasitizing, the hyphae grow

considerably faster and are less branched. The hyphae of the parasitized fungi are attacked by twining and appressorial formation (Fig. 9).

Sporangiophores - extramatrical on natural substrates, intramatrical on agar; simple, up to 3 mm long. Width is 2-9 μm , \bar{x} = 4.4 μm at the lower portion, often randomly developing many fine, hair-like branches along the entire length. Adjacent to the sporangium, the sporangiophore may widen to 19 μm (\bar{x} = 8.8 μm) and become thick-walled (to 3 μm). Proliferation is rare. The sporangium is separated from the sporangiophore by a thick, hyaline, false-pedicellate plug (Fig. 10). When the sporangiophore walls are thick, they often constrict at a point below the subsporangial plug to form a secondary plug (Fig. 10).

Sporangia - hyaline to subhyaline, nondeciduous, terminal, lageniform to obpyriform (43-184 x 56-107 μm , \bar{x} = 127.6 x 63.3 μm) with an elongate (10-51 x 9-10 μm , \bar{x} = 26.4 x 9.7 μm) dehiscence tube that contains a dehiscence plug (Fig. 11). Sporangial walls are smooth and thin, although they may be thick near the subsporangial plug and are always thick near the base of the dehiscence tube. The dehiscence tube (Fig. 12) is straight, bulges slightly at the distal end, then constricts sharply, apparently to grip the plug, and terminates in a flared skirt. The walls of the dehiscence tube are thick at the base and gradually become thin at the distal end. The dehiscence plug is cylindrical (14-90 x 9-10 μm , \bar{x} = 41.0 x 9.7 μm) and sometimes bears a faint indentation where it was gripped by the end of the tube. The distal terminus extends beyond the dehiscence tube and is convex; the proximal base is concave or cucullate. A small gelatinous mass separates the zoospores from the dehiscence plug. Zoospores may or may not be visibly cleaved before release. Zoospores are released by forceful ejection of the dehiscence plug from the dehiscence tube (Fig. 13). The plug is followed

by the gelatinous mass, which rapidly evanesces or is swept away. The base of the plug becomes distinctly cucullate-bullate. Sporangia and dehiscence plugs are persistent for at least several days (Fig. 14). The dehiscence tube and plug are conspicuous features during early stages of sporangial development.

Zoospores - reniform to irregular, laterally biflagellate. Encysted zoospores are 7-9 μ m, \bar{x} = 8.1 μ m diameter, one germination tube is produced.

Sexual reproduction - not observed.

Salinity tolerances - (at 31 C) growth in distilled water media, positive; optimal growth and sporangial production, 15-30 ‰; growth at 45 ‰, weak.

Temperature tolerances - (at 15 ‰) growth at 33 C, positive; at 35 C, weak.

Bait dish tests - sesame seeds are colonized slowly, sporangia are formed.

Habitat - rarely observed; first isolated from an unidentified leaf, Bear Cut, Miami, Florida, March 1970; several isolates were found on submerged decaying Rhizophora mangle leaves at Matheson Hammock, Miami, April 1972; Key Biscayne, Florida, July 1973; Puntarenas, Costa Rica, August 1973; and from a submerged, decaying leaf of Hymenocallis latifolia at Jonathan Dickinson Park, Jupiter, Florida, May 1973. Other fungi isolated with P. epistomium included Pestalotia, Fusarium and Americosporium.

Type culture - isolated at Bear Cut, Miami, Florida from an unidentified leaf, March 1970. Deposited at ATCC No. 28293.

The distinctive feature of P. epistomium is a congenital dehiscence tube with a persistent cylindrical dehiscence plug.

Phytophthora mycoparasitica sp.n.

Hyphae - variable, slow growth (≈ 0.26 mm/day) in axenic culture; branch frequently, irregular, 2-9 μm , $\bar{x} = 3.9$ μm in diameter. In parasitic culture, the hyphae of P. mycoparasitica grow faster and are more sparsely branched. Hyphae are smooth-walled and develop numerous umbonate or lunate septa with age. Hyphae of parasitized fungi are attacked by appressoria, twining and sometimes hyphal invasion (Fig. 15).

Sporangiophore - intramatrical on agar, extramatrical in water cultures on sesame seeds or agar blocks. Sporangiphores are simple, 3-9 μm , $\bar{x} = 5.4$ μm wide, rarely proliferate, are often multiseptate. The sporangium is separated from the sporangiophore by a thickened hyaline plug or septum which may or may not protrude into the sporangium.

Sporangia - hyaline to subhyaline (26-131 x 14-111 μm , $\bar{x} = 82$ x 61 μm), nondeciduous, terminal, obpyriform with a short ($\bar{x} = 22$ μm), tapering dehiscence tube (Fig. 16). The surface is denticulate, the spines (1-4 μm , $\bar{x} = 2.5$ μm in length) are clustered in small, irregular groups with the spines angled towards the center of the group (Fig. 17). Sporangial walls fairly thick, especially near the base of the dehiscence tube. The dehiscence plug is hyaline, gelatinous, cone-shaped (5-15 x 3-10 μm , $\bar{x} = 9.2$ x 7.7 μm); the proximal end is concave, and the distal end, which extends beyond the end of the tube, is mucronate. The dehiscence tube and plug form during early stages of sporangial development. The dehiscence plug partially dissolves from both ends, the remainder is forced out of the neck to release the zoospores. The plug has not been observed after ejection and probably evanesces rapidly. Sporangia have been observed on CMA+, on sesame seeds in water cultures and in parasitic agar plate culture.

Zoospores - reniform, laterally biflagellate with approximately equal

length flagella. Encysted zoospores germinate by a single germ tube. Encysted zoospores 6-10 μm , \bar{x} = 7.6 μm in diameter.

Sexual reproduction - not observed.

Temperature and salinity tolerances - not tested.

Bait dish studies - sesame seeds and CMA agar blocks are colonized slowly, sporangia are produced.

Habitat - isolated from a submerged, decomposing Rhizophora sp. leaf, collected September 1972, Sunzai Pulau, Selangor, Malaysia by Dr. A. Sase Kumar. On the initial isolation plate, P. mycoparasitica parasitized Pestalotia sp. In tests with this Pestalotia isolate and other Pestalotia spp. collected in Florida, strong parasitism by appressoria and twining occurred, with suppressed growth of the Pestalotia spp. and with enhancement of growth and sporangial production of P. mycoparasitica. Penicillium sp. was also found to be a host, with appressoria, twining and internal penetration.

Type culture - deposited at ATCC No. 28292.

The distinctive feature of P. mycoparasitica is the spiny sporangium with a congenital dehiscence tube and conical evanescent dehiscence plug.

Phytophthora spinosa sp.n. var. spinosa var.n.

Hyphae - growth is rapid (3.7 mm/day on CMA+, 3.4 mm/day on CMA).

Initially at the agar surface the hyphae are tortuous and richly branched, after two days becoming more submerged and less branched. Hyphae are irregular, 3-9 μm , \bar{x} = 5.2 μm in diameter, smooth-walled and nonseptate at all ages. The colony is rosette in appearance.

Sporangiophores - usually intramatrical on CMA, often extramatrical on natural substrates. Sporangiohores are indistinct from vegetative hyphae, are simple, proliferate irregularly and infrequently, 7-9 μm , \bar{x} = 7.8 μm

in diameter. The sporangium is separated from the sporangiophore by a hyaline plug or septum (3-10 μm , \bar{x} = 6.5 μm in length) that is located slightly below the sporangium in a false pedicel. The subsperangial plug begins forming as a venturi-shaped constriction in the sporangiophore (Figs. 18 & 19).

Sporangia - hyaline to subhyaline, thick-walled; entirely, partially or non-aculeolate; terminal, nondeciduous, globose to ovate or obovate (Figs. 20 & 21), 60-107 μm , \bar{x} = 80 μm in diameter, distally unipapillate, papilla inconspicuous. Sporangial size and degree of spine coverage appear to be nutritionally determined. Sporangia formed on a rich substrate tend to be large and fully spined, while those formed on poorer substrates are smaller and have fewer proximal spines or no spines at all. On CMA, sporangia develop in 24-48 hours, submerged and on the surface. Spines (Fig. 22) (12-29 x 4-6 μm , \bar{x} = 20 x 4.3 μm) are often hollow near the base and partially filled with sporangial protoplasm, which is granular, often with irregular vacuoles. Zoospore release is through the formation of a persistent, thin-walled, short or long, flask-shaped dehiscence tube (Fig. 23); vesicle formation is absent. Dehiscence tube formation begins and is completed just before the zoospores are cleaved. This formation appears to be hydrotrophic; if no water covers the papilla the tube will elongate in the direction of water for distances greater than the diameter of the sporangium. Zoospore release follows evanescence of the distal portion of the dehiscence tube.

Zoospores - reniform to irregular, laterally biflagellate. Encysted zoospores 7-11 μm , \bar{x} = 8.4 μm in diameter. Germination is via 1-2 germ tubes. In the absence of a nutrient substrate, the zoospores form very small, globose, smooth-walled, precocious germ sporangia capable of releasing one or more zoospores.

Sexual reproduction - not observed.

Salinity tolerances - (at 31 C) growth on distilled water media, negative; optimal growth, 15-36 ‰; growth at highest salinity tested (45 ‰), positive.

Temperature tolerances - (at 15 ‰) growth at 37 C, positive; at 39 C, weak.

Bait dish studies - weak colonization of sesame seeds, cellophane coated with egg albumin and sterile pieces of Rhizophora mangle leaves.

Habitat - P. spinosa var. spinosa was first isolated March 1969 from a Rhizophora mangle leaf that had been submerged in seawater (Biscayne Bay, Florida) for one week. Subsequent intensive sampling indicates that nearly all R. mangle leaves are colonized during the first two weeks of submergence, often in less than 24 hours. This species was not observed on senescent leaves still on the tree, and was rarely isolated from leaves that had decayed for three or more weeks. Isolations were also made from R. mangle leaves collected at several locations on the east and west coasts of Florida; in the Bahamas at Nan-O-War Cay (Abaco), Conception Island and Andros Island; in the Caribbean at Conaves Island (Haiti), Colombia, Grand Cayman, the Netherlands Antilles and Trinidad; in the Hawaiian Islands at Kaneohe Bay, Oahu and Kona, Hawaii. Other substrates include R. mangle seedlings, and leaves of sea grape, Australian pine, white mangrove, coconut palm and buttonwood. Substrates on which P. spinosa var. spinosa was not observed include the sea grasses Thalassia, Syringodium and Diplanthera; and shore plants Sesuvium, Axonopus, Phloxerus, Salicornia, Juncus and Cakile.

Type culture - isolate from Rhizophora mangle leaf found submerged in seawater at Bear Cut, Miami, Florida, January 1972. Deposited at ATCC No. 28294.

P. spinosa differs from other members of the genus by the presence of a spiny sporangium with a thin-walled, hydrotrophic dehiscence tube that forms just prior to zoospore release.

Phytophthora spinosa sp. n. var. lobata var. n.

This variety was isolated from Rhizophora sp. leaves collected in Vietnam, the Seychelles and Malaysia, and has the basic characteristics of the variety spinosa with the following exceptions:

1. Growth rate of the hyphae is considerably faster, 4.5-6.0 mm/day on CMA, depending on isolate.
2. The sporangium (Figs. 24 & 25) initially is obpyriform, becoming auriculate, then continuously develops lateral lobes until a single sporangium resembles a botryose group of fused sporangia.
3. The sporangium is unipapillate (Figs. 24 & 26). The papilla is inconspicuous, located in a prominent protuberance at the apex of the sporangium.
4. Zoospore germination is restricted to one germ tube.
5. Growth in distilled water medium positive to 33 C; on 45 % medium growth tests were positive to 37 C.
6. Habitat - The variety was first observed from a leaf of Rhizophora sp. collected in a mangrove swamp, April 1972, near Kung Sat, South Vietnam. Another isolate was found on a submerged leaf of Rhizophora sp. from a mangrove swamp near Sunzii Pulau, Selangor, Malaysia, September 1972. Additional isolates were obtained from Rhizophora sp. leaves at Rung Sat, December 1972 and February 1973, and from Rhizophora sp. leaves from the Seychelles, Indian Ocean, April 1974.
7. Sizes - hyphae, diameter 3-12 μ m, \bar{x} = 6.8 μ m; sporangiophore, diameter

5-12 μm , $\bar{x} = 8.1 \mu\text{m}$; subsporangial plug, length 9-18 μm , $\bar{x} = 13.2 \mu\text{m}$; sporangial length (plug to papilla) 51-75 μm , $\bar{x} = 67 \mu\text{m}$ and width 56-150 μm , $\bar{x} = 97 \mu\text{m}$ (when single lobed); apical protrusion, width 18-36 μm , $\bar{x} = 25.8 \mu\text{m}$; spines, 11-19 x 3-5 μm , $\bar{x} = 13.4 \times 3.5 \mu\text{m}$; encysted zoospore, diameter 7-9 μm , $\bar{x} = 7.5 \mu\text{m}$.

Type-culture - isolated from Rhizophora sp. collected April 1972 near Rung Sat, South Vietnam. ATCC No. 28291.

Phytophthora vesicula Anastasiou et Churchland

The majority of our observations agreed with the original description; an exception was the fate of the vesicle following zoospore release. Anastasiou and Churchland (1969) reported that the vesicle collapsed and evanesced. The vesicle, in the isolates that we examined, gradually shrank back to the papilla and then disappeared. In addition, we were not able to induce oogonial or antheridial production. There were some morphological variations among certain strains. An isolate from Long Island, Bahamas had lens-shaped papillae (3-9 x 12-20 μm , $\bar{x} = 6.2 \times 16.8 \mu\text{m}$) in contrast to the narrower papilla of the typical P. vesicula (5-10 x 7-15 μm , $\bar{x} = 7.3 \times 10.0 \mu\text{m}$). The growth rate of this Bahamian isolate was approximately 1 mm/day (radial growth) on CMA and CMA+, whereas that of P. vesicula was 5 mm/day.

The subsporangial plug of P. vesicula was described as having an apophysis-like knob on the sporangial side, or less frequently on the sporangiophore side. While the majority of the isolates that we observed are in agreement with the description, isolates from Vietnam and Malaysia differed by having the knob-like projections on both sides of the plug. Other septa in the sporangiophore often have a small knob in the center. Other atypical P. vesicula strains were isolated from R. mangle leaves at Andros Island,

Bahamas, and from diseased Thalassia testudinum seedlings collected near Grand Bahama Island. The sporangiophore branching in P. vesicula is usually sympodial; however, in these atypical isolates the branching was pinnate. The succeeding branch originated well below the first sporangium and developed at a right angle to it. The sporangiophore branches were fusiform, swelling in the middle to about three times the thickness at the ends (end of the sporangiophore was 2-3 μm , \bar{x} = 2.3 μm in diameter; middle was 6-9 μm , \bar{x} = 7.9 μm in diameter). The growth rate of these strains on CMA+ was rapid, 8.7 mm/day.

Pythium grandisporangium sp.n.

Hyphae - smooth, relatively straight and unbranched, 2-6 μm , \bar{x} = 3.3 μm in diameter, the radial growth is fast - up to 17.5 mm radial growth per day; hyphae develop thickened lunate septa with age.

Sporangiophores - indistinct from vegetative hyphae, intra- or extra-matrical, simple, external proliferation or branching rare, 5-7 μm , \bar{x} = 5.9 μm in diameter. Internal proliferation does not occur.

Sporangia - smooth-walled, subhyaline to yellowish, terminal, often with the long axis at nearly right angles to the concomitant hyphae (transverse). The shape (Fig. 27) is irregular bursiform-ventricose (35-131 x 22-74 μm , \bar{x} = 85.4 x 50.9 μm) with a tapering neck (22-146 μm , \bar{x} = 61.8 μm long), ending in a papilla (9-14 μm , \bar{x} = 10.5 μm in diameter). The total sporangial length was 91-235 μm , \bar{x} = 147.1 μm . Vesicle (Fig. 28) sessile, produced either terminally or laterally, evanescent in approximately 5 min. Zoospore cleavage begins at 1-2 min. after vesicle formation, is complete after 3-4 min.; zoospore activity inflates and eventually bursts the vesicle.

Zoospores - zoospores reniform, laterally biflagellate, diameter 7-8

μm , $\bar{x} = 7.5 \mu\text{m}$ when encysted, germination usually by one germ tube, occasionally up to four.

Oogonia - Formed in large numbers on CMA+ in less than three days, subhyaline, terminal, smooth, spherical, diameter 36-45 μm , $\bar{x} = 41 \mu\text{m}$, wall thin (Fig. 29).

Antheridia - formed with the oogonia on CMA+ in less than three days, usually monoclincous, occasionally diclincous, one to several that are tightly adpressed to the oogonium.

Oospores - single, plerotic, yellowish, spherical, smooth, 29-36 μm , $\bar{x} = 33.1 \mu\text{m}$ in diameter surrounded by a wall 2-5 μm , $\bar{x} = 4.1 \mu\text{m}$ in thickness (Fig. 30).

Salinity test - average radial growth rate on CMA/15‰ is 10.5 mm/day, on CMA/DW - 5.2 mm/day. Oogonia developed on CMA/DW but did not mature into oospores.

Habitat - isolates were collected from yellow leaves of Rhizophora mangle submerged in fresh water, yellow leaves of Distichlis spicata submerged in 19 ‰ and 30 ‰ SW and yellow leaves of Cidium jamaicensis submerged in 10 ‰ SW, all in a salt-marsh, dwarf-mangrove area inland from Little Card Sound, Florida, October-November 1973.

Type culture - isolate from Distichlis spicata leaves submerged in 30 ‰ SW in the above salt marsh in November 1973. Deposited at ATCC No. 28295.

P. grandisporangium is distinguished by large, irregular bursiform-ventricose sporangia (91-235 μm) with tapering necks that end in a papilla, the size of the oogonia (36-45 μm) and the thickness of the oospore wall (2-5 μm).

Latin Diagnoses

Phytophthora bahamensis sp.n.

Sporangiophora a hyphis non distinctis. Sporangiofera intramatrixialia aut extramatrixialia. Sporangia ex sporangiophoris sejuncta obturamento hyalino. Sporangia hyalina, haud decidua, terminalia, bursiformia (\bar{x} = 61 x 28 μ m) ad multilobata appendicibus setiformis aut obturbinata ad obclavata (\bar{x} = 68 x 23 μ m) exappendiculata. Tubus dehiscens prominens (diameter \bar{x} = 5 μ m) epistomio. Vesicula absens. Zoosporae reniformes, lateraliter biflagellatae (diameter (\bar{x} = 3 μ m) germinantes tubo germinalis 1-3. Sexus non observatus. Habitatio: fungus marinus submergus, plantis putrescentibus. TYPUS: ATCC No. 28296.

Phytophthora epistomium sp.n.

Sporangiophora intramatrixialia aut extramatrixialia. Sporangia ex sporangiophoris sejuncta obturamento hyalino crasso. Sporangia hyalina, haud decidua, terminalia, lageniformia ad obpyriformia (\bar{x} = 128 x 68 μ m). Tubus dehiscens longus (\bar{x} = 26 x 10 μ m) prominens epistomio elongato (\bar{x} = 41 x 10 μ m). Sexus non observatus. Zoosporae (diameter \bar{x} = 3 μ m) reniformes ad irregulares, lateraliter biflagellatae, germinantes tubo germinali singulari. Habitatio: fungus marinus submergus, parasitus in fungus et praesetium Pestalotia et Fusarium. TYPUS: ATCC No. 28293.

Phytophthora mycoparasitica sp.n.

Sporangiophora (latitudo \bar{x} = 5 μ m) intramatrixialia aut extramatrixialia, simplicia, prolifera rariflora, saepe multiseptata. Sporangia ex sporangiophores sejuncta obturamento hyalino crasso. Sporangia (\bar{x} = 82 x 61 μ m) haud decidua, terminalia, denticulata, obnapiformia, tubo dehiscenti brevi (\bar{x} = 22 μ m). Epistomium dehiscens hyalinum, gelatinum, conicum (\bar{x} = 9 x 8 μ m).

Vesicula absens. Zoosporae reniformes (diameter \bar{x} = 8 μ m), lateraliter biflagellatae, germinantes tubo germinali singulari. Sexus non observatus.

Habitatio: fungus marinus submergus, parasitus in fungus ac praesetium

Pestalotia et Penicillium. TYPUS: ATCC No. 28292.

Phytophthora spinosa sp.n. var. spinosa var. n.

Sporangiophora hyphis a non distinctis. Sporangiohpora intramatrixalis aut extramatrixalia, simplicia, prolifera irregularia, (diameter \bar{x} = 3 μ m). Sporangia ex sporangiophores sejuncta obturamento hyalino (latitudo \bar{x} = 6 μ m). Sporangia hyalina, haud decidua, terminalia, globosa ad ovata (diameter \bar{x} = 80 μ m), aculeata aut non aculeata, unipapiliata. Tubus dehiscens ampulliformis; longitudo variabilis. Vesicula absens. Zoosporae liberati evanescenti ad apicem tubi dehiscents. Zoosporae reniformes ad irregulares (diameter \bar{x} = 8 μ m), lateraliter biflagellatae, germinantes tubis germinalis 1-2. Sexus non observatus. Habitatio: fungus marinus submergus plantis putrescentibus. TYPUS: ATCC No. 28294.

Phytophthora spinosa sp.n. var. lobata var. n.

Sporangia obpyriformia, auriculata ad multilobata. TYPUS: ATCC No. 28291.

Pythium grandisporangium sp.n.

Sporangiophora a hyphis non distinctis. Sporangiohpora intramatrixalia aut extramatrixalia, singularia (diameter \bar{x} = 6 μ m), prolifera externa rariflora, prolifera interna non praesentia. Sporangia laevia, subhyalina ad flava, terminalia, irregularia bursiformia ad ventricosa (\bar{x} = 85 x 61 μ m); collum contractum (longitudo \bar{x} = 62 μ m) papillato terminali (diameter \bar{x} = 11 μ m). Vesicula sessilis, terminalis ad lateralis. Zoosporae reniformes,

lateraliter biflagellatae (diameter \bar{x} = 7 μ m) germinantes tubos germinales 1-4. Oogonia subhyalina, laevia, sphaerica (diameter \bar{x} = 41 μ m). Antheridia monoclina aut diclina, unum ad pleuriam. Oosporae singulares, pleroticae, flavae, sphaericae (diameter \bar{x} = 33 μ m). Crassities parvis oosporae \bar{x} = 4 μ m. Habitatio: plantae putrescentes palude salina. TYPUS: ATCC No. 28295.

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The bar in each figure represents 20 μ m with the exception of Figures 2 and 20 where it represents 100 μ m, and the bar in Figure 23 is equivalent to 20 μ m for Figures 22 and 23.

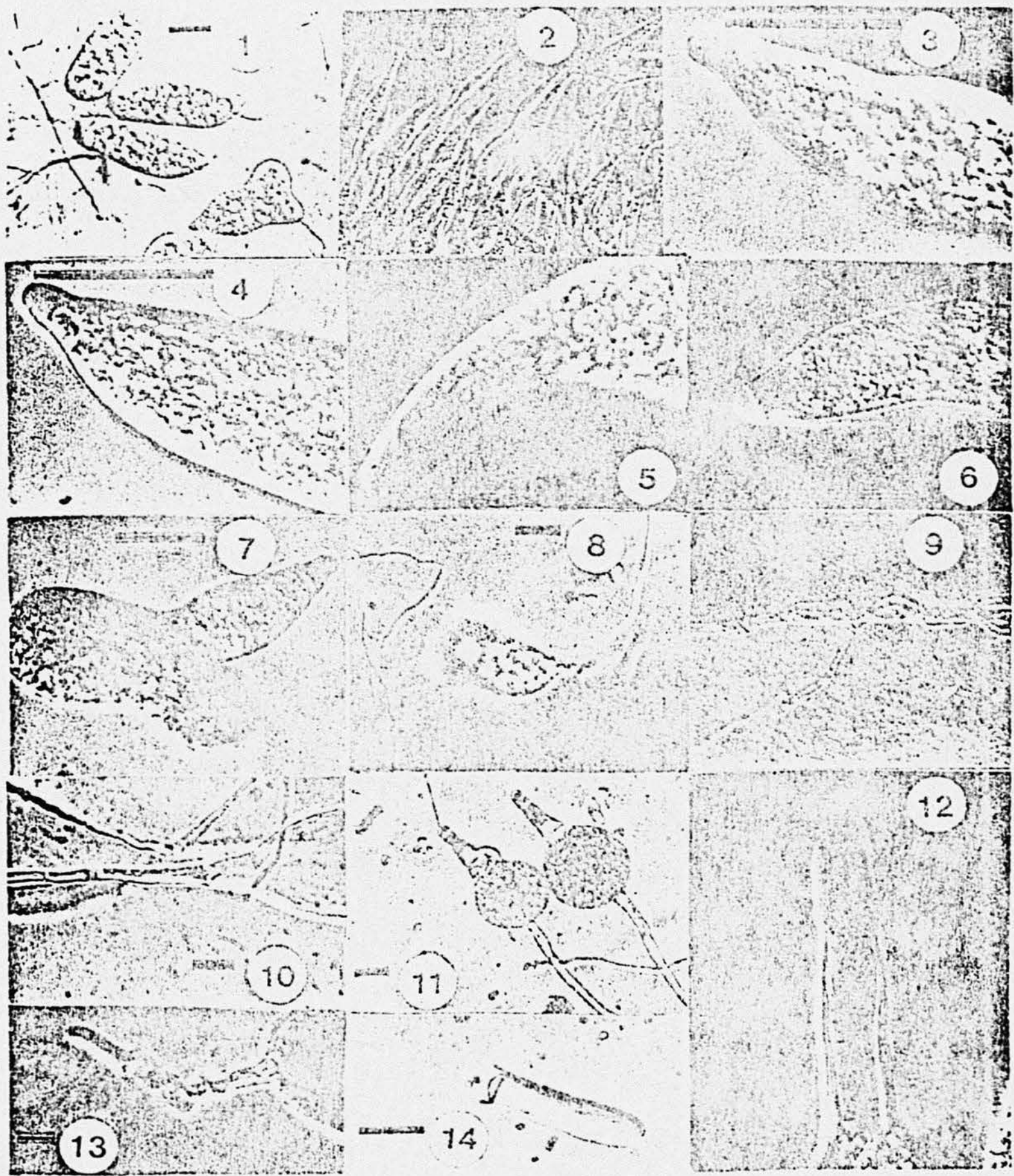
Table 1. Phytophthora and Pythium spp. isolated from decaying mangrove (Rhizophora mangle) leaves.

	<u>Phytophthora</u> <u>bahamensis</u>	<u>P. epistomium</u>	<u>P. mycoparasitica</u>	<u>P. spinosa</u> <u>var. spinosa</u>	<u>P. spinosa</u> <u>var. lobata</u>	<u>P. vesicula</u>	<u>Pythium</u> <u>grandisporangium</u>
<u>Miami, Florida</u>							
Bear Cut		+		+		+	
Card Sound						+	+
Mangrove Point				+		+	
Matheson Hammock		+		+		+	
Turkey Point				+		+	
West Point		+		+		+	
<u>Florida</u>							
Flamingo				+		+	
10,000 Islands				+		+	
Windy Key				+		+	
<u>Bahamas</u>							
Abaco				+		+	
Andros Island				+		+	

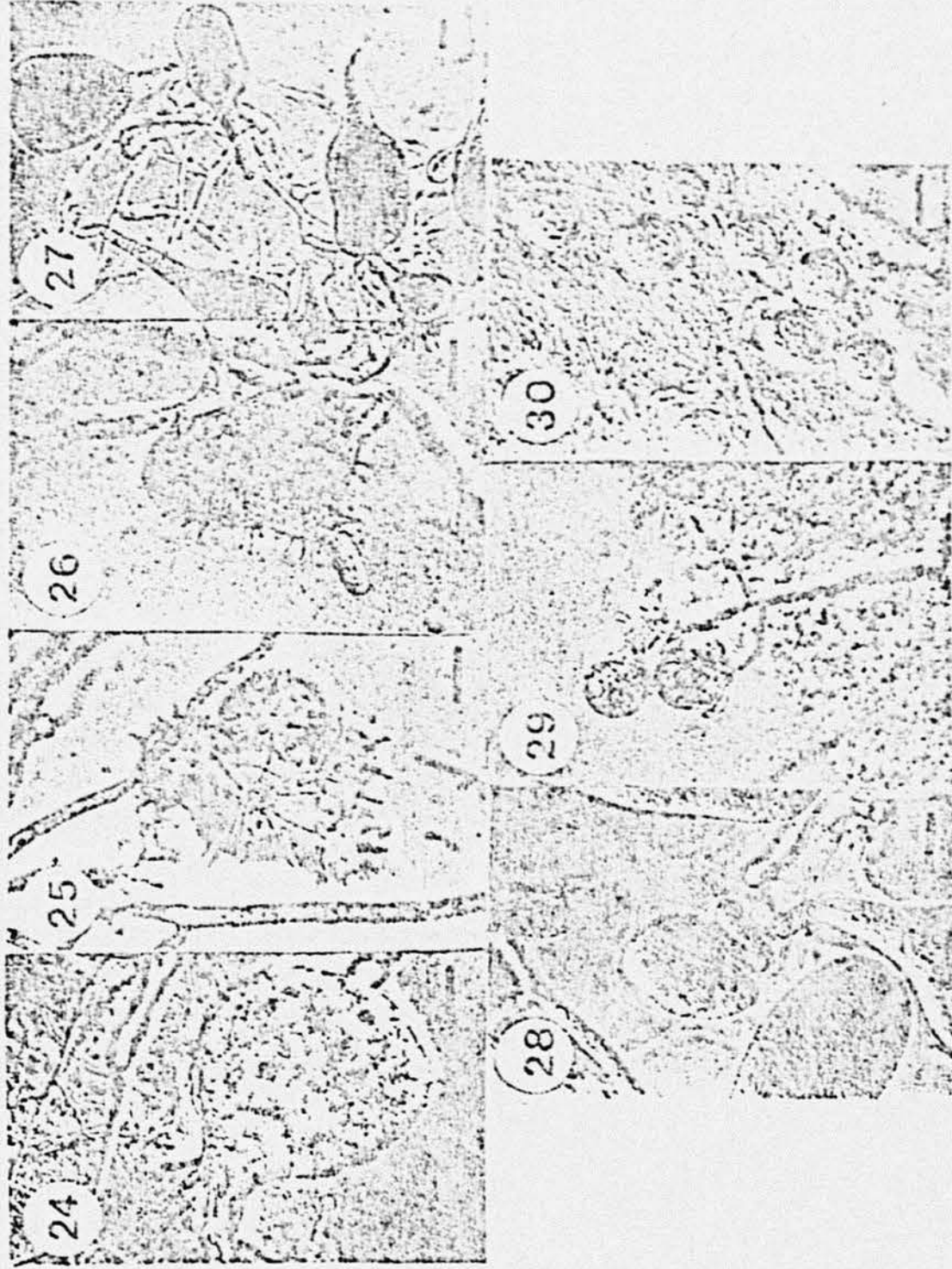
Table 1. Continued

	<u>Phytophthora</u> <u>bahamensis</u>	<u>P. epistomium</u>	<u>P. mycoparasitica</u>	<u>P. spinosa</u> <u>var. spinosa</u>	<u>P. spinosa</u> <u>var. lobata</u>	<u>P. vesicula</u>	<u>Pythium</u> <u>grandisporangium</u>
Conception Island	+			+		+	
Long Island						+	
<u>Caribbean</u>							
Bonaire				+		+	
Colombia				+		+	
Costa Rica		+				+	
Curacao				+		+	
Gonave Island, Haiti				+		+	
Grand Cayman	+			+		+	
Jamaica						+	
Trinidad				+		+	
<u>Indian-Pacific</u>							
Malaysia *			+		+	+	
Viet					+	+	
Seychelles *					+	+	
Hawaiian Islands				+		+	

* Rhizophora species other than R. mangle







UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

TECHNICAL REPORT

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Effects of Thermal Effluents on the Fishes and
Benthic Invertebrates of Biscayne Bay -
Card Sound, Florida

by

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ABSTRACT

Field studies on the effects of thermal additions from the Florida Power and Light Company's discharge at Turkey Point have been conducted to determine the effects of this effluent on the macro-invertebrates and fishes of the area.

Replicate samples with a 3 m (10 foot) otter trawl lined with .63 mm (1/4 in.) bar mesh were made monthly at 51 stations. Data on temperature, salinity and oxygen were collected during each sampling period. Additional chemical data were collected when opportunity existed.

The experimental results suggest that maximum summer temperatures above 32°C cause detrimental changes in the environment which are reversible in the winter, while temperatures above 33°C cause damage which does not recover during the cooler months. Intermittent flow of discharge water is not as damaging as constant flow.

Card Sound was occupied by a sponge-brittle star community but many organisms were common to both the Sound and Biscayne Bay. The discharge into Card Sound lasted about one year and temperatures in excess of 33°C were uncommon. Only a few indicator species showed stress and higher apparent abundance of others offset their decrease. Generally no lasting damage occurred in Card Sound.

Recovery after closing Grand Canal was relatively complete at station SE I, 200 yards from the effluent. Station G showed signs of recovery, but time is needed to allow colonization by sea grasses before the area recovers fully.

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INTRODUCTION

Concern over the effects of thermal additions from steam electric stations has been expressed by numerous scientists and conservation organizations. Adams (1968) reviewed most of the pertinent literature at that time in an 87 page manuscript. Since 1968, research and the literature on the effects of power plant operations has expanded exponentially (see Coutant, 1969, 1969b, 1970; Ulrikson and Stockdale, 1970). Until recently, little work has been done on the problems in tropical or subtropical estuaries. However, extensive research is now being conducted in Puerto Rico by M. J. Cerame-Vivas, in Guam by Jones, in Hawaii by P. L. Jokiel and in South Florida by the Rosenstiel School of Marine and Atmospheric Science, which has an ongoing multi-disciplinary study of the problem in Biscayne Bay and Card Sound.

In 1964, Florida Power and Light Company began construction of a major power generating station approximately 25 miles south of Miami at Turkey Point on the western shore of Biscayne Bay. The generating station consists of two fossil fuel units and two nuclear fuel units. The first unit, a fossil fuel unit, produces 432,000 KWe and utilizes 635 cu ft/sec of cooling water. This unit began producing in 1967. The second unit, a duplicate of the first, began producing in 1968. Unit three, a nuclear fueled reactor, rated at 760,000 KWe and utilizing 1490 cu ft/sec of cooling water, began testing in the summer of 1973 and began on line production in November 1973. Unit four, a second nuclear reactor, became operational early in 1974.

Initially, cooling water was borrowed from Biscayne Bay from north of Turkey Point and was discharged south of the point back into Biscayne Bay. During the period June 1968-February 1971, approximately 90% of the discharge occurred through the southernmost Biscayne Bay effluent canal called Grand Canal.

After a Federal Court Ruling (Atkins, 1971) an alternate cooling scheme was developed. A closed system of radiator canals was constructed for cooling. In the interim dilution with unit 3 and unit 4 pumps, discharge into Card Sound, and operation in a closed mode have been used in an effort to minimize the environmental impact on the receiving waters.

The objectives of this study were (1) to predict the effects of the heated discharge from the Turkey Point nuclear power units on the benthic fauna; (2) to measure the effects of the fossil fuel units; and (3) to study the benthic fauna and fishes of southern Biscayne Bay and Card Sound.

METHODS

Hydrographic Studies

Temperature was recorded during each trawling trip at each sampling station with a mercury thermometer or thermister probe. In addition, continuous recording Ryan Model F thermographs were maintained at stations SEI, I, A, B, D, E, and F (Fig. 1).

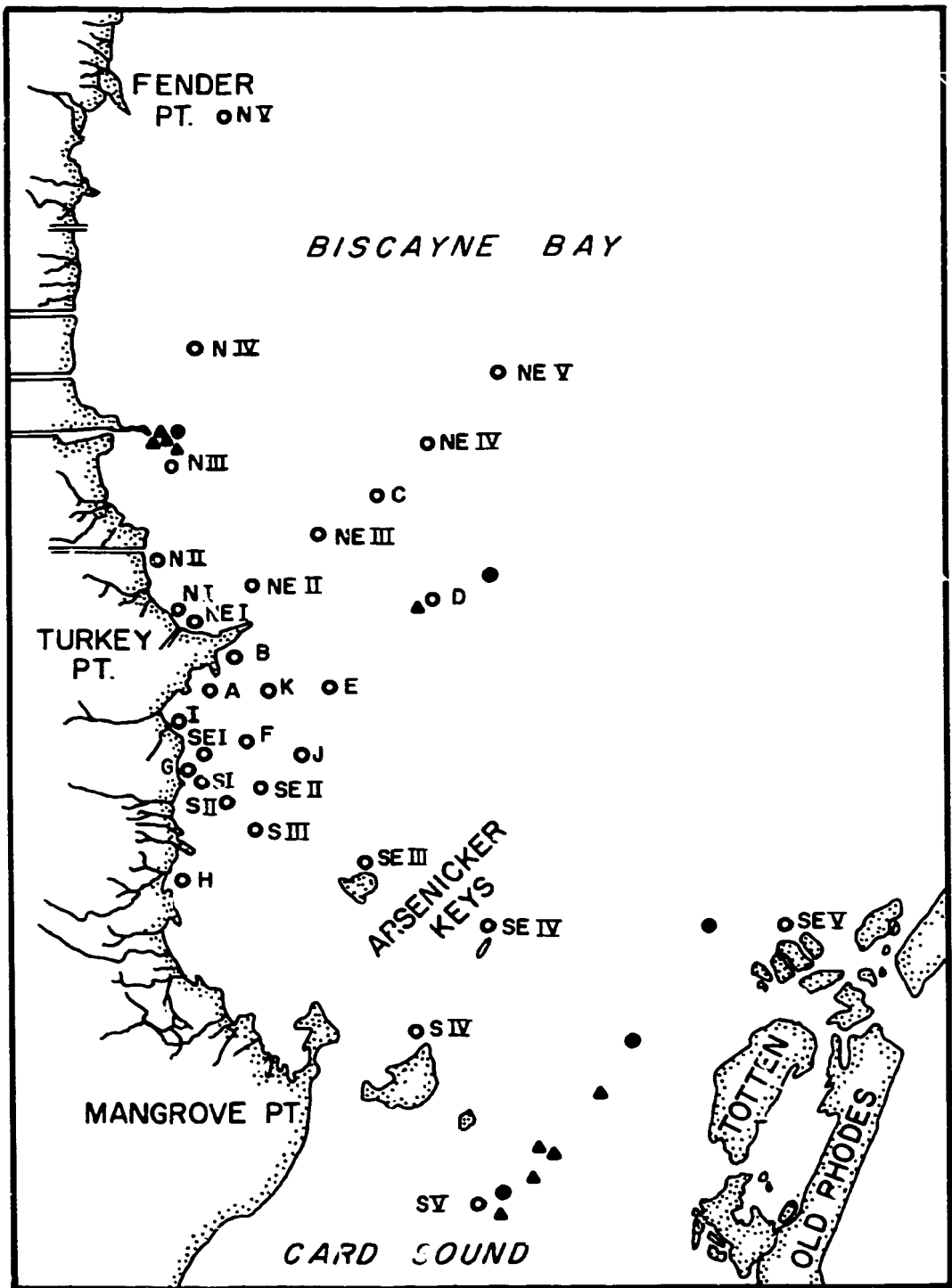


FIGURE 1. Location of stations in Biscayne Bay

Surface and bottom measurements of salinity and oxygen were made at each trawling station during each trawling trip. Oxygen was measured with a YSI model 54 in situ recorder. Salinity was determined with an American Optical refractometer, with a Beckman RS5-3 portable salinometer, or by determination on the Wheatstone conductivity bridge.

Biology

Seven trawl samples were taken at each of the trawl stations at monthly intervals. An otter trawl, with a foot rope length of 3 m, lined with 0.63 mm bar mesh was used for all samples. The tows were made with the wind. The net covered an average distance of $43 \text{ m} \pm 2.7 \text{ m}$ (95% C.I.) on measured tows in September 1972. The net opening was generally slightly over 2 m while being towed and thus, the catch per tow represents approximately the catch per 100 m² of bottom. Due to differences in mouth opening with loading, distance trawled under varying wind speeds, and depth of station, plus the uncertain escapement and selectivity, the authors only use an index of apparent relative abundance, the catch per tow. At the completion of each 2 minute tow the net was emptied into a wash tub. After seven tows were completed the contents of each tub were rough sorted. The kind and weight of vegetation were recorded and the animals preserved in 10% formalin. Later the reduced samples were sorted and counts of each species made. Prior to January 1971, no polychaetes were identified or counted. Starting in January 1971, polychaetes were identified and counted to the family level. Amphipods, Isopods, the gastropod, Batillaria minima, and the pelecypod, Brachidontes exustus, were not counted because of their small size which allowed escapement and inadequate sampling and their extreme abundance in some seasons.

Day catches were compared to night catches for twenty Biscayne Bay stations, with a non-parametric paired t-test. Night samples were collected within 24 hours of the day samples. Five different stations were sampled each month for a period of four months during the summer of 1969. Two tows were made at each night station and the relative abundance of animals was compared with two of the seven daylight samples which had the closest vegetation weights.

Analysis

Statistical treatment was confined to major taxa (i.e., phyla) and species that comprised more than 1% of the total animal catch. For the phyla, a Friedman's non-parametric analysis of variance was used to detect differences in catch among stations with the effects of months removed by coding. A simple arithmetic mean and 95% confidence interval was used to judge which stations produced high and low catches.

For the more abundant species the logarithm of the catch plus one was determined and the total catch calculated by summing these log values for the seven tows. Parametric analysis of variance was performed on the catches with stations and months representing primary components. Interactions were tested against the error mean square and the principal components against the pooled interaction and error mean square (Brownlee, 1965). Confidence intervals were calculated for month and station means.

Observations of catches falling outside these limits were declared significant. In addition a stepwise multivariate regression with the logarithm (catch + 1)/tow as the dependent variable and vegetation weight, temperature, salinity, deviation of temperature from mean and deviation of salinity from mean as independent variables was conducted for each of the dominant species. This indicated the major variable controlling the catches of each species and allowed the determination of the importance of temperature in the control of catch.

Finally, for each phyla and the combination of all taxa, three indices of diversity (Odum, 1971) were calculated for each station each month. The indices were:

$$d_1 \text{ (species richness)} = \frac{S-1}{\log_e N}$$

where S = number of species

N = number of individuals

$$\bar{H} \text{ (Shannon General Diversity)} = -\sum \left(\frac{N_i}{N} \right) \log_e \left(\frac{N_i}{N} \right)$$

where N_i = number of individuals of a species

N = total number of individuals

$$e \text{ (evenness)} = \frac{\bar{H}}{\log_e S}$$

where \bar{H} = Shannon General Diversity Index

S = number of species

Philosophy of Station Design

During the first phase of this study four radiating lines of stations were selected in Biscayne Bay to establish information on the extent of impact from the fossil units and to establish background data for measuring effects of the entire power station. The stations used were NI-V, NE I-V, SE I-V, and S I-V. During the next phase of study more emphasis was placed on learning the effects of temperature on the distribution of animals subjected to various degrees of heating. Thus, stations A-H were added as controls and affected stations. In phase three we attempted to obtain background information in Card Sound and finally the effort was reduced to five stations in Card Sound and two in Biscayne Bay to monitor the effects of the effluent in the Sound and to measure recovery in Biscayne Bay. The locations of the stations in Biscayne Bay are shown in Figure 1 and those in Card Sound in Figure 2. Physical descriptions of these stations, including distance from the effluent, distance from shore, water depth, sediment depth, sediment type, vegetation type, as well as observations on temperature, salinity and dissolved oxygen were presented by Roessler, Tabb, Rehrer and Garcia (1974).

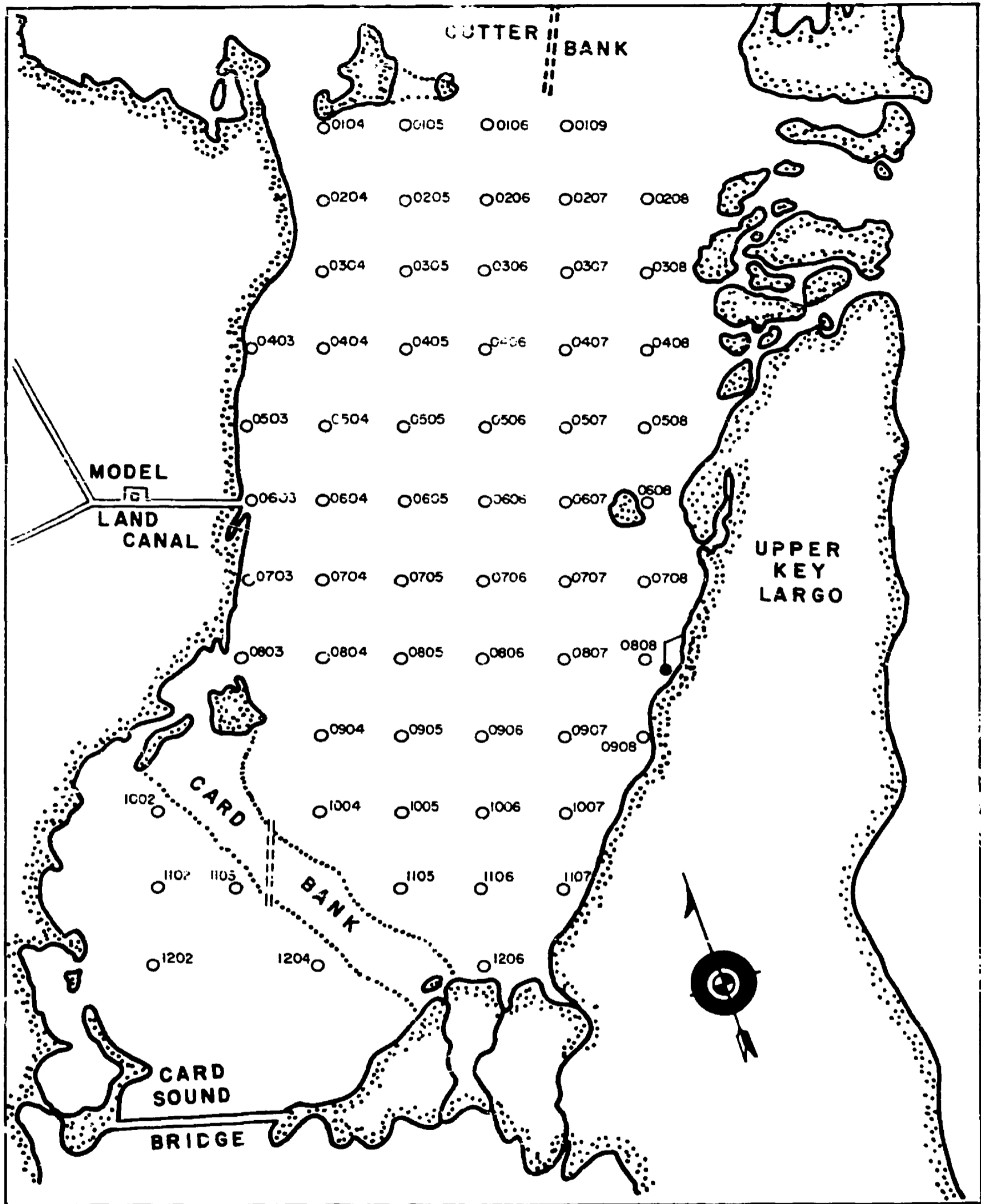


FIGURE 2. Location of stations in Card Sound

RESULTS

Temperature -- Biscayne Bay

From July 1968 to February 1972, Florida Power and Light Company operated two units each of which produced 432,000 KWe and utilized 615 cu ft/sec of cooling water borrowed from the Bay north of Turkey Point. Water temperature was raised 6-7°C while passing through the plant. There was a 1-2°C drop in temperature as the water passed down the canal to the mouth of Grand Canal (Nugent, 1970).

Monthly temperatures for each trawling station were presented by Roessler, et al. (1974) for the period July 1968-June 1971. Additional data from 32 hydrographic stations were presented by Segar, Gerchakov and Johnson (1971) and data collected independently by the Environmental Protection Agency was reported by Tebo, Estes and Lassiter (1968) and Hagan and Purkerson (1970). Figure 3 shows seasonal temperature data for stations NE III, SE III, D and SE V, other stations are illustrated in the section on animal distribution.

Station N III was used as a control to measure ambient temperature during July 1968-December 1968 and station D on Pelican Bank was used as a measure of ambient temperature from January 1969-June 1972. After that, when the work in Biscayne Bay became primarily concerned with the recovery of stations SE I and G previously damaged by the effluent, station 0104 in Card Sound was used as the control temperature station.

The average winter ambient temperature was about 17°C. The lowest observed temperature was 9°C. In summer, ambient temperature was about 31°C with a maximum near 35°C occurring in shallow areas in mid summer. A few stations generally out of the influence of the thermal plume experienced temperatures of 37-38°C in September 1968. These anomalously high temperatures may have been "hot pockets" of effluent water which quickly passed over the stations, but more likely were observer errors.

Off the Grand Canal where approximately 1100 cu ft/sec of discharge water entered the bay, an area of 30 to 50 acres was elevated 5°C above ambient. Proceeding outward, succeeding areas were elevated as follows: 75 acres to +4°C, 170 acres to +3°C and 300 acres to +2°C above ambient (Gerchakov, Segar and Stearns, 1971). These areas and temperatures were predicted by a model of Lee and Rooth (1971) and confirmed by comparison with infrared aerial measurements of temperature in the Turkey Point plume. Temperatures typical of winter, spring, summer and fall are given in Figure 4.

In general, the plume was oriented in a northeasterly direction. Out of 86 observations the plume traveled northeasterly in 80 cases and was deflected to the east or southeast only during periods of northwesterly winds which generally accompany cold fronts (Fig. 5). This northeasterly transport was relatively constant and occurred on both ebb and flood tides (Fig. 6). On several occasions, it was noted that the thermal plume curved around Turkey Point and recirculation occurred.

Stratification occurred only during ebb tides and only during periods of calm (0-5 mph) winds which lasted for 12 hours or more. Such low wind

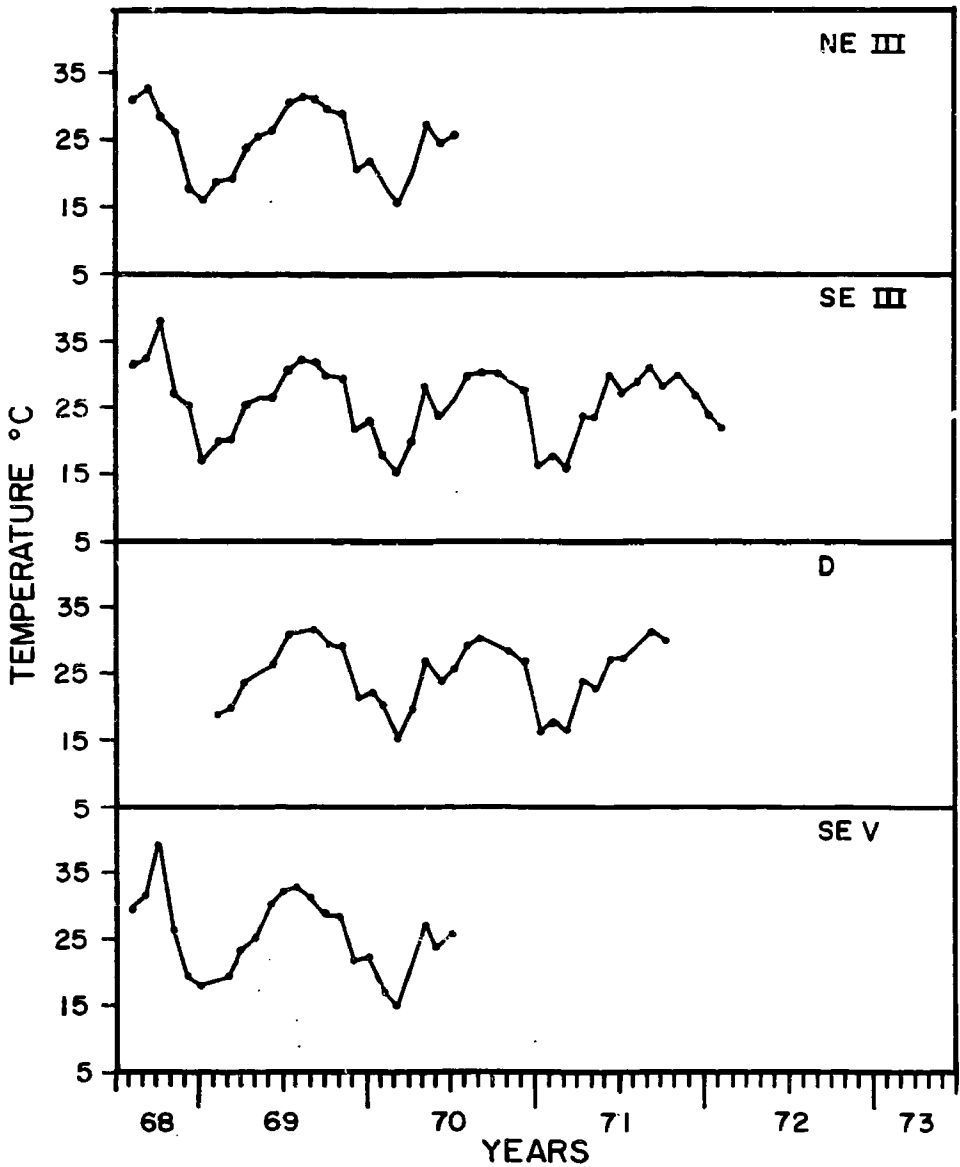


FIGURE 3. Seasonal distribution of temperature at stations NE III, SE III, D and SE V in Biscayne Bay

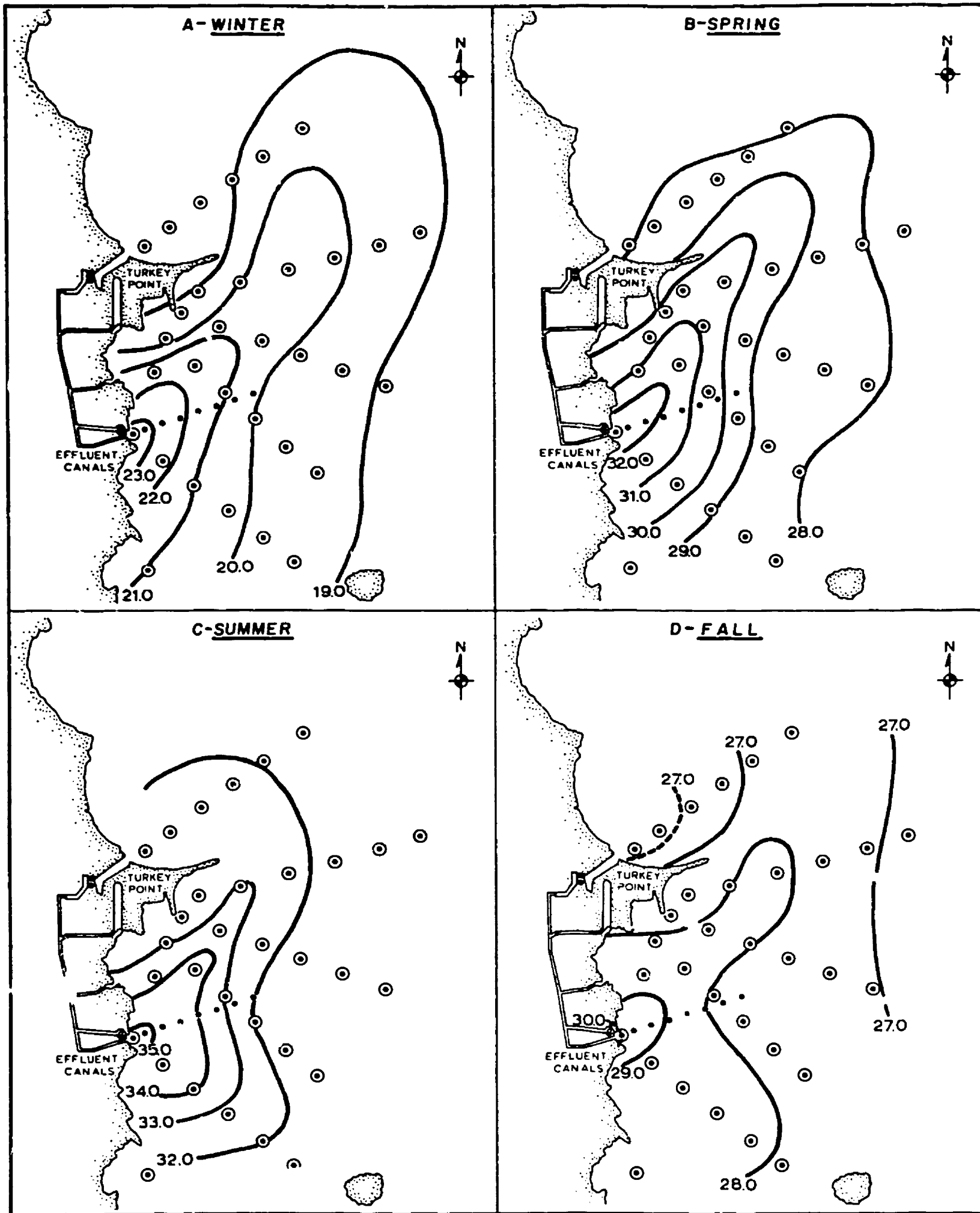


FIGURE 4. Temperature profile in °C in (A) winter, (B) spring, (C) summer, and (D) fall

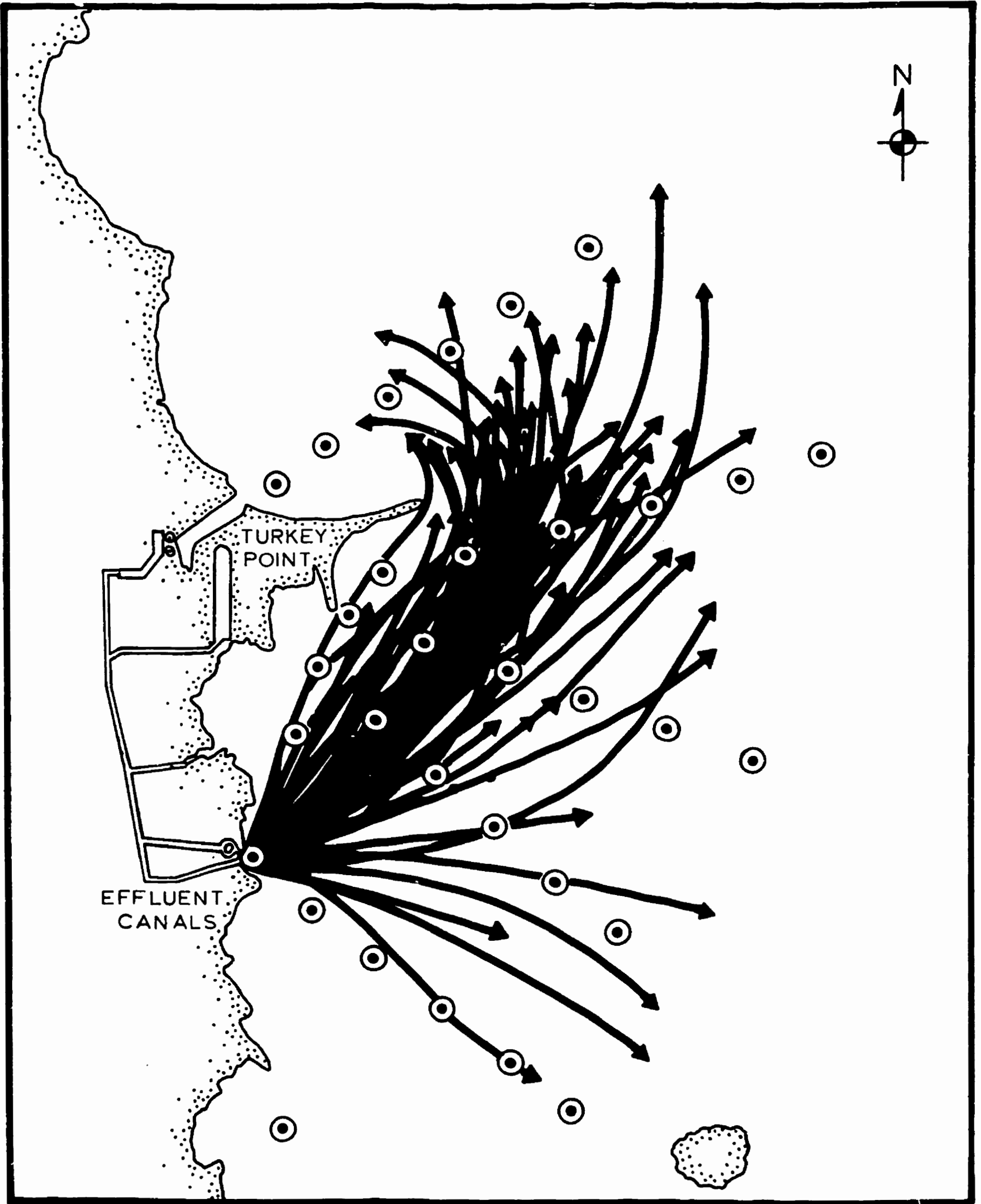


FIGURE 5. Thermal plume axis in 1969 and 1970

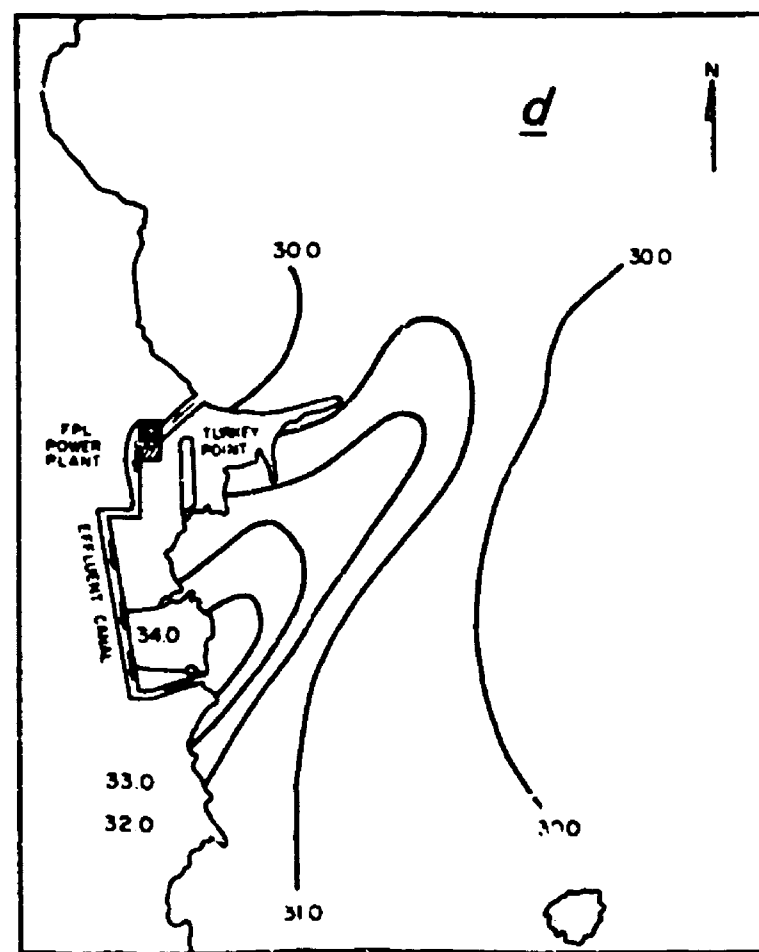
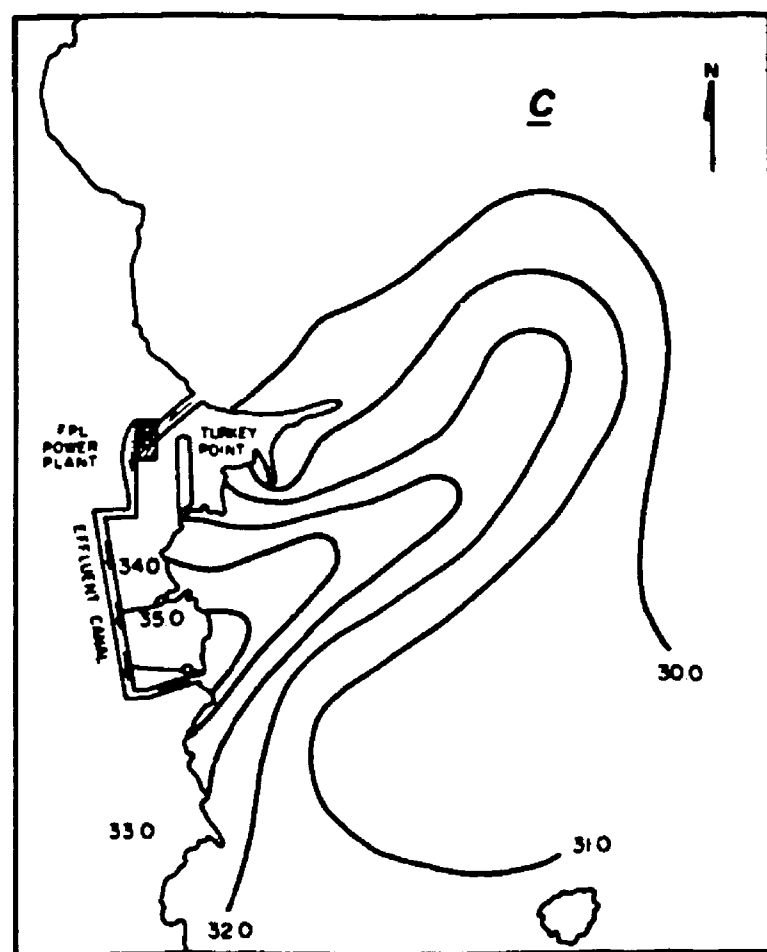
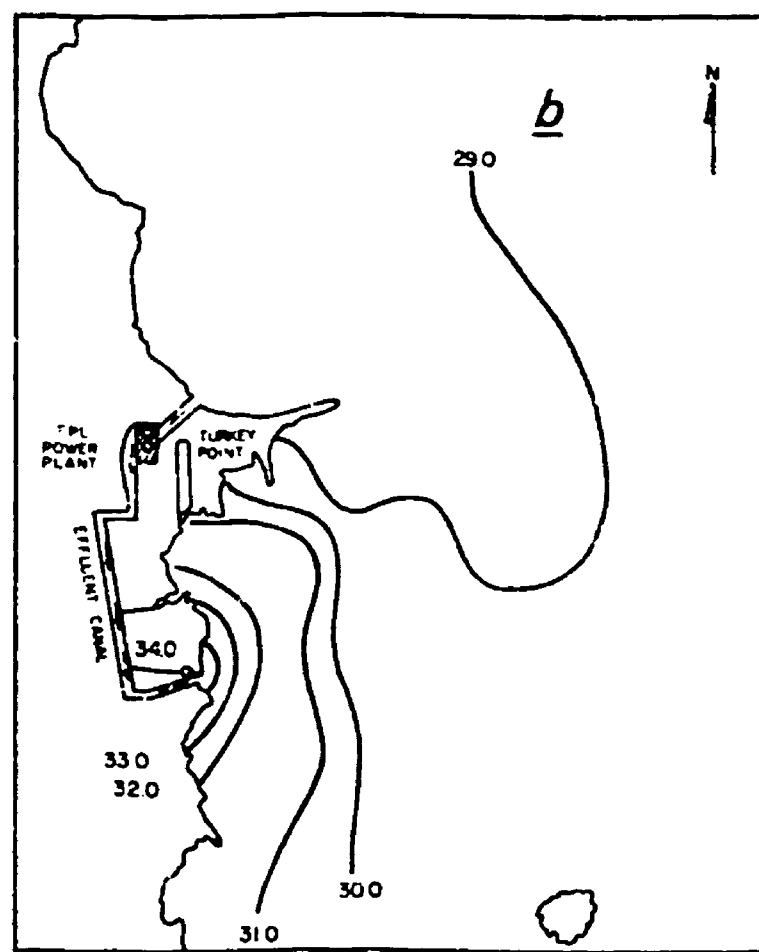
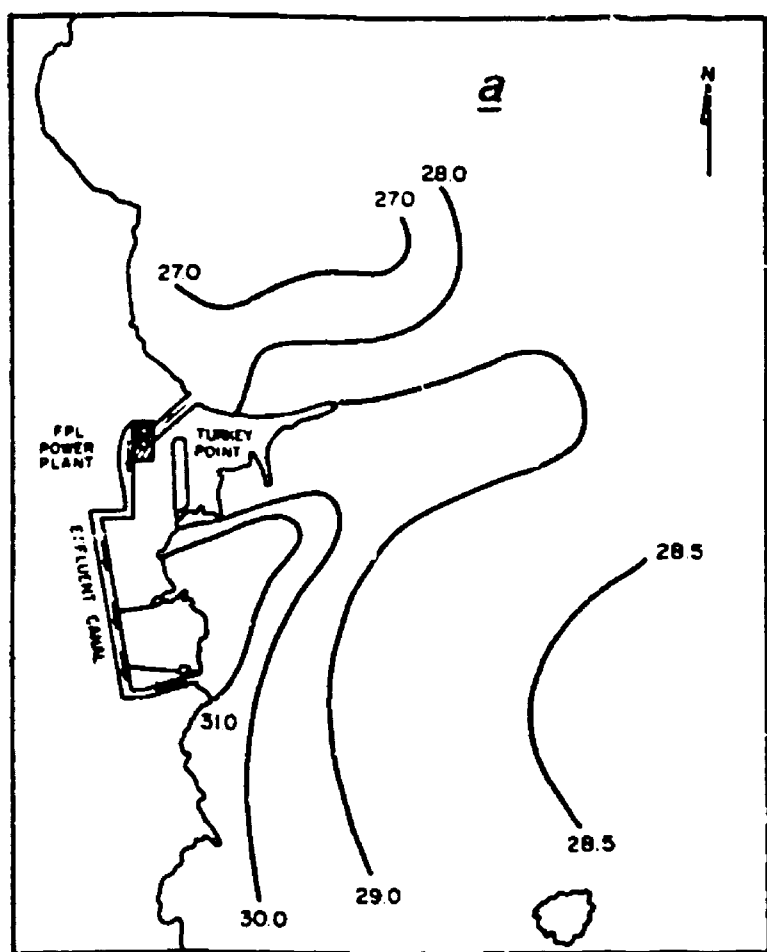


FIGURE 6. Tidal changes in surface temperature profile at (A) late flood, (B) early ebb, (C) late ebb, and (D) early flood

speeds are unusual in the Miami area and climatological data from Homestead Air Force Base (approximately 3.5 miles west of Turkey Point) indicated that wind speeds less than 5 mph occurred only 13% of the year. This varies seasonally; the largest percent of calm wind (17%) occurred in August and the smallest (9%) occurred in March.

It was believed that the long-term average properties of the thermal plume could be ascertained by measurements of the temperature distribution in the sediments. This assumption was based on the theory that the sediment temperature is determined by the diffusion of heat from the water-sediment interface and would provide a history of the thermal conditions of the waters above.

Figure 7 indicates the temperature of (a) the bottom water, (b) the sediment surface, (c) the sediment at 10 cm, and (d) the sediment at 20 cm on 12 August 1969. In view of the persistence of the thermal plume axis, it was not surprising that the thermal pattern in the sediments was similar to the water above. Gerchakov, Rooth, Segar and Stearns (1973) have discussed the sediment temperature profiles in detail.

Diurnal variations of 2-3°C or more were common. Figure 8 shows thermograph traces at two stations SE I, 200 yards northeast of the effluent, and station A, a control area, during a 5-day period during July 1969 when temperatures were extremely high. The effects of tide are indicated by the lower curve: ESSA Coast and Geodetic Tide Tables (1969) corrected by data from Schneider (1969). Plant load, solar radiation, and time of high tide, combine to produce maximum temperature around noon during spring tides. The temperature was not elevated as much during neap tides when high water occurred in morning and evening hours.

The seasonal pattern of daily maximum, minimum and average temperature (based on eight three-hour intervals starting at 0000 hours) for station D is shown in Figure 9. The Ryan thermographs have a 30°C range and the lower limit was 15 or 20°C, therefore, temperatures below these values were not recorded.

The thermograph was in continuous operation from January 1970 until March 1971. Minor gaps in June and November were due to instrument repair. Temperature drops were obvious in the general warming trend during March and April. The cold front activity is again observed in November and throughout the winter months. During the summer, temperatures remain relatively constant except for diurnal variations. Heavy thunder showers, when they occur near low tides, can cause large diurnal variations. At station D the average daily temperature reached 33°C during a single day in June 1970. The maximum daily temperature exceeded 33°C on 17 days and exceeded 35°C only on one day.

A thermograph was in operation at station A from February 1969-December 1970. Figure 10 indicates the daily maximum, minimum and average temperature is about 1.5°C higher than at station D. The large daily variation is the result of tidal influence which allows the thermal plume to pass over this station during the ebb tide and retards it on the flood tide.

Average daily temperatures exceeded 35°C on one day in July 1969. The maximum daily temperature exceeded 35°C on 5 days in July and 4 days in

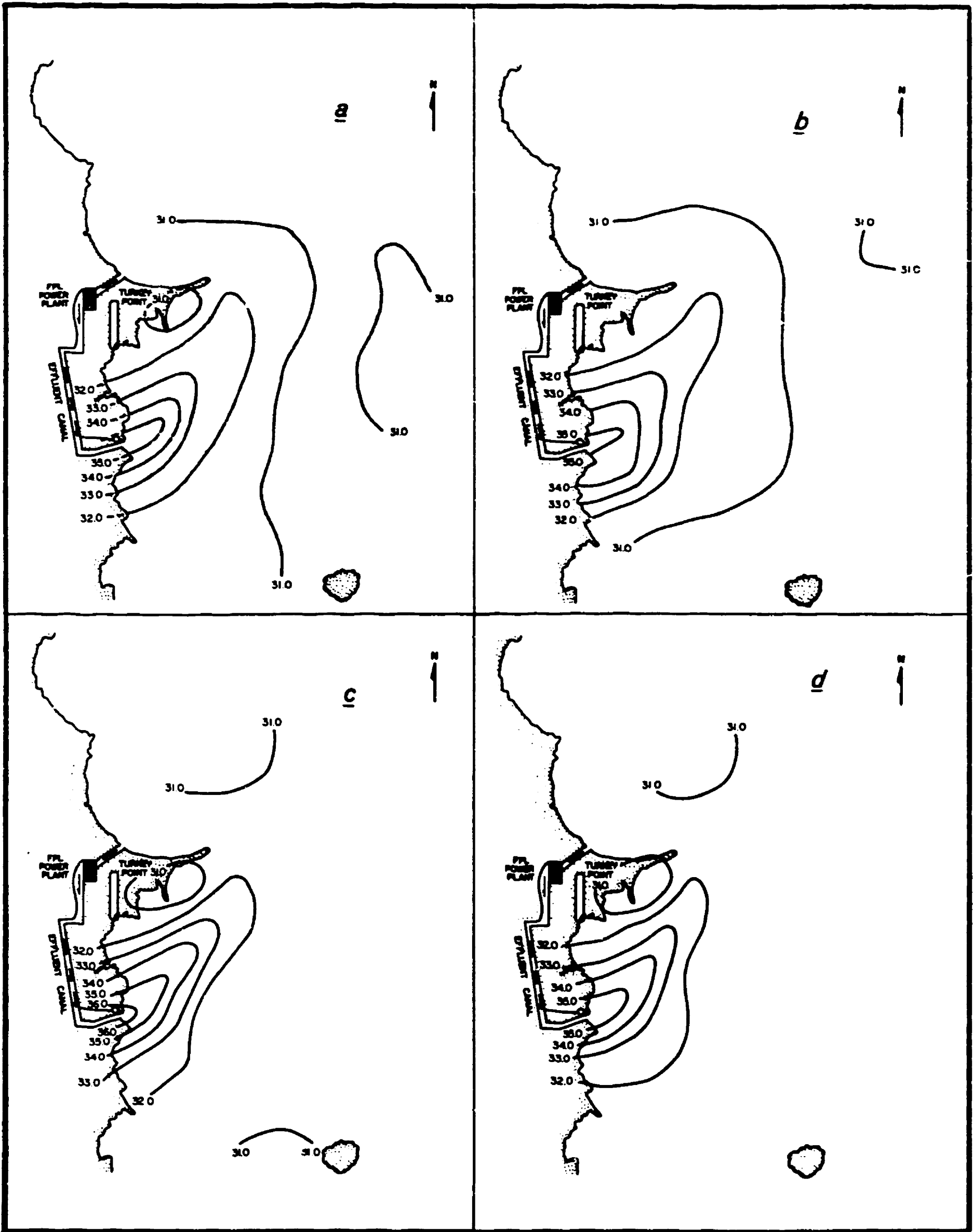


FIGURE 7. Bottom water and sediment temperatures (A) bottom water (B) 1 cm depth, (C) 10 cms depth, and (D) 20 cms depth

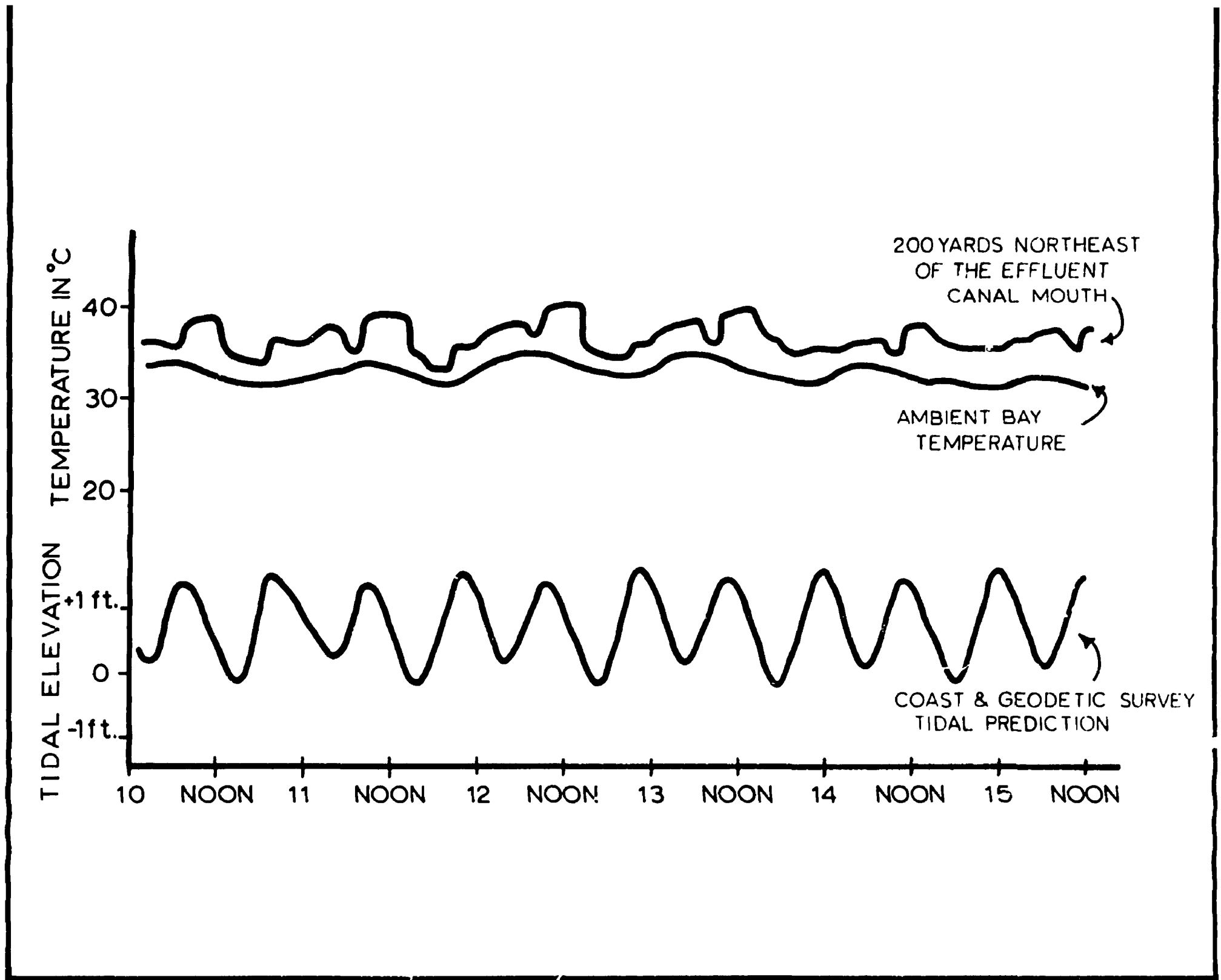


FIGURE 8. Temperature and tidal cycle for the period 10-15 July 1969; the hottest discharge temperatures recorded

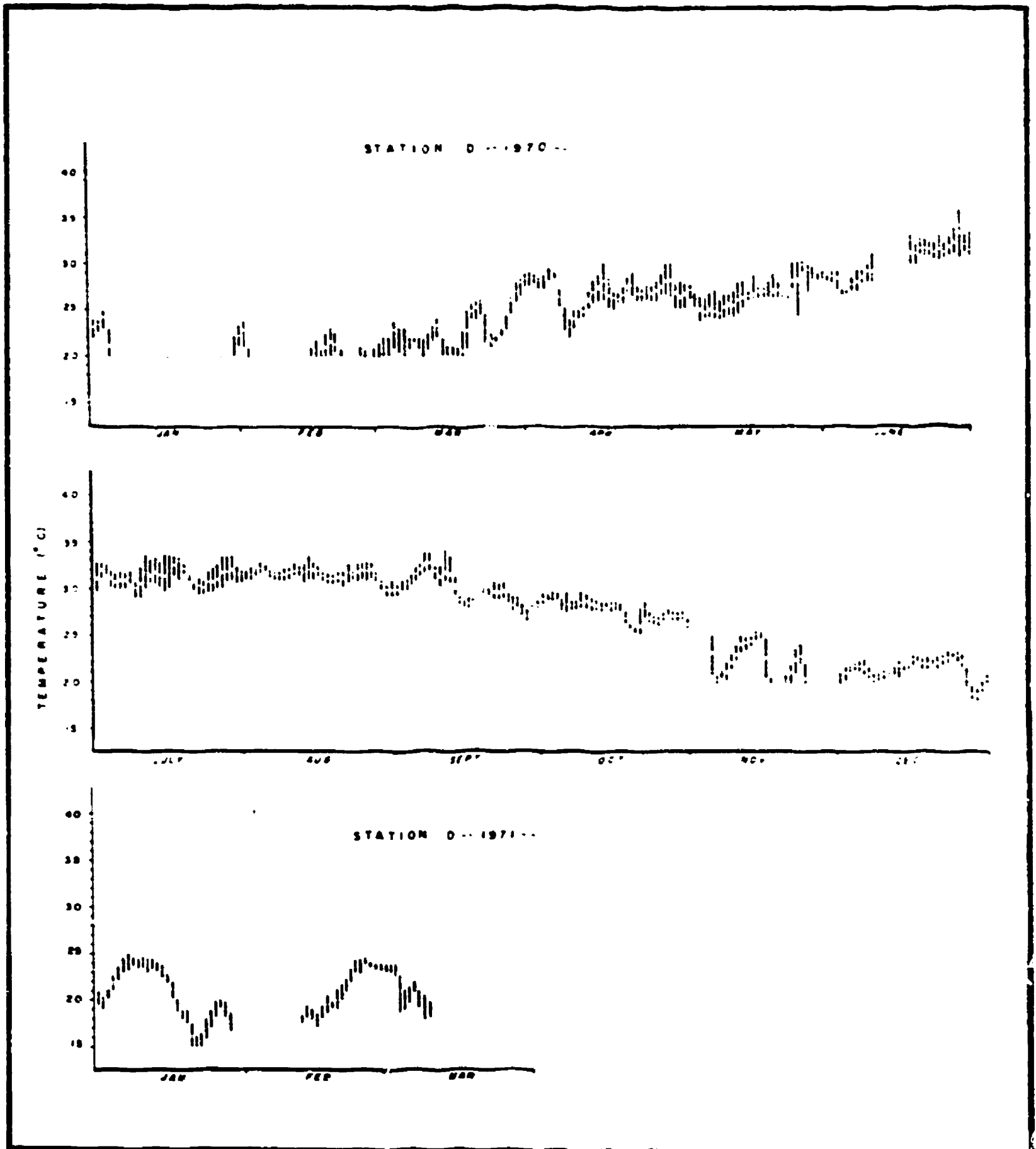


FIGURE 9. Daily maximum, minimum and average temperature at control station D in 1970-71

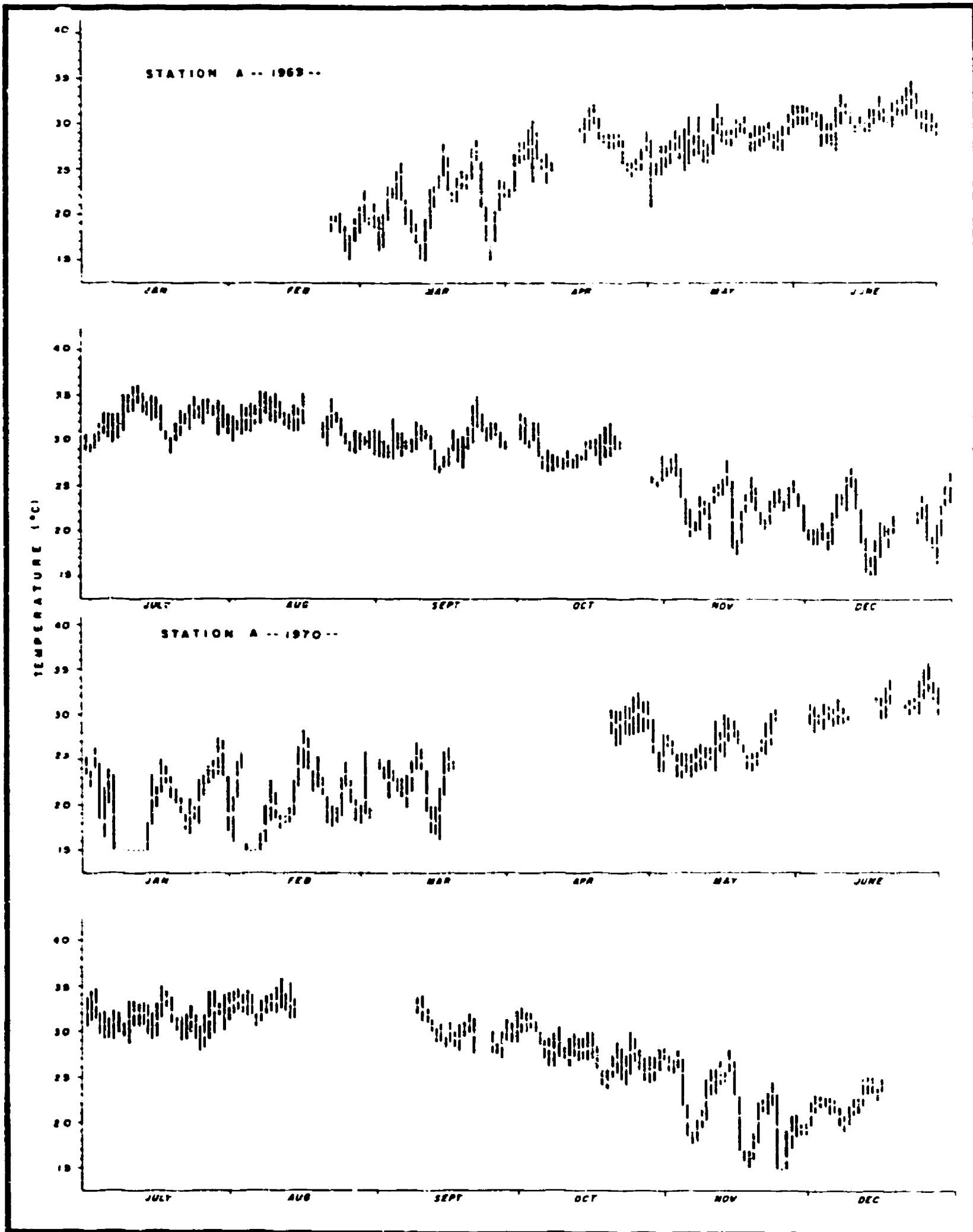


FIGURE 10. Daily maximum, minimum and average temperature at station A in 1969-70

August 1969; 2 days in June, 1 day in July and 3 days in August 1970. The average daily temperature exceeded 33°C on 11 days in July and 6 days in August 1969; 2 days in June, 2 days in July and at least 5 days in August 1970. The daily maximum was above 33°C on 4 days in June, 18 days in July, at least 16 days in August and 2 days in September 1969; 7 days in June, 15 days in July and almost all of August and early September 1970.

The thermograph data for station F which averages about 2°C above that at station D is shown in Figure 11. This station was generally in the path of the thermal plume and also exhibits greater daily temperature fluctuations than D.

At station F, average daily temperature exceeded 33°C for 5 days in August 1969 and the daily maximum exceeded 35°C on 2 days. In 1970, average daily temperatures exceeded 35°C on 6 days in June, 10 days in July and from mid-August through early September. Average daily temperatures exceeded 33°C from mid-June through September or for a period of about 4 months.

Thermograph data for station SE I is presented in Figure 12. This station, located 185 m NE of the mouth of the effluent canal, is continuously in the thermal plume. Temperatures at this station averaged 3.5°C or more above those at station D. Maximum temperatures in excess of 35°C were recorded from May-October 1969; June-September 1970 and in May 1971. Daily averages exceeded 35°C in May-August 1969 and June-September 1970. The maximum and average daily temperatures exceeded 33°C in April-October 1969 and April-September 1970. Thus, the temperature exceeded 33°C for a period of six months.

Station I, located in the mouth of Little River, a minor discharge canal which receives about 8% of the discharge, is subjected to tidal variations in temperature (Nugent, 1970). The flood tide backs up the canal and cooler bay water covers the station. On ebb tides the effluent covers the station and high temperatures are experienced.

A copy of the thermograph trace and adjusted tidal cycle is shown in Figure 13. This results in about a 5°C difference between daily maximum and minimum temperatures (Fig. 14). Thus, although the daily maximum temperatures exceeded 33°C from June-mid-September 1970 and part of April and May 1971, the average daily temperature only exceeded 33°C, on 7 days in July and 4 days in August 1970. The daily average temperature never exceeded 35°C, but the maximum daily temperature was in excess of 35°C on 23 days during the summer of 1970 and on 3 days in May 1971. More detailed analysis of the temperature structure within the canal system was given by Nugent (1970).

Temperature -- Card Sound

Baseline temperature data in Card Sound was gathered for approximately one year prior to the February 1972 completion of the cooling canal extension. Information gathered between then and February 1973 indicated the temperature field occurring when both Card Sound and Biscayne Bay received the diluted effluent. Data collected between February and June 1973 represents temperature conditions when the extensive closed cooling system

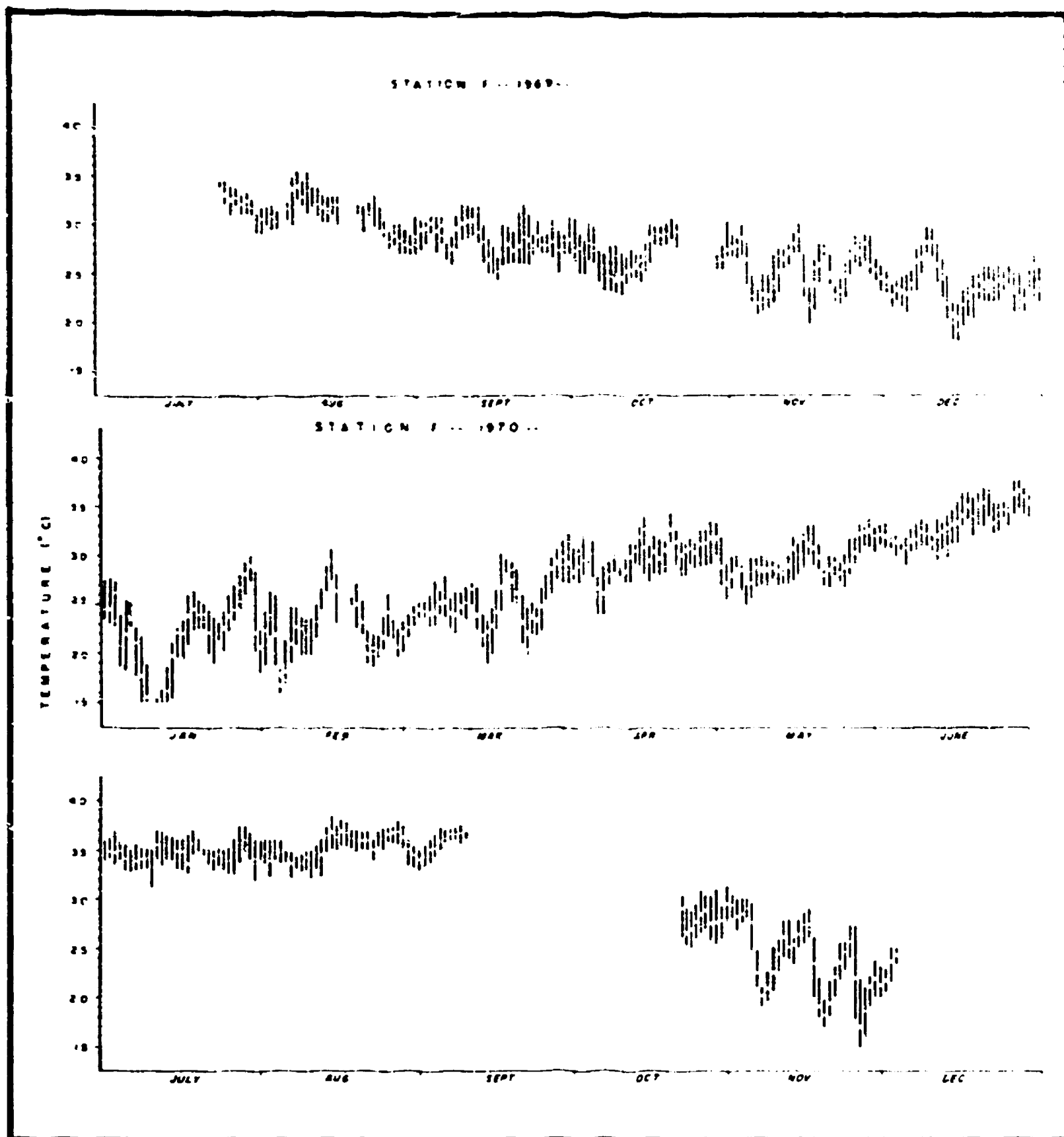


FIGURE 11. Daily maximum, minimum and average temperature at station F in 1969-70

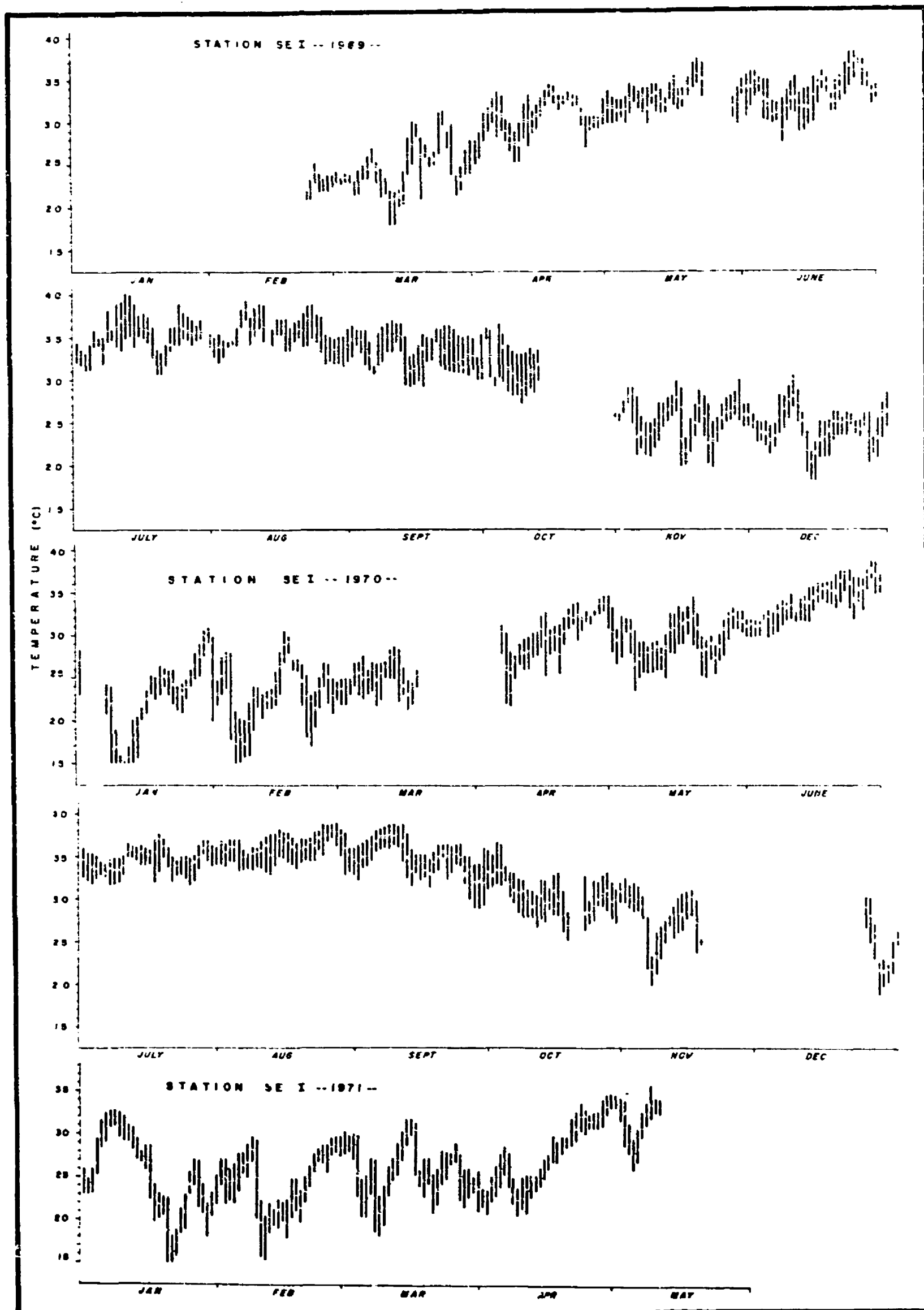


FIGURE 12. Daily maximum, minimum and average temperature at station SE I in 1969, 1970, and 1971

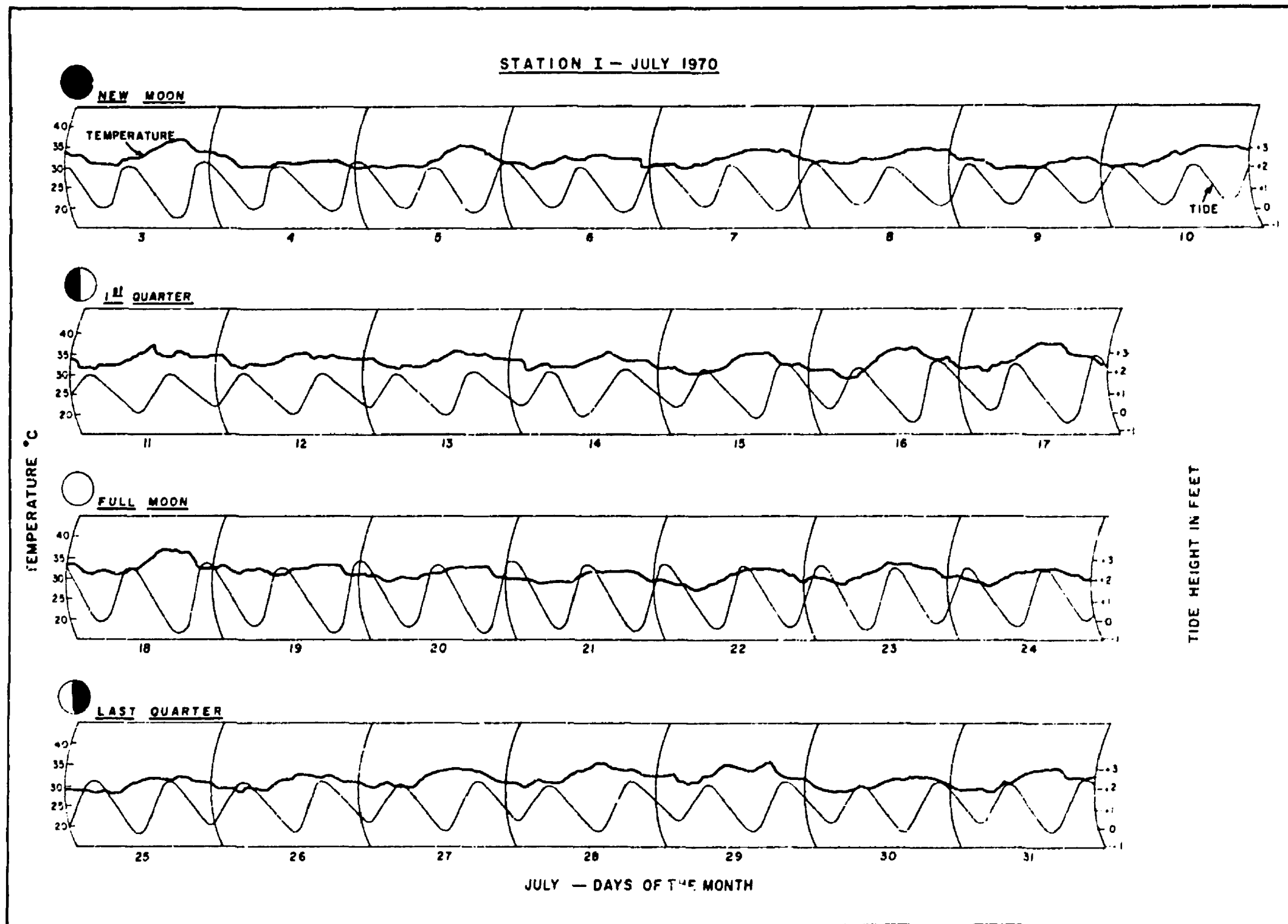


FIGURE 13. Temperature and tidal cycle for the month of July 1970 at station I

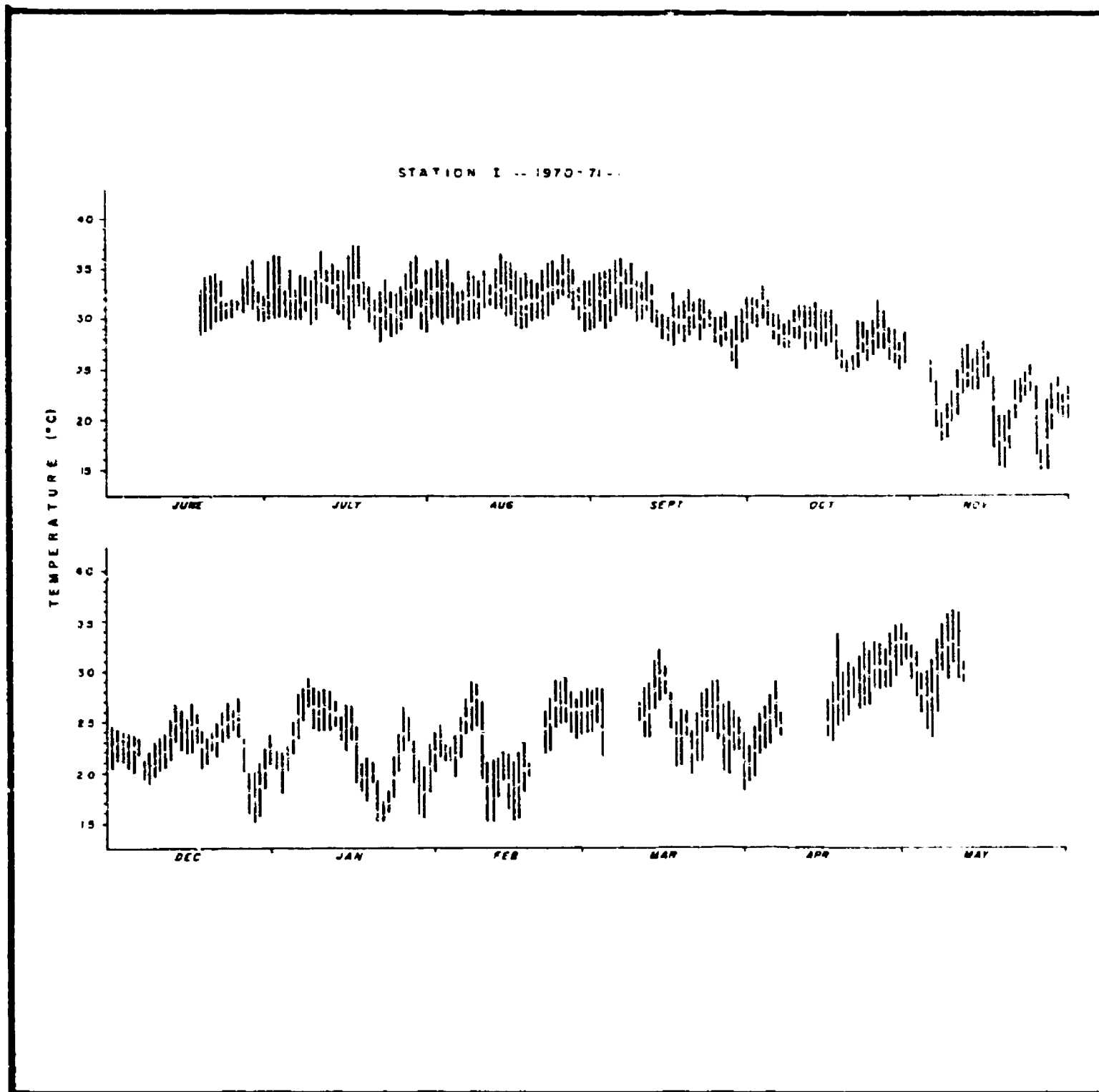


FIGURE 14. Daily maximum, minimum and average temperature at station I in 1970-71

was operational. Temperature data were presented in Segar, Gerchakov and Johnson (1971) and analyzed by Lee and Rooth (1971). Data for stations 0104, 0503, 0603 and 0604 are shown in Figure 15. Generally the effluent did not exceed the ambient bay (0104) temperature by more than 3°C, and only once was the temperature at 0603 in excess of 35°C.

Chemistry

During each trawling trip salinity and dissolved oxygen were measured. In addition, measurements by others--see Segar, Gerchakov and Johnson (1971) and Lee and Rooth (1971)--have been made in their chemical and physical studies.

Salinity in Biscayne Bay was correlated with rainfall values but this relation was somewhat modified by the influence of runoff when flood control dams on Florida City Canal, Mowry Canal, Moody Canal, and others, were opened to permit drainage. Normally, there was a salinity gradient with low salinity near the western shore and an upward gradient as one proceeded eastward. This phenomenon is also discussed by Kohout and Kolopinski (1964). During the 1970-71 drought period, this salinity gradient was reversed. Figure 16 illustrates a typical wet season and dry season isohaline distribution.

The mainland shore stations were subjected to large salinity fluctuations, those in mid-bay experienced a smaller range of salinity and those stations near the passes which connect directly to the ocean received the least salinity variation (Fig. 17). Station N II is a mainland station influenced by Homestead Canal runoff, station G is the effluent, station D is a mid-bay station and station S V is near the Florida Keys and influenced by oceanic waters via Ceasar and Broad Creeks (see Taylor, 1971).

Data on salinity at 32 additional hydrographic stations in Biscayne Bay and at times other than when trawling was done are summarized by Segar, Gerchakov and Johnson (1971).

Additional salinity data for Biscayne Bay and Card Sound are available; Tebo, Estes and Lassiter (1968), Lee and Rooth (1971).

Lee and Rooth (1971) have examined the salinity in Card Sound and have indicated that the normal salinity gradient implied little mixing of the western portion of the Sound with the Atlantic except during periods of strong northwesterly winds such as accompany cold fronts.

Data for stations 0104, 0504, 0603 and 0604 in Card Sound are shown in Figure 18. The salinity tended to be oceanic to hypersaline during the period of study. Only a surface lens of low salinity water was evident off the Model Land Canal in the rainy season.

Oxygen

Measurements of dissolved oxygen indicated that the water was generally well oxygenated. Subsequent to passage through the plant a slight reduction in oxygen occurred probably due to simple equilibration with the atmosphere at the elevated temperature. An additional decrease occurred

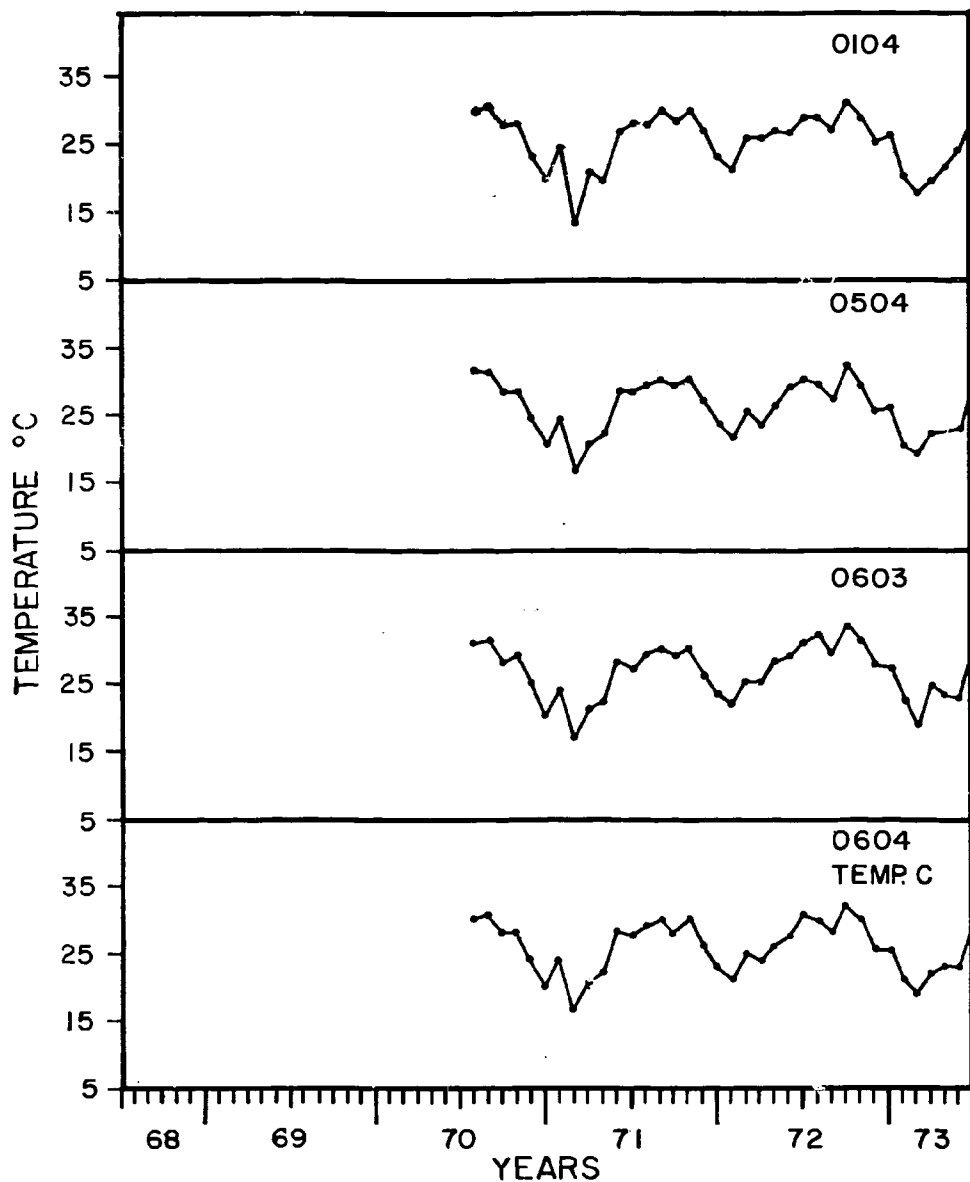


FIGURE 15. Seasonal distribution of temperature at stations 0104, 0504, 0603, and 0604 in Card Sound

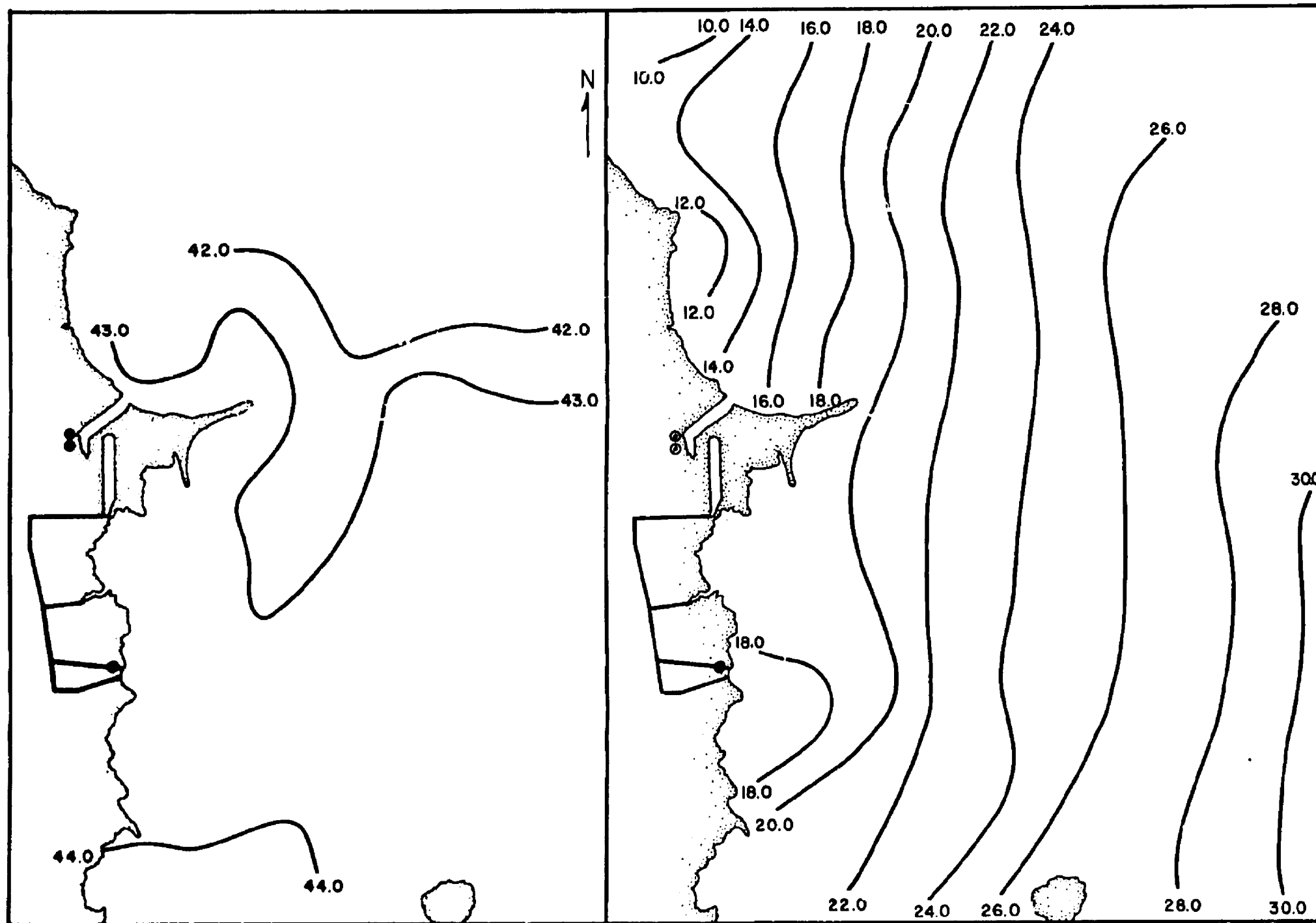


FIGURE 16. Isohalines in Biscayne Bay during (A) dry season and (B) wet season

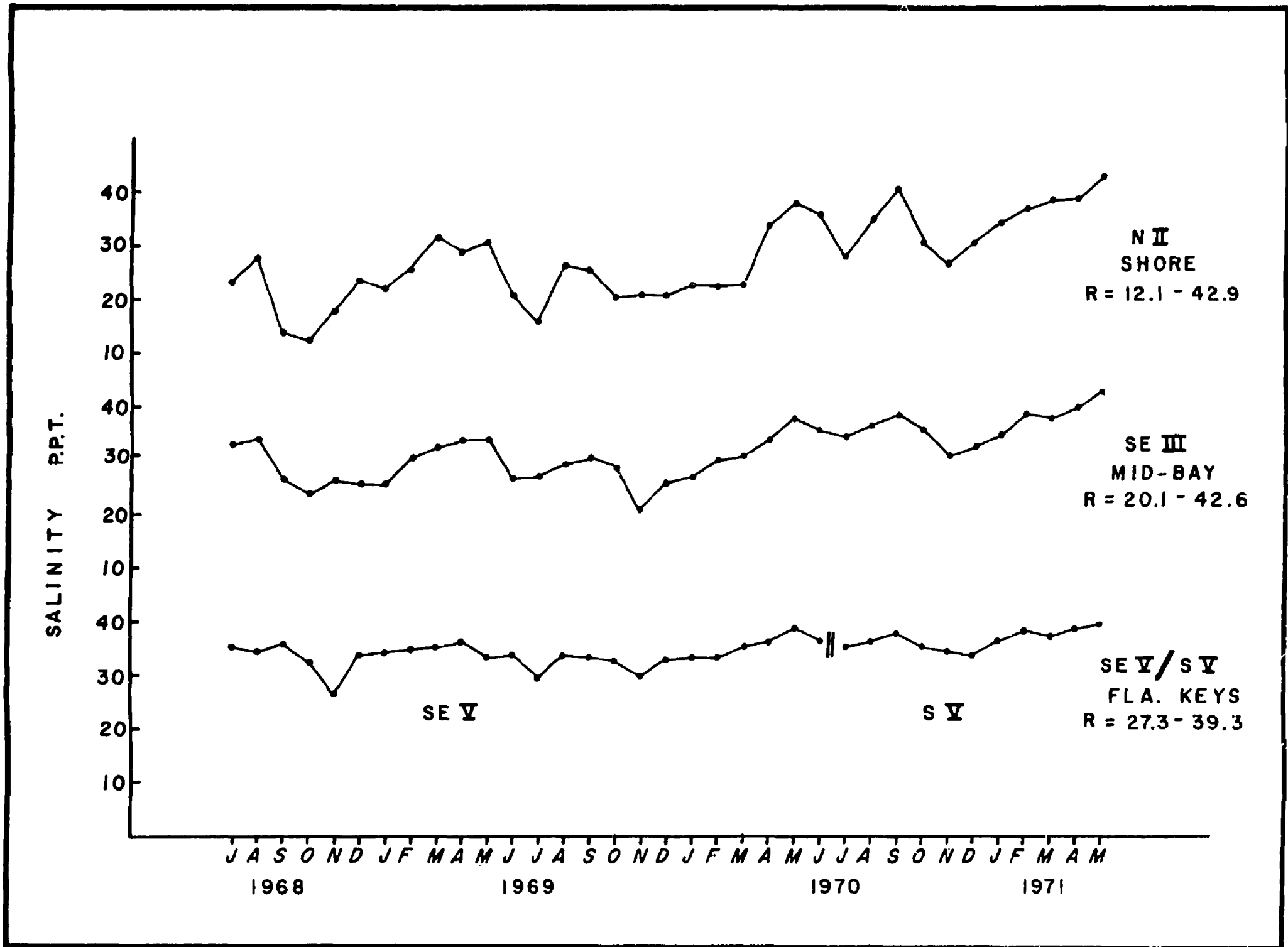


FIGURE 17. Monthly salinity observations at an inshore station - N II, a mid-bay station - SE III, and eastern bay stations - SE V and S V

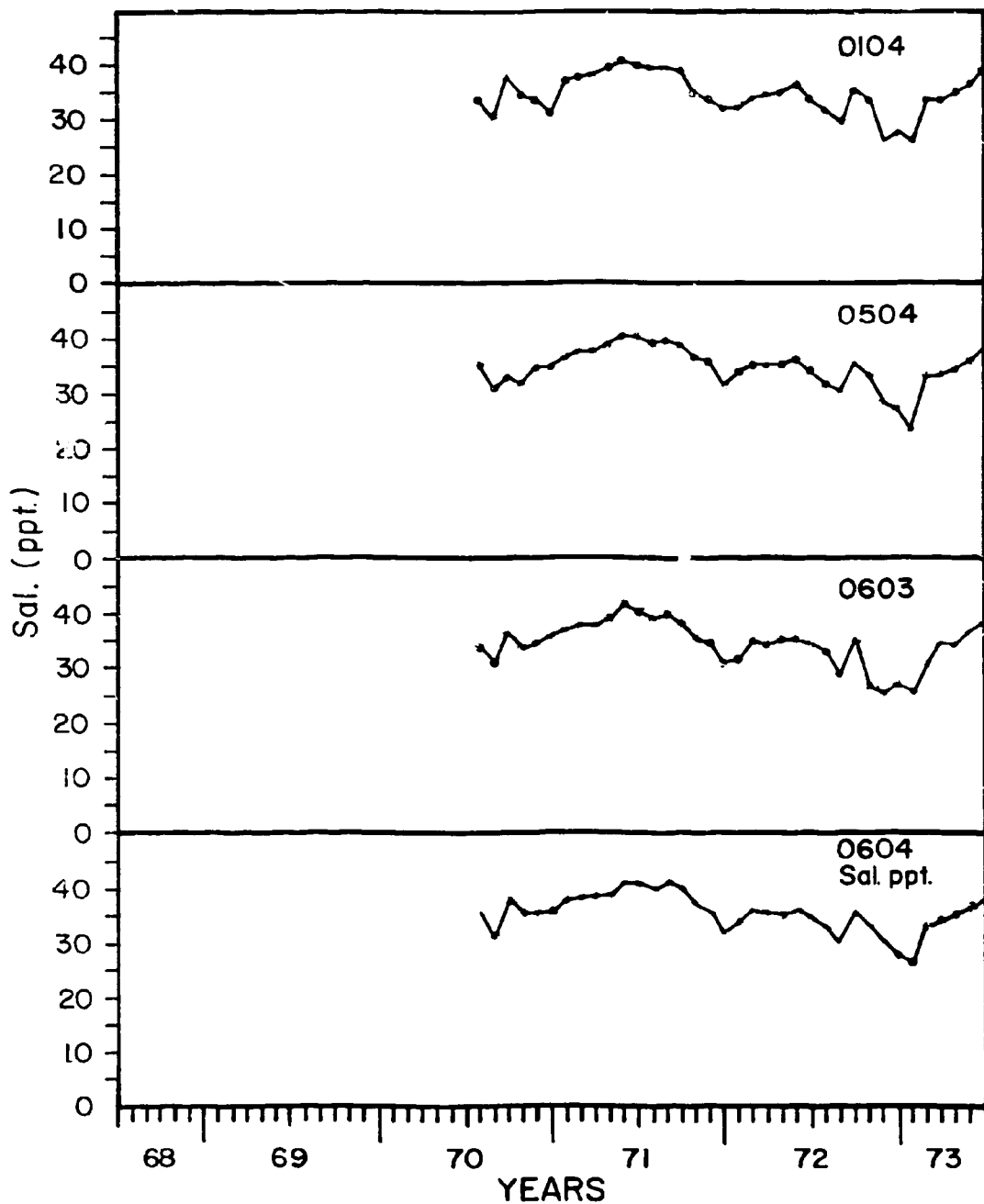


FIGURE 18. Seasonal distribution of salinity at stations 0104, 0504, 0603, and 0604 in Card Sound

when large amounts of organic materials were being contributed by runoff from the mangrove region adjacent to the plant (Nugent, 1970).

Diurnal oxygen cycles were particularly evident on calm days. Oxygen values were low in early morning hours and increased to supersaturated conditions by afternoon. This was the result of photosynthesis by sea grasses and macroalgae. A typical diurnal pattern is shown in Figure 19. Extreme oxygen values ranged from 83% saturated (3.4 ml O₂/l) to 230% saturation (11.1 ml O₂/l).

In the area immediately around the canal mouth, supersaturation was rarely observed. This was probably due to the lack of macroalgae and sea grass, combined with the swift currents and high turbulence.

Generally, oxygen values followed a natural seasonal curve with higher values occurring in the colder winter months and lower values in the warm summer months. The supersaturated conditions, which occurred in summer over dense grass or algae beds, was an exception to this pattern but can easily be attributed to photosynthesis and little wind-induced mixing of the water. Monthly oxygen measurements for stations G, SE I, F and D in Biscayne Bay are shown in Figure 20. Additional data for 32 hydrographic stations and for times other than during trawling operations were summarized by Segar, Gerchakov and Johnson (1971). Oxygen at Card Sound stations 0104, 0504, 0603 and 0604 are shown in Figure 21.

Other chemical parameters could not be related to animal distribution due to the sporadic nature of collection and analysis of water samples and the lack of funds to continue the chemistry program. Data collected under the support of the AEC were summarized by Segar, Gerchakov and Johnson (1971) and interpreted by Gerchakov, Segar and Stearns (1971).

Measurements of the nutrients, nitrite, nitrate, phosphate, total phosphorous, silicate, total dissolved inorganic carbon, and total dissolved organic carbon were made as well as measurements of dissolved iron, copper, zinc, pH, alkalinity and Eh of the sediments. In addition, in Card Sound, measurements of gross alpha and gross beta radiation were made together with gamma spectra analysis for selected ions.

Segar, Gerchakov and Johnson (1971: IV-60-6) summarized their findings and stated that micronutrients (NO₂, NO₃, Si O₃ and PO₄) were slightly enriched in the discharge water. The carbon dioxide/carbonate system of the heated water may have been altered by plant operation. Trace transitional metals (Fe, Cu, Zn) are enriched in the area of heated water.

More recent findings from Card Sound have been published by Thorhaug, Segar and Roessler (1973) and Segar, Gilio and Pellenberg (1972 and 1973).

In general, nutrients were found to be low in the Sound and in runoff water. The effluent was slightly enriched in nitrate, nitrite, phosphate, silicate and total dissolved organic carbon (Gerchakov *et al.*, 1973). Trace transition metals appear low in the sediments and biota but normal to high in the water. This may be due to the lack of clay minerals in the sediment. In general, the sediments of the Sound have lower concentrations of V, Fe, Cd, Pb, Zn, Cu and Ni than do the sediments in the effluent at

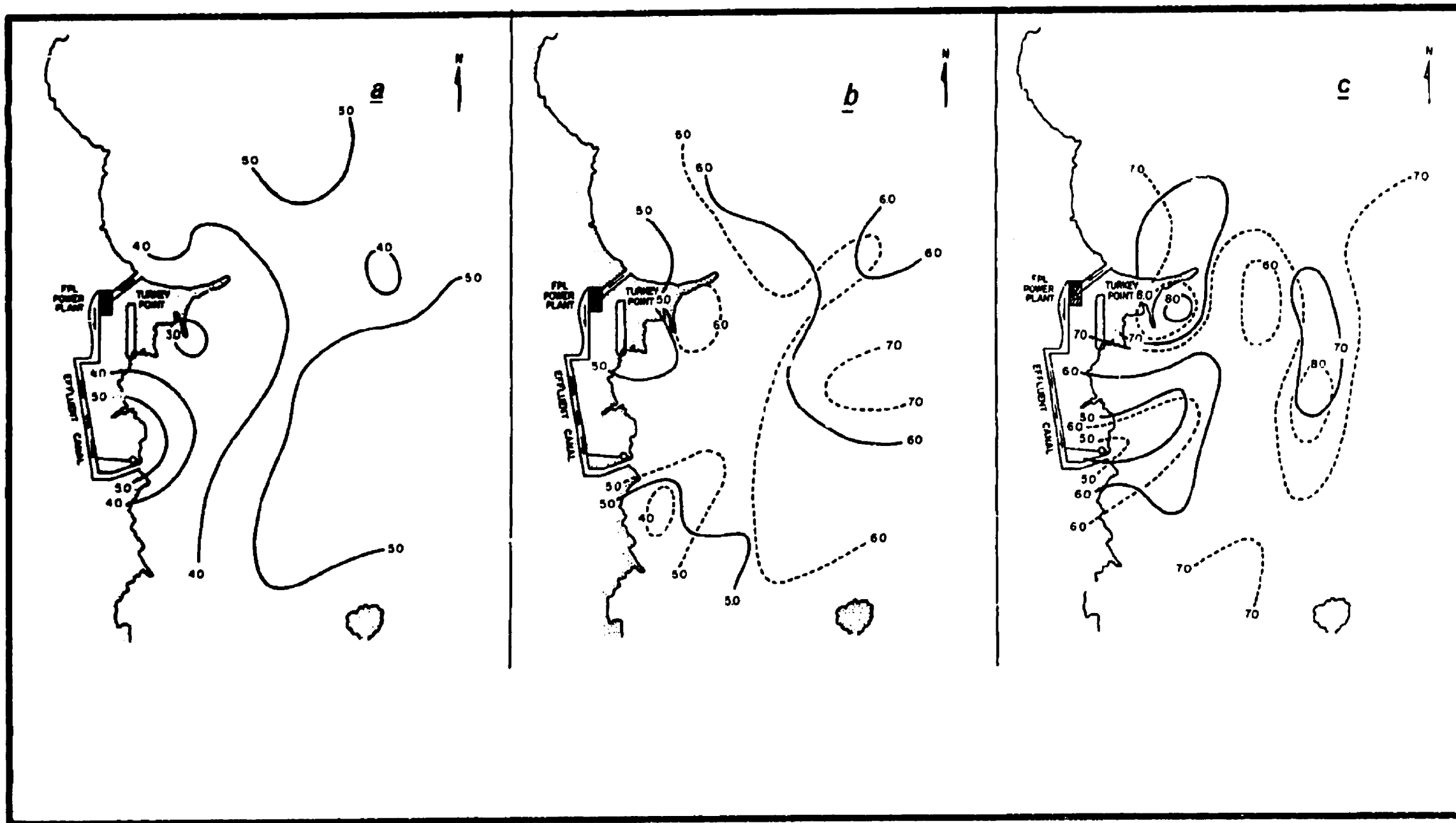


FIGURE 19. Diurnal variation of dissolved oxygen (mls, O_2/L): (A) 0810-0945; (B) 1154-1306, (C) 1455-1625 hours DST in August 1969. Solid lines are surface values --- dashed lines are bottom values

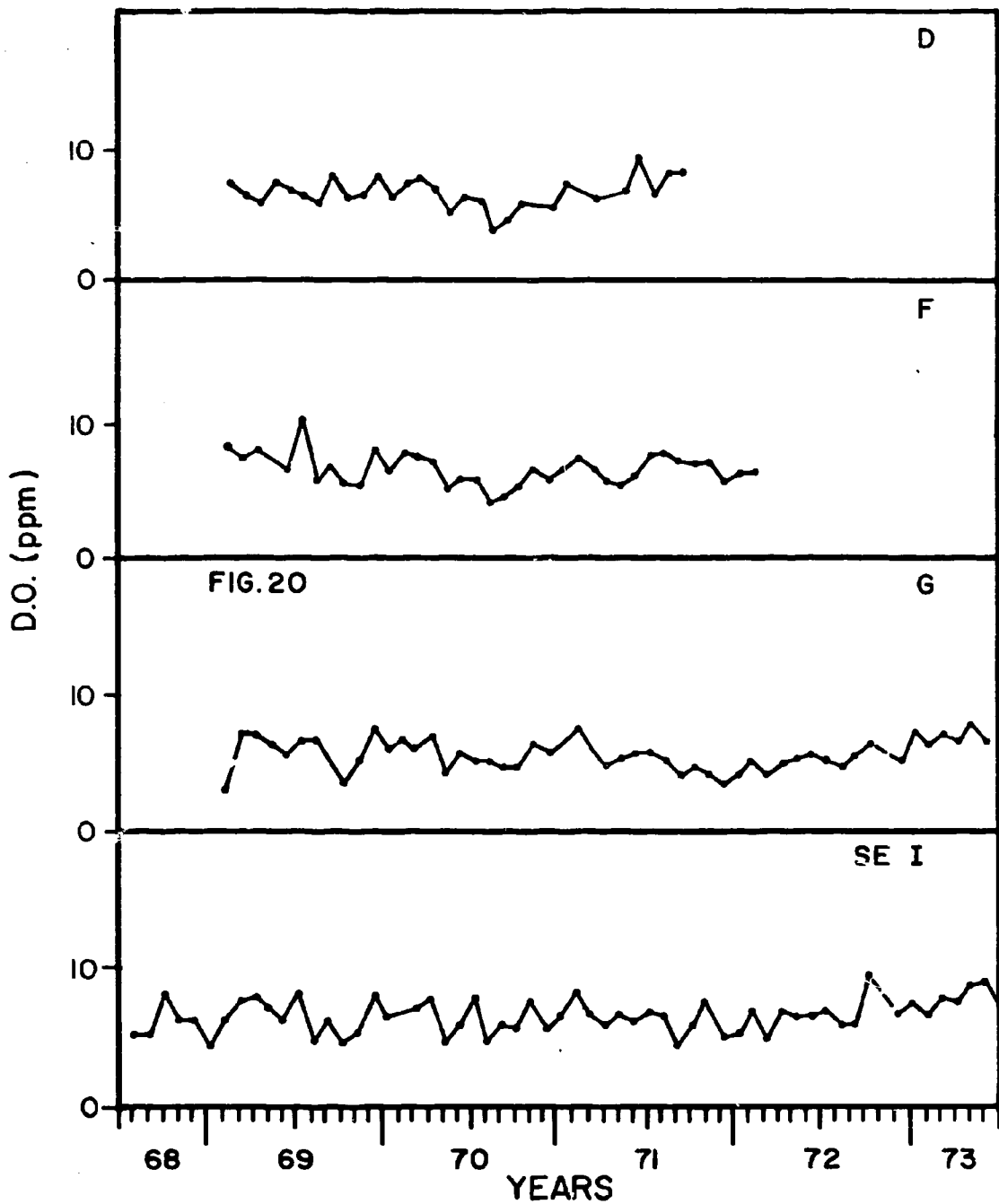


FIGURE 20. Seasonal distribution of dissolved oxygen at stations G, SE I, F and D in Biscayne Bay

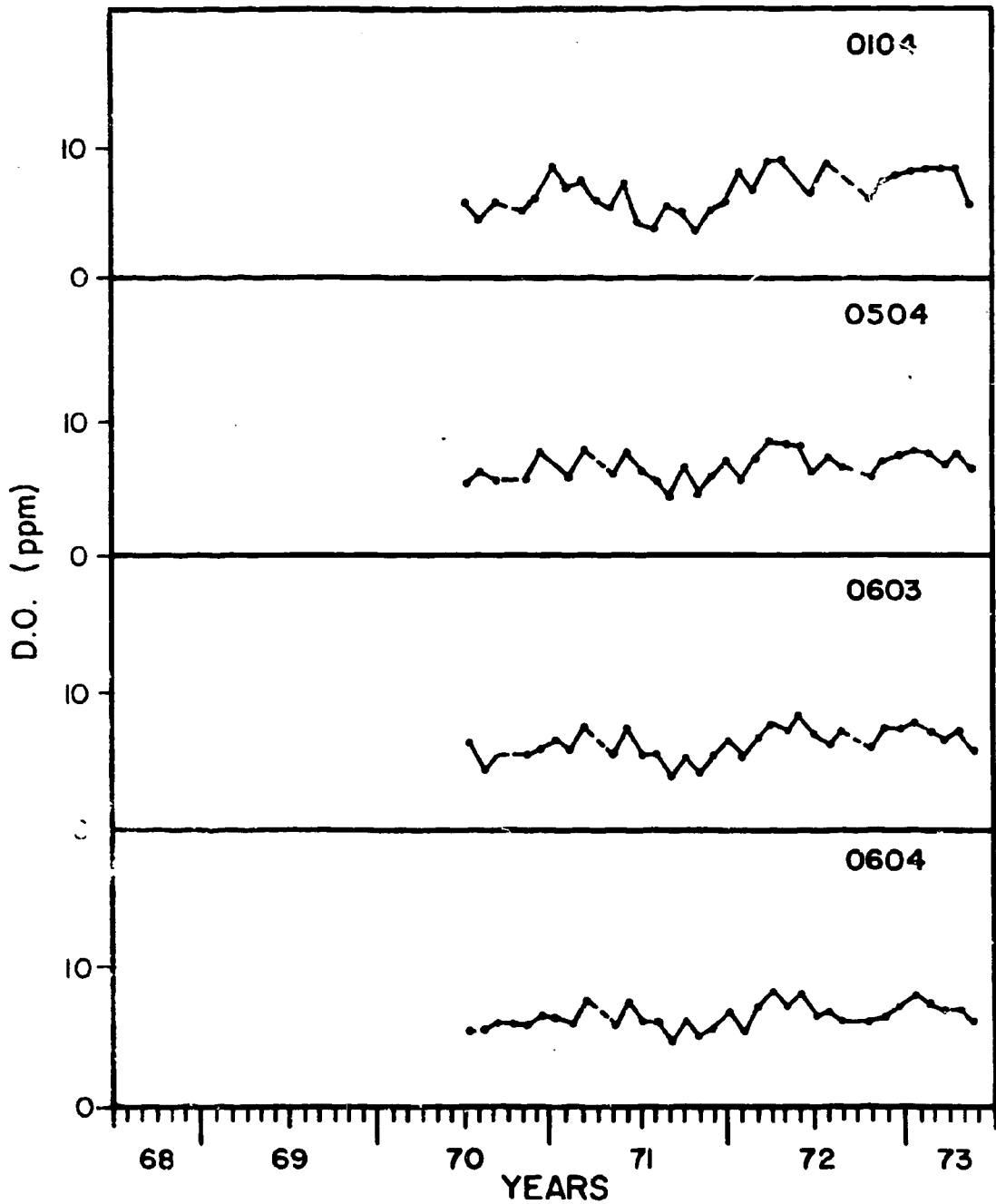


FIGURE 21. Seasonal distribution of dissolved oxygen at stations 0104, 0504, 0603, and 0604 in Card Sound

Turkey Point. The silver concentration is about the same at both places. Values are given for both areas by Thorhaug, Segar and Roessler (1973).

Exclusion and Optimal Temperatures

For each of the 491 taxa collected in the trawl samples, a 10 by 45 matrix of catch at each 5 ppt salinity increment (5 = 0-5) and 1°C (15 = 14.1-15.0) was constructed for each species. Data on catch and effort for stations N I, N II, N V, NE II, SE II, SE III and SE V in September 1968, and station S I in November 1968, were excluded because of temperature discrepancies. All other station month combinations were used. To obtain the catch matrix, the number of animals of each species from each station each month was summed for the seven tows. Then the proper salinity-temperature coordinate was located and the sum of the individuals of each species added to the previous total. Simultaneously, the effort, seven tows, was added at the appropriate salinity-temperature in an effort matrix. Upon completion of the 491 catch matrices and the effort matrix, catch per tow matrices were computed by dividing the catch matrices by the effort matrix. The catch per tow matrices for polychaetes was not computed because polychaetes were not identified or counted prior to January 1971.

Row totals of the catch matrices divided by the row total for the effort matrix provides data on the catch per tow at 1°C intervals. Similar treatment of column totals provides data on catch per tow by 5 ppt salinity intervals.

For each species it was possible to select the highest temperature at which the species was caught, the lowest temperature at which the species was caught, the temperature at which the highest catch per tow was made (mode), the temperature above which 50% of the catch per tow was made (median), the temperature below which 75% of the catch was made (UET₇₅) and the temperature below which 90% of the catch was made (UET₉₀). These data for the 56 most abundant species is given in Table 1, together with the numbers of individuals caught and the whole wet weight biomass.

The modal (highest catch per tow) temperature varied from a low of 13°C for the rainwater killifish, Lucania parva, to a high of 37°C for the commercial shrimps of the genus Penaeus. The average of the modes for the four abundant fishes was 22.5°C, for the 31 abundant mollusks the average of the modes was 24.4, for the eight abundant crustaceans the average of the modes was 22.9°C, for the five abundant sponges the average of the modes was 22.0°C and for the eight abundant echinoderms the average of the modes was 20.0°C.

The median temperature (half the catch per tow above and half below) ranged from a low of 18°C for the snail, Triphora nigrocincta, to a high of 37°C for the shrimps, Penaeus spp. The average of the medians for fishes was 22°C, for mollusks 23.5°C, for crustaceans 24.1°, for sponges 27°C, and for echinoderms 23.3°C. The UET₇₅ (75% upper exclusion temperature) ranged from 21°C for the snail, Triphora nigrocincta, to a high of 37°C for the shrimp, Penaeus spp. The average of the UET₇₅ for fish was 28.8, for mollusks 27.0, for crustacea 28.4, for sponges 27.2 and for

Table 1. Temperature range, optimal temperature and exclusion temperature for 56 species from Biscayne Bay and Card Sound

Species	Temp. Range	Modal Temp.	Median Temp.	75% Exclusion	90% Exclusion	Total ^{1/} Catch	Biomass whole wet wt. gr.
FISHES:							
<u>Lucania parva</u>	13-35	13	19	29	32	2,097	None ^{3/}
<u>Micrognathus crinigerus</u>	13-35	17	21	27	31	2,602	175
<u>Gobiosoma robustum</u>	13-35	30	25	30	32	2,127	355
<u>Opsanus beta</u>	13-37	30	23	29	32	2,096	30,895
Average	13-35	23.5	22	29	32		
MOLLUSCS:							
<u>Acmaea sp.</u>	14-34	24	22	24	28	1,344	7
<u>Argopecten irradians</u>	14-38	24	25	29	31	2,961	10,073
<u>Amgudalum papyria</u>	14-33	30	29	30	30	3,785	None
<u>Anachis pulchella</u>	13-33	16	22	26	28	1,576	58
<u>Anachis translirata</u>	14-34	24	22	25	29	1,280	24
<u>Bulla striata</u>	13-35	33	29	32	33	11,946	717
<u>Cardita floridana</u>	13-32	26	25	27	29	1,176	129
<u>Cerithium eberneum</u>	14-35	33	31	33	34	7,059	1,186
<u>Cerithium muscarum</u>	13-37	33	31	33	34	25,225	5,196
<u>Columbella spp.</u>	14-37	33	28	31	33	6,128	None
<u>Columbella rusticoides</u>	13-34	24	22	26	30	3,328	799
<u>Congerina leucophaeta</u>	14-33	30	30	31	32	1,203	None
<u>Crassispira leucocyma</u>	14-32	19	22	25	28	1,002	10
<u>Crassostrea virginica</u>	13-34	14	14	26	30	1,525	70
<u>Crepidula maculosa</u>	13-35	30	24	29	31	1,205	12
<u>Diodora cayenensis</u>	13-35	20	22	26	30	1,753	130
<u>Haminoea spp.</u>	14-35	30	30	31	32	1,288	10,948
<u>Hyalina torticula</u>	13-33	24	23	24	28	2,176	9
<u>Lima pellucida</u>	14-34	20	22	27	30	6,802	231
<u>Litiope melanostoma</u>	13-32	29	29	29	30	2,103	None
<u>Mitra gemmata</u>	14-34	24	22	25	29	13,271	173

Table 1. Continued

Species	Temp. Range	Modal Temp.	Median Temp.	75% Exclusion	90% Exclusion	Total ^{1/} Catch	Biomass whole wet wt. gr.
<u>Mitrella lunata</u>	13-35	31	24	30	31	49,716	348
<u>Modulus modulus</u>	13-37	34	30	33	34	16,749	1,909
<u>Pinctada imbricata</u>	13-34	20	22	26	28	2,367	123
<u>Prunum apicinum</u>	14-35	14	23	30	33	5,456	295
<u>Rissoina chesneli</u>	13-37	20	23	28	33	32,787	164
<u>Tegula fasciculata</u>	15-33	26	23	26	29	1,182	343
<u>Tricolia affinis</u>	13-34	19	20	24	27	68,709	482
<u>Triphora nigrocincta</u>	15-34	17	18	21	28	1,980	8
<u>Turbo castaneus</u>	13-37	16	24	28	30	4,546	2,158
<u>Vermicularia spirata</u>	13-37	20	23	31	33	15,157	3,789
Average	13-37	24	24	28	30		
CRUSTACEANS:							
<u>Callinectes ornatus</u>	13-34	22	24	30	32	1,140	18,103
<u>Hippolyte pleuracantha</u>	13-34	14	19	24	29	10,707	171
<u>Neopanope packardii</u>	13-37	14	22	28	32	8,499	3,907
<u>Paguristes tortugae</u>	13-34	24	22	25	29	3,888	657
<u>Pagurus bonairensis</u>	13-37	25	24	30	33	89,616	22,135
<u>Penaeus spp.</u>	13-37	37	37	37	37	1,006	None
<u>Periclimeres americanus</u>	13-34	24	21	24	29	1,213	115
<u>Thor floridanus</u>	13-37	23	24	29	33	138,325	4,703
Average	13-37	23	24	28	32		
SPONGES:							
<u>Ircinia fasciculata</u>	13-34	20	22	27	29	1,972	1,789 kg ^{2/}
<u>Haliclona viridis</u>	13-34	16	21	27	30	1,046	None
<u>Tethya diploderma</u>	14-35	21	23	27	30	1,256	5,697
<u>Chondrilla nucula</u>	14-35	23	23	27	32	18,711	42,436

Table 1. Continued

Species	Temp. Range	Modal Temp.	Median Temp.	75% Exclusion	90% Exclusion	Total ^{1/} Catch	Biomass whole wet wt. gr.
<u>Oligoceras hemorrhages</u>	14-35	30	23	28	30	1,082	None
Average	13-35	22	22	27	30		
ECHINODERMS:							
<u>Lytechinus variegatus</u>	15-32	17	23	28	30	1,253	73,889
<u>Echinaster sentus</u>	13-34	25	24	27	30	1,413	6,952
<u>Ophiostigma isacanthum</u>	14-34	21	24	28	32	3,090	68
<u>Ophiactis savignyi</u>	13-34	21	22	26	29	6,819	143
<u>Ophiothrix orstedii</u>	15-34	18	24	28	30	1,009	271
<u>Ophiopsila riisei</u>	15-34	21	23	28	29	10,732	741
<u>Ophioderma brevispinum</u>	14-34	21	24	28	31	1,516	388
<u>Leptosynapta parvipatina</u>	13-35	16	22	27	31	13,132	525
Average	13-35	20	23	28	30		

^{1/} Includes catches at stations excluded for Temperature anomaly

^{2/} Sponges weighed in kilograms.

^{3/} None weighed for biomass

echinoderms 27.5. The UET_{90} (90% exclusion temperature) ranged from a low of 27°C for the snail, Triphora nigrocincta, to a high of 37°C for Penaeus. The average UET_{90} for fishes was 31.8, for mollusks 30.5, for crustacea 31.8, for sponges 30.2 and for echinoderms 30.3°C. The exclusion curves (sighted by eye) for selected species are shown in Figures 22 and 23.

In addition to determining the optimal and upper exclusion temperatures for the 56 indicator species, it is possible to examine the preference and exclusion temperatures of the various phyla and the total species. From the data on the maximum temperature at which a species was caught, it is possible to construct an upper exclusion curve. If the cumulative percent of the number of species never occurring at a temperature in excess of T_1 is plotted against T_1 where T_1 covers the temperature range observed (i.e., 13°C to 37°C) an ogive is formed. The ogive is close to the cumulative normal curve and a probit transformation provides a straight line relation between temperature and exclusion of species. From this relation the exact temperature needed to exclude any percent of species can be determined or conversely the temperature needed to protect any percentage of species can be calculated. The distribution of effort is shown in Figure 24.

A similar relation can be obtained using the minimum temperature at which a species was caught; and it is possible to predict the lower limits of temperature needed to protect any percent of the species.

The intersection of these two curves indicates the temperature at which the conditions are optimal for species richness. Below this optimal temperature cold limits tropical species and causes a decrease in richness; above this optimal temperature heat limits thermal sensitive species. One will note that even at the optimal temperature some species (either thermophilic or psychophilic) are eliminated. These normally seasonal migrants can only be maintained with fluctuating temperature.

A third curve, the maximum catch curve, is derived from the catch per tow matrix. Because of the unequal effort, polychaetes were not included in this analysis. A plot of the cumulative percent of the number of species exhibiting maximum catch per tow at or below each 1°C interval versus temperature can be used to calculate the temperature at which the maximum number of individuals occur. This temperature is where the curve intersects the 50% line.

The combined upper and lower exclusion curves for all 491 taxa combined, for 99 species of fish, for 199 species of mollusks and for 80 species of crustaceans is shown in Figure 25. The maximum catch per tow curve for the same taxa is shown in Figure 26.

The data shown in Figure 25 were transformed to their probits. The lower exclusion temperature where 75% of the species were lost to cold (LFT_{75}), the lower exclusion temperature where 50% of the species were lost due to cold (LET_{50}), the maximum diversity optimum (max. div.) temperature at the intersection of the two curves, the upper exclusion temperature at which 50% of the species were lost to heat (UET_{50}), and the upper exclusion temperature at which 75% of the species were lost to heat (UET_{75}) were calculated. These values were calculated for all taxa combined, for fishes, mollusks, and crustaceans as illustrated, and for

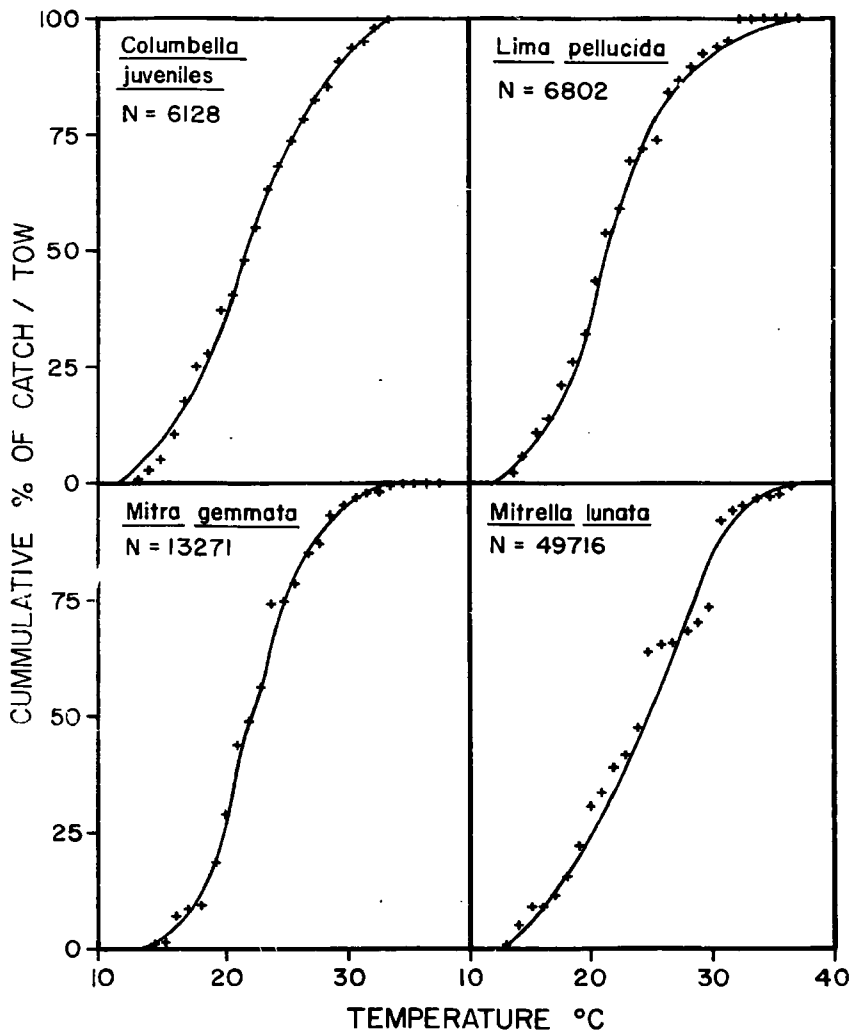


FIGURE 22A. Exclusion curves for dominant fish

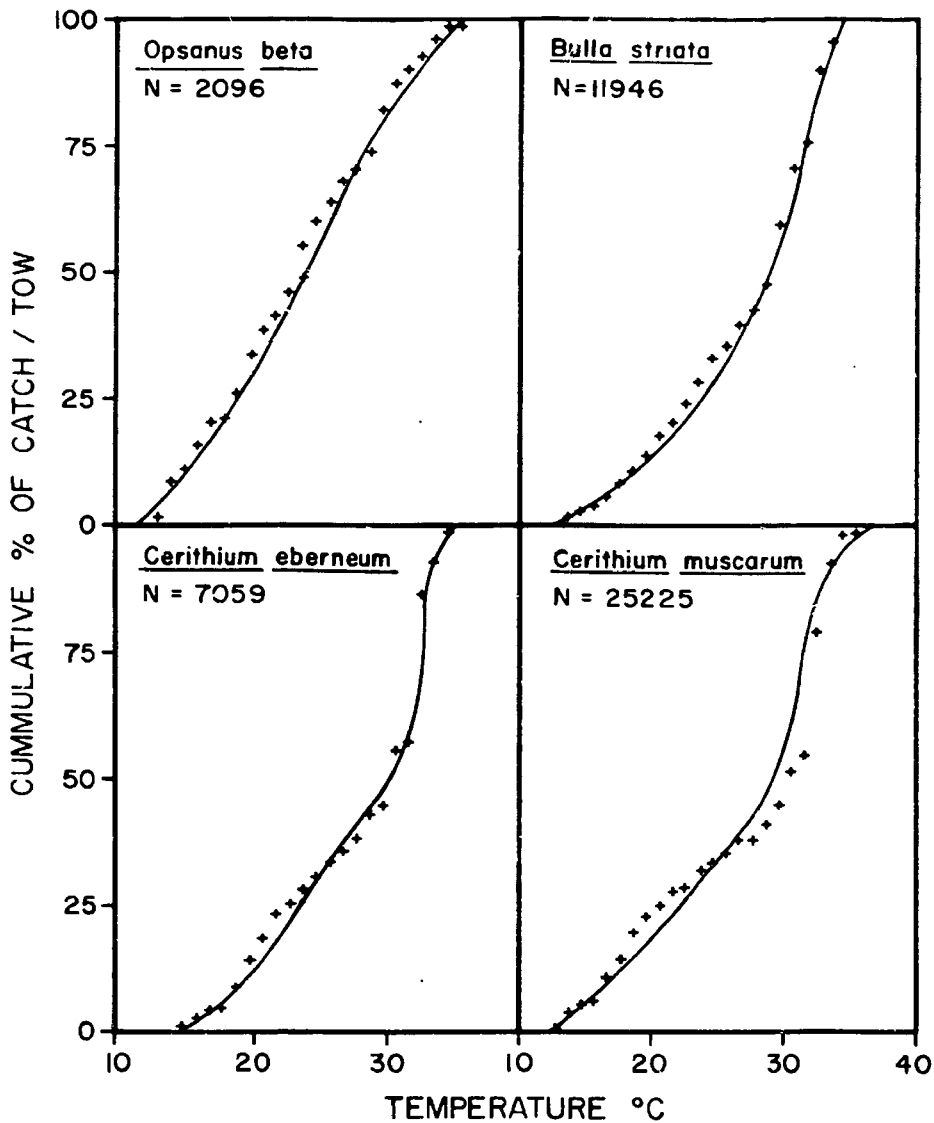


FIGURE 22B. Exclusion curves for dominant mollusks

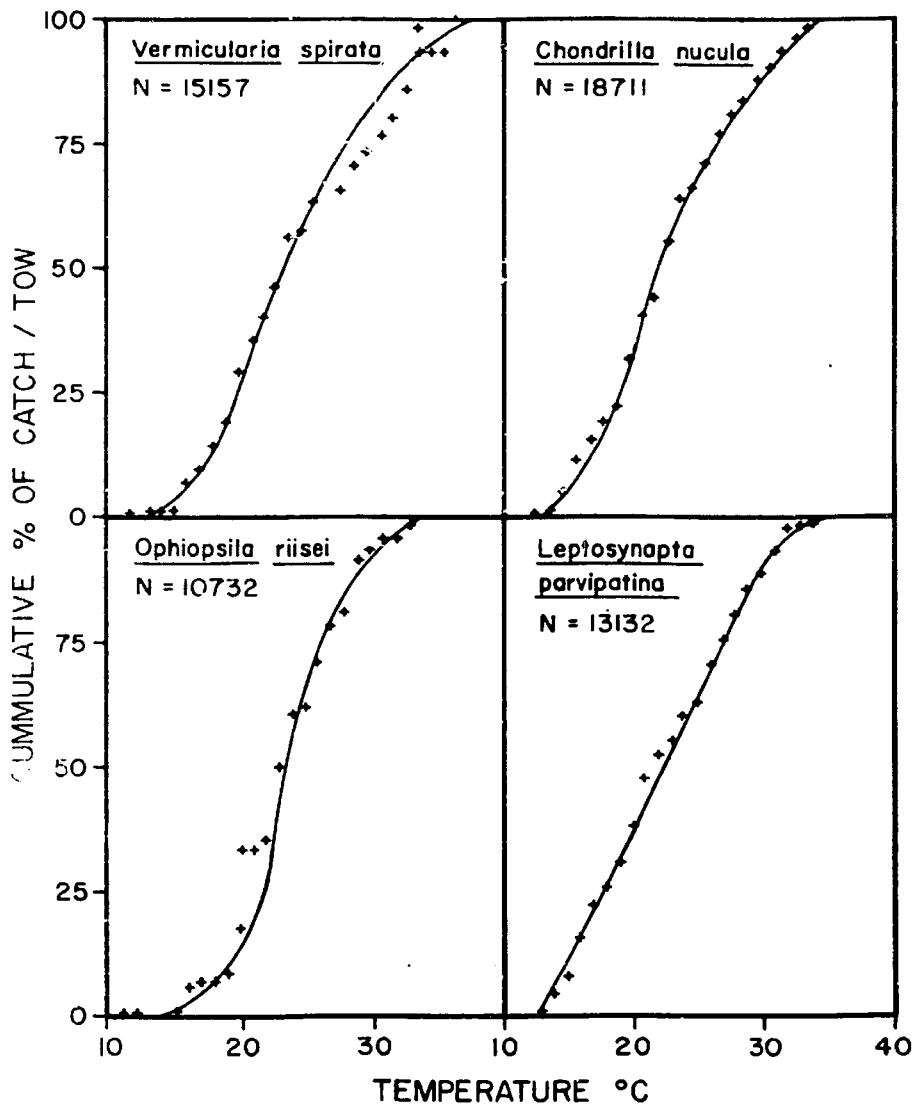


FIGURE 22C. Exclusion curves for dominant sponges

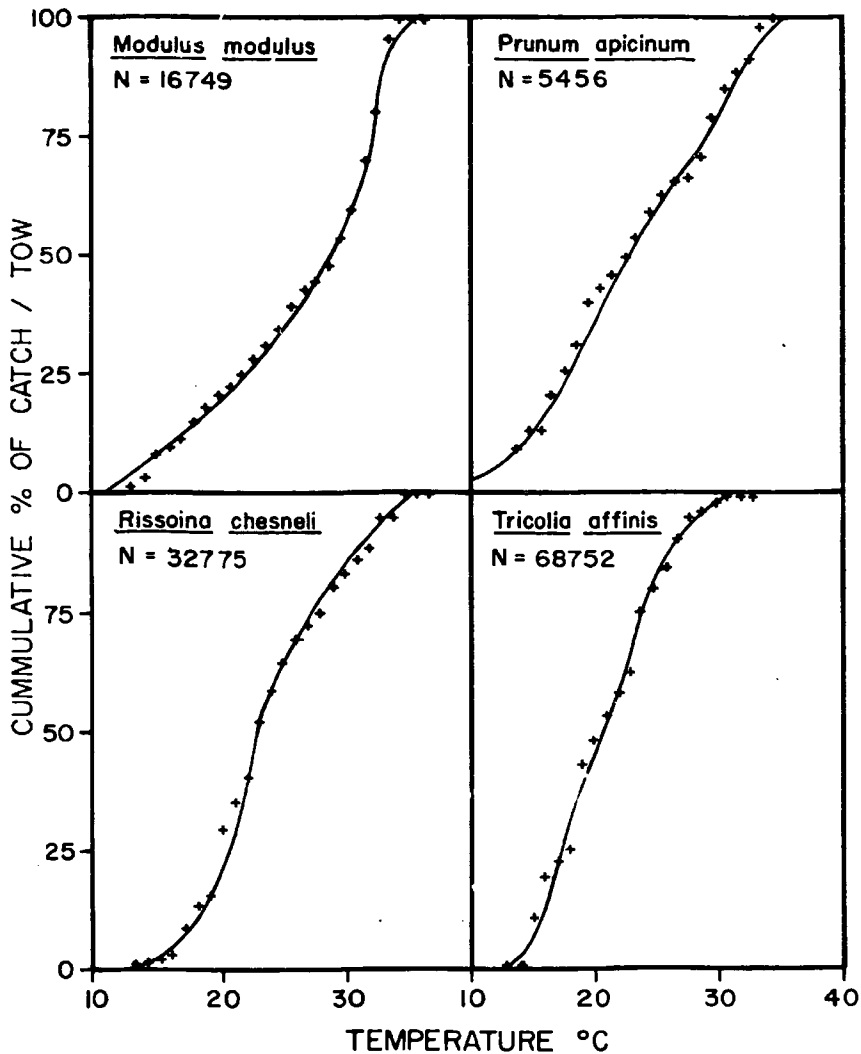


FIGURE 22D. Exclusion curves for dominant echinoderms

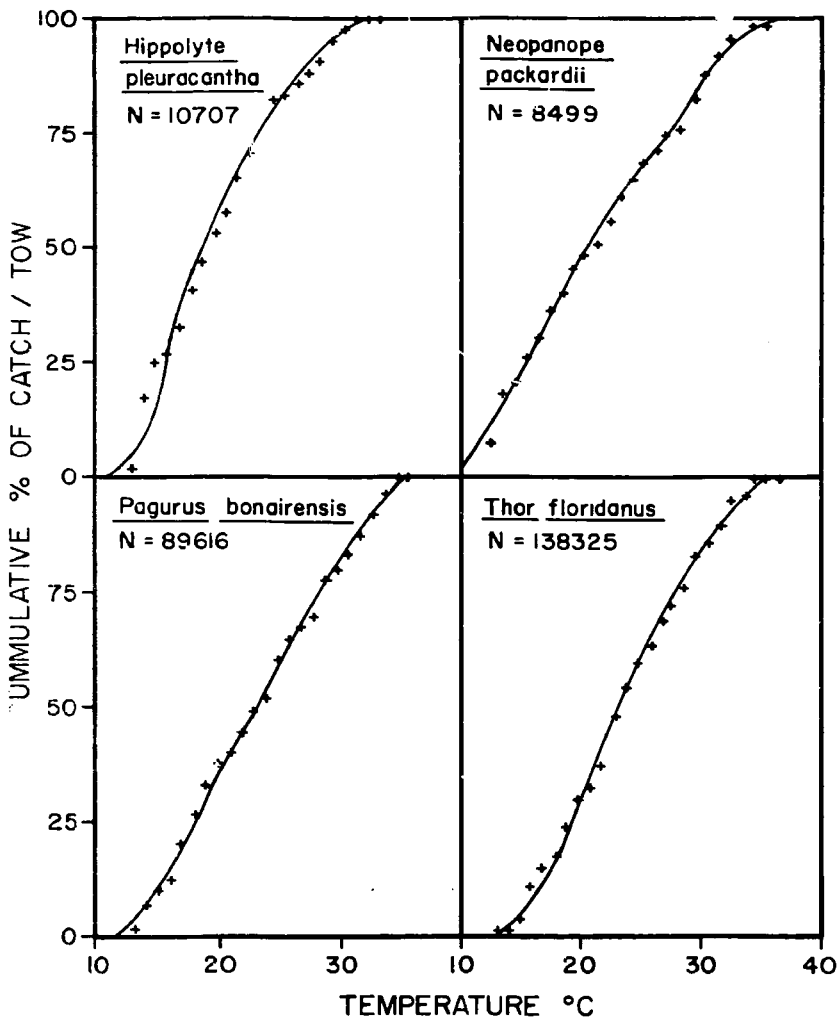


FIGURE 23. Exclusion curves for four species of the dominant crustaceans

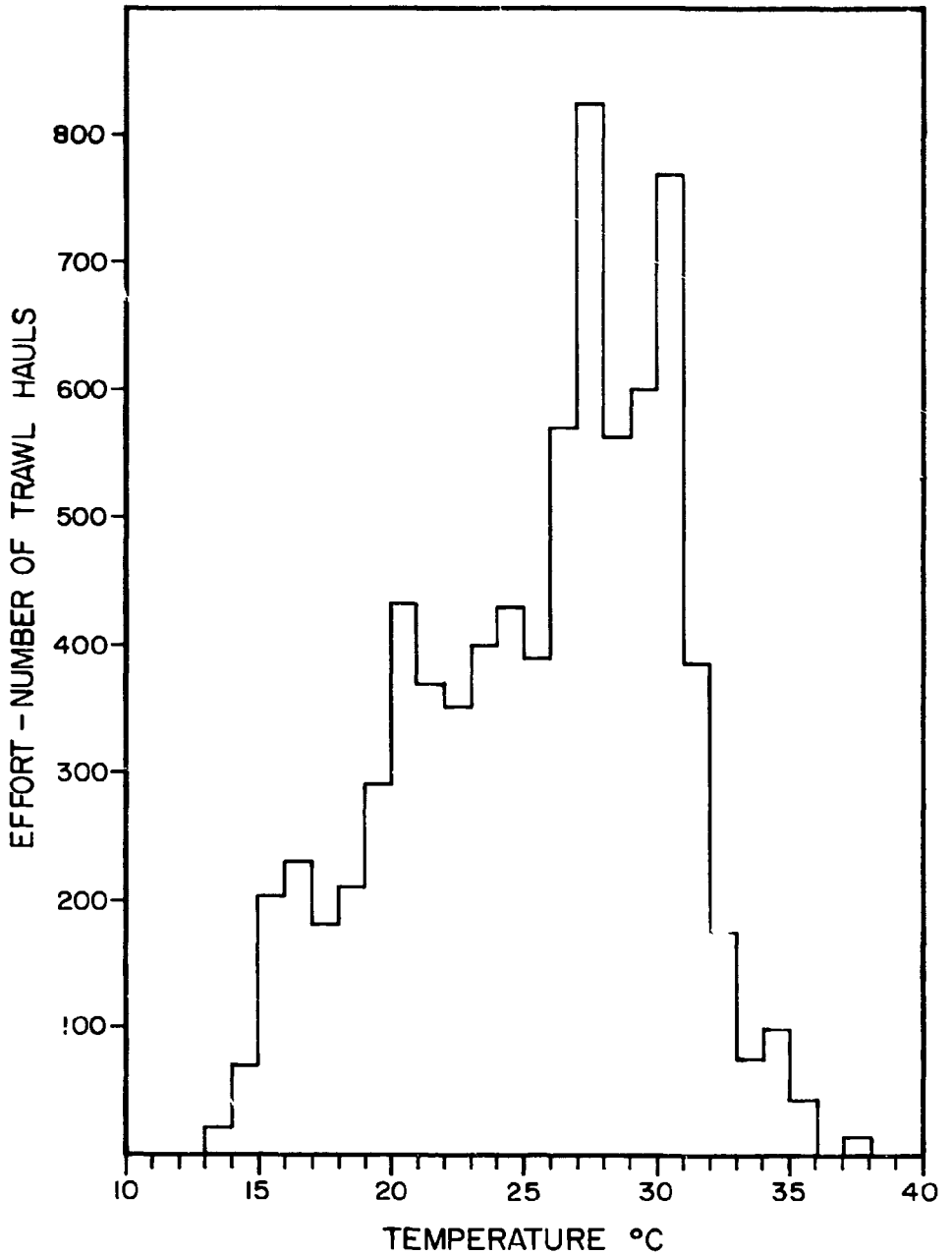


FIGURE 24. Distribution of effort by temperature

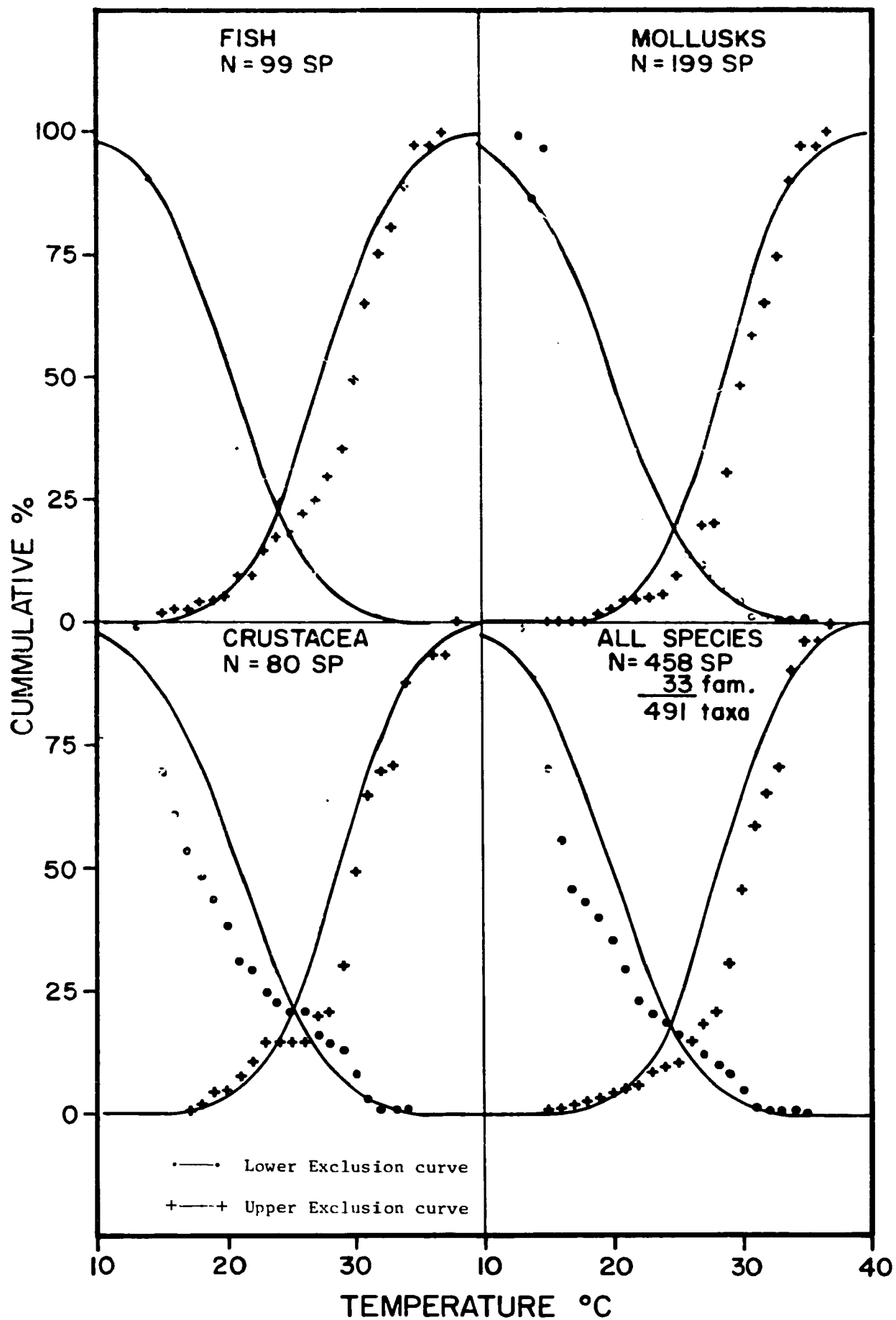


FIGURE 25. Exclusion curves for fish, mollusks, crustaceans and total taxa

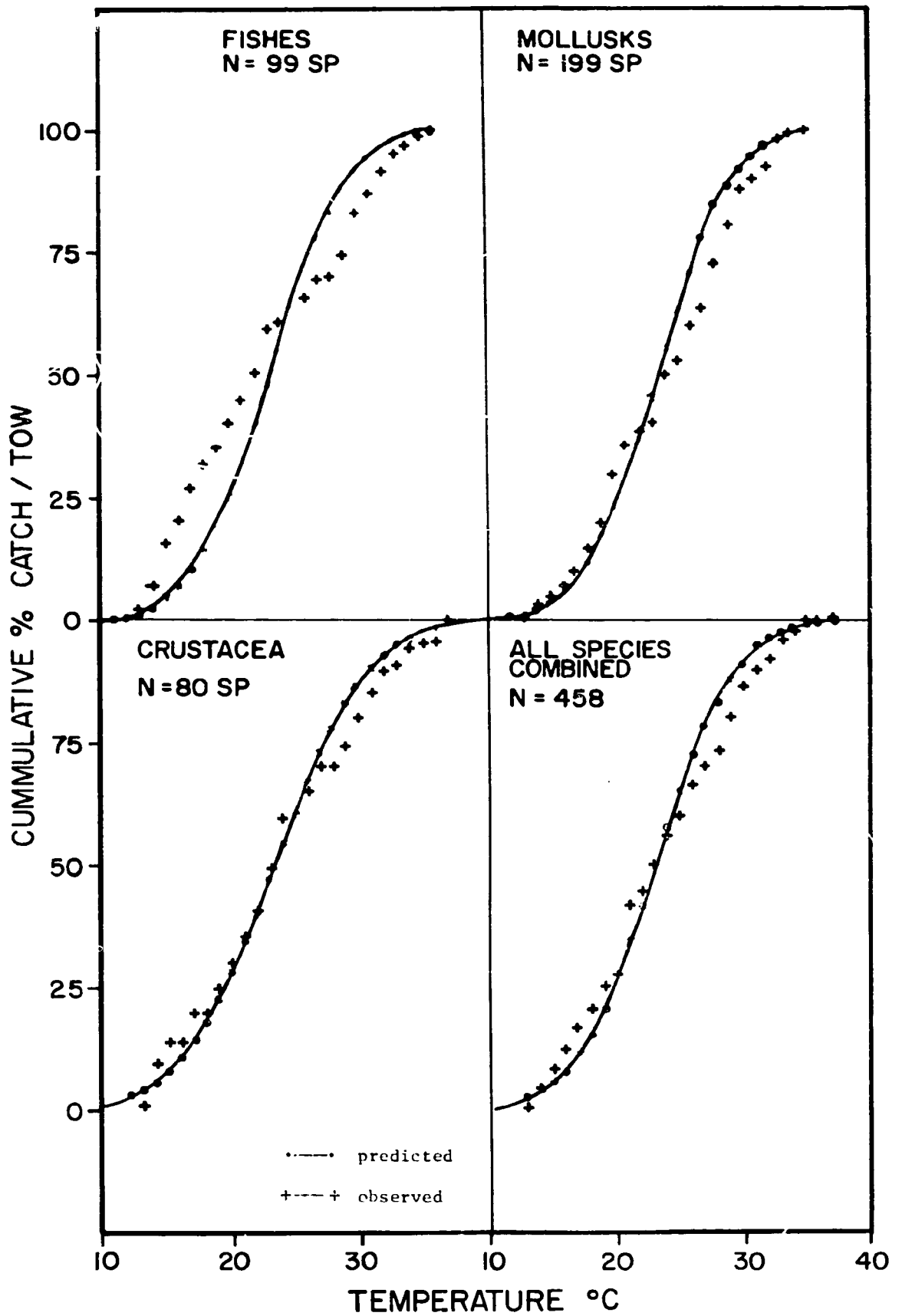


FIGURE 26. Cumulative catch per tow versus temperature

33 families of polychaetes, 30 species of porifera, 17 species of coelenterates, and 28 species of echinoderms. The results are summarized in Table 2, together with the optimal temperature for numbers of individuals (max c/e) calculated from the maximum catch per tow curves (Fig. 26). Polychaetes were not analyzed and the total taxa reflects the absence of 33 families of polychaetes.

Although only 50 and 75% exclusion temperatures were calculated, any percent exclusion can be computed using the computed slopes and intercepts in Table 3. This Table also shows the coefficient of determination for each of the relations.

An examination of Figure 25 indicates the predicted UET₅₀ is generally 1-2°C below the observed temperature and the predicted UET₇₅ is generally also 1-2°C below the observed values. The LET₅₀ and LET₇₅ values predicted by the probit transform are considerably above those observed in the field. A linear interpolation between points gives the estimates in Table 4.

While the optimal temperatures, UET values, and the LET₇₅ are reasonably close (within 1 or 2°C), the predicted LET₅₀ is above the observed values by as much as 3-4°C. The discrepancies between predicted and observed lower exclusion temperatures arise from a more gradual decrease between approximately 17-25 and a more rapid decrease below 17 for the LET₅₀ than predicted. Similarly, the UET observed values increase more gradually between 25 to 29° than predicted and more rapidly than expected at temperatures in excess of 29°C.

Obviously, 100% of the species cannot be protected because some tropical (warm water) and temperate (cold water) forms are excluded at the optimal temperature. The maximum number of species would be present if temperatures were kept near the optimum diversity temperature of 24°C. However, this does not consider the necessity of fluctuating temperatures needed to induce sexual development, spawning, or larval survival. It is believed, that the best conditions would include seasonal fluctuations from 20 in winter to 30°C in summer. This is approximately the normal seasonal averages.

As was previously stated, the summer ambient temperature was near 31°C with maximum daily temperatures near 33°C being common during the day in shallow water. The winter average ambient temperature was near 19°C but recordings as low as 9°C were made. Thus, both cold spells which have dropped temperatures to 9°C and increased summer temperature in the effluent could be expected to cause mortalities or emigrations.

On 9-10 January 1970, the temperature fell to 9-10°C and a massive fish kill was observed in the Bay and adjacent shallows of the ocean. Fishes affected included Haemulon spp., Scarids, Harengula, Sphyræna, Acanthostracion, Eucinostomus and Sphoeroides. Blue crabs (Callinectes sapidus) were also killed. Gray snapper (Lutjanus griseus), mullet (Mugil spp.), and toadfish (Opsanus beta) were apparently unharmed.

On 26 June 1969, a fish kill was observed in the effluent plume. The water temperature was approximately 35°C. Most of the dead fish were Opsanus beta (toadfish). Hagan and Purkerson (1970) reported dead

Table 2. Exclusion and optimal temperatures for animals in Biscayne Bay/
Card Sound, Florida -- July 1968 - September 1972

Taxa	LET ₇₅	LET ₅₀	Max. C/e	Max. div.	UET ₅₀	UET ₇₅	% unprotected at max. div.
Fish	17.2	20.5	23.2	24.1	27.6	30.8	23
Mollusks	16.4	20.0	23.4	24.8	28.7	31.6	18
Crustacea	16.8	20.5	23.4	25.0	28.7	31.8	21
Polychaetes	15.4	18.7	*	23.8	29.3	32.8	15
Porifera	15.0	17.6	21.4	23.0	31.2	35.0	08
Coelenterates	15.0	18.7	21.1	26.9	29.4	30.6	07
Echinoderms	17.1	20.5	23.3	25.9	29.5	31.7	14
Combined	16.6	20.0	23.0*	24.5	28.5	31.6	19

* Polychaete families not calculated due to unequal effort. They were also eliminated from the combined taxa.

Table 3. Equations for calculating optimum and exclusion temperatures

		a	b	r ²
FISHES 99 species	LET	9.15	-0.2029	0.81
	Max C/e	.30	0.2022	0.77
	UET	- .78	0.2091	0.86
MOLLUSKS 199 species	LET	8.69	-0.1847	0.78
	Max C/e	- 0.04	0.2150	0.94
	UET	- 1.61	0.2301	0.86
CRUSTACEA 80 species	LET	8.77	-0.1837	0.76
	Max C/e	1.07	0.1677	0.90
	UET	- 1.29	0.2189	0.85
POLYCHAETES 33 families	LET	8.82	-0.2044	0.59
	UET	- 0.61	0.1917	0.62
PORIFERA 30 species	LET	9.53	-0.2581	0.60
	Max C/e	0.17	0.2254	0.91
	UET	0.40	0.1732	0.56
COELENTERATES 17 species	LET	8.42	-0.1831	0.49
	Max C/e	0.36	0.2194	0.76
	UET	-12.42	0.5918	0.86
ECHINODERMS 28 species	LET	9.07	-0.1990	0.65
	Max C/e	0.03	0.2131	0.88
	UET	- 3.96	0.3035	0.74
ALL SPECIES 458 species + 33 families	LET	8.94	-0.1973	0.81
	Max C/e ^{1/}	0.51	.1947	0.95
	UET	- 1.29	.2206	0.86

^{1/} All species Max C/e excludes polychaetes (458 species)

Table 4. Predicted and observed optimum and exclusion temperature

	LET ₇₅		LET ₅₀		Max. C/e		Max. div.		UET ₅₀		UET ₇₅	
	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.
FISH	17	15	21	17	23	22	24	25	28	30	31	32
MOLLUSKS	16	15	20	17	23	24	25	26	29	30	32	33
CRUSTACEA	17	15	21	18	23	23	25	27	29	30	32	33
POLYCHAETES	15	14	19	15	<u>1/</u>	<u>1/</u>	24	27	29	32	33	33
PORIFERA	15	14	18	15	21	21	23	27	31	33	35	34
COELENTERATES	15	15	19	16	21	21	27	27	29	29	31	31
ECHINODERMS	17	15	21	18	23	21	26	28	30	31	32	33
ALL COMBINED	17	15	20	17	23	23	24	25	29	30	32	33

1/ Polychaete families not calculated due to unequal effort. They were also eliminated from the combined taxa.

Menippe mercenaria (stone crabs), pistol shrimp, bottom dwelling fish, spider crabs, blue crabs, small clams, snails, sponges, bay corals (Siderastrea sp.) and algae at that time.

On the morning of 22 June 1971, another fish kill was recorded. Approximately 2,000 fish were killed in the discharge canal. Plant records showed the temperature of the discharge water was 37.2°C at the time of the kill, but temperatures as high as 40.5°C were observed during the previous days. Most of the dead fishes were Harengula pensacolatae (scaled sardine). Also observed were Lutjanus griseus, L. synagris, Sphoeroides testudinus, Sphyræna barracuda, Haemulon album, Eucinostomus spp., Caranx sp., Archosargus probatocephalus, Centropomus undecimalis, Lagodon rhomboides and the swimming crab Callinectes ornatus.

Field observations (see Seagar et al., 1971) have indicated that about 30 acres of Bay area are elevated 5°C or more, about 100 acres are elevated more than 4°C, about 250 acres are elevated more than 3°C, and 424 acres are elevated more than 2°C over the ambient for each month. In summer, when the ambient Bay temperature is 30-31°C, these temperature elevations produce about 150 acres at 33-34°C in which (based on the observed all species exclusion values), approximately 71% (349 species) are excluded, about 70 acres between 34-35°C where 80% (442 species) are excluded, and 30 acres above 35°C where 97% or more (476 or more) species are excluded. At the normal summer temperature 45% (221 species) are excluded.

In winter, when the Bay ambient is near 20°C, the higher temperatures should permit a greater survival and diversity of species. Our field observations indicated this was true only when the "sea grass-macroalgae" community recovered in the fall and winter. In the area elevated more than 4°C above ambient, the vegetation did not recover seasonally and the standing crop of animals did not increase significantly in winter. In addition, with the loss of the flora, nearly all species of animals caught in trawls were absent during the summer.

Animal Distribution and Abundance

Supplemental Experiments

1. Day-Night Comparisons

Compared to other studies (Roessler, 1965; Tabb and Manning, 1961) done with identical nets and procedures, catches of fishes and invertebrates appeared low in the area of Turkey Point. Roessler (1965) indicated that night samples taken in other parts of Biscayne Bay produced significantly greater numbers of fishes than day samples. Difficulties of navigation and sample handling procedures precluded routine night sampling. However, a series of day-night comparisons were made at Turkey Point during the summer of 1969. The results (Table 5) indicated no significant differences between day and night catches of fishes.

Although the trawl did not adequately sample the larger fast swimming species, nor the snapper and grunt populations which prefer to congregate around rock ledges, coral heads, or submerged trees, gear selectivity is not the sole reason for low catches. Similar gear used in Biscayne Bay

Table 5. Night-day comparisons of catches at 20 stations at Turkey Point

Taxa	Number of Species	Z	Pr
FISHES	19	.28	.400 ns
MOLLUSKS	57	2.63	.004 **
CRUSTACEANS	19	2.61	.005 **
PORIFERA	6	.11	.460 ns
ECHINODERMS	8	.42	.340 ns

ns = not significantly different

** = significantly different Pr \leq .01

(Roessler, 1965) and Everglades National Park (Tabb and Manning, 1961; Tabb, unpublished) have collected significant numbers of fishes. In addition, observations made while diving to obtain information on the efficiency of the net in the Turkey Point area indicated few fishes were present.

The day-night comparisons (Table 5) indicated significantly more mollusks and crustacea were taken at night. Other animals, such as sponges and echinoderms, were caught in equal abundance in daylight and night samples. Despite the greater abundance of mollusks and crustacea at night, no species were caught at night which were not also taken in daylight.

2. Distance of Tow

In order to obtain quantitative estimates from trawl samples the distance towed, the mouth opening during the tow, and the escape rate for each species must be determined. Otherwise, only apparent relative abundance can be discussed. In September 1972, experiments were conducted on the length of tow at 7 stations in Biscayne Bay and Card Sound. The trawling procedure was identical to that described in the methods except at the start of the tow a measured line attached to a 5 pound weight was dropped overboard at the headline of the net. At the end of the two minutes the distance trawled was recorded to the nearest meter.

Figure 27 depicts the results of the experiment. The mean distance towed was 43.1 m with a 95% confidence interval of ± 2.7 m. There was a significant difference in distance towed among stations and those in shallow, inshore areas tend to have shorter towing distance than those in deeper offshore areas (Table 6). This may well be due to the greater effect of wind on the vessel at offshore stations.

The net when first starting to fish had a 2 m opening. Therefore, the average tow would be 2×43 or 86 m^2 . However, as the amount of material (algae, sponge, rock, etc.) caught in the net increased, the mouth opening would decrease. Thus, the 86 m^2 area is an overestimate of the area sampled.

In addition, no measure of selectivity for the 491 taxa caught could be obtained. Hence, we discuss only relative catch or catch per tow in the general biological section to follow.

3. Diversity

In addition to studies on relative abundance of individuals as a composite, by taxa and selected indicator species, the community structure was examined with diversity indices. Three indices were computed for each station each month for fishes, mollusks, crustacea, polychaete families, porifera, coelenterates, echinoderms, and miscellaneous taxa and a combination of all of the above. The indices calculated were:

- (d₁) Species richness,
- (H) Shannon General Diversity, and
- (e) evenness

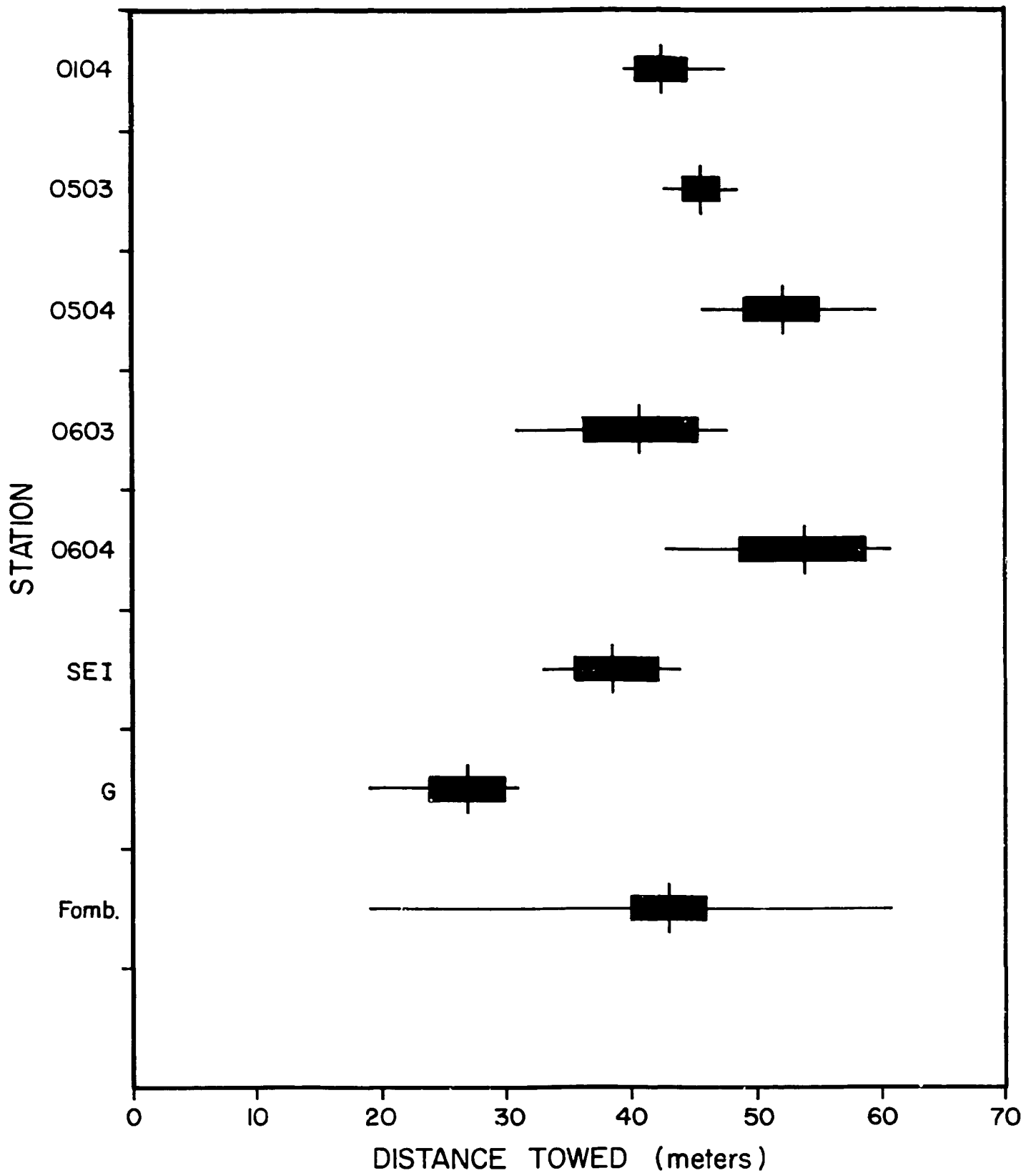


FIGURE 27. Comparison of distance of tow at 7 stations trawled in September 1972. Vertical line represents mean, horizontal line represents range, solid box represents 25 percent confidence interval. Data based on seven tows

Table 6. Comparison of distance towed in 7 samples at 7 stations in Biscayne Bay and Card Sound

Station	SE I	G	0503	0603	0604	0504	0104
Mean	38.7	27.1	45.9	40.9	54.0	52.4	42.9

Source	df	MS	F
Among Stations	6	574.45	28.37 **
Error	42	20.25	
Total	48		

** Significant at Pr _ .01

Additionally, the number of species and number of individuals was listed. The indices for individual taxa are not correlated with the indices for the composite. The composite d_1 is always larger than the component taxa. The H value is variable and was generally some weighted average of the individual taxa but it may exceed that for any of the component taxa (see station SE I, Table 7). In August 1972, the range of species was from 7 at G to 72 at 0604 and the individuals range from 37 at G to 805 at 0604. The combined 'e' value appears to be a weighted average except when it is lower than the individual taxa data, as at SE I where the polychaeta are represented by 1 family with 69 individuals. The evenness here is small but cannot be computed because $\log_e S = 0$ and division by zero is undefined. In such cases, we choose to set $e = 0.0$. In cases where $N = 1$ and $S = 1$ we choose to set $e = 1.000$. Because of the lack of relation among the various taxa and combined taxa, and our belief that, in the absence of data on trophic levels, a better representation of the "community" is obtained by using the combination of all taxa only the total species richness, general diversity and evenness is discussed.

Figure 28 depicts the temperature cycle, species richness, general diversity and evenness index of the total animal catches at inshore control stations in Biscayne Bay for the periods sampled. All of these stations are on the sediment shelf. Station N III is a control and has a richness index of about 4, the general diversity is about 2 and the evenness shows some variability but is somewhat above 0.5. Station NE II is near Turkey Point Peninsula and is generally unaffected by the effluent. The richness index is near 4-5, similar to N III. The general diversity index is about 2 and the evenness is about 0.6. N II is also unaffected by temperature, but during the 1968 and 1969 rainy season, the salinity fell to near 0. The richness is about 3, somewhat lower than nearby stations which received less salinity perturbations. General diversity is near 2 or about the same as other nearshore control stations. Evenness is about 0.7 or about normal for control stations. Station H was south of the effluent and occasionally was affected by the discharge. It was elevated about 1-2°C above ambient. Richness was between 4 and 5, general diversity was between 1.5 and 2, while the evenness index was near 0.6. Station H did not appear different than control stations. The scant data available for station I are included because this station located at the mouth of a minor effluent canal received heated effluent on ebbing tide but not on flooding tides. The richness and general diversity indices are similar to control stations, but the evenness component is higher. This station is of special significance because it indicates intermittent discharge has a less adverse effect than continuous discharge.

Figure 29 depicts a series of nearshore stations which were affected by various amounts of temperature increase. Station G is in the mouth of the effluent and is usually about 5°C above ambient. The species richness was about 1 until early in 1972 after the Card Sound Canal diverted part of the effluent away from Biscayne Bay and dilution became a common practice to lower temperature. After February 1973, when Grand Canal was closed, the species richness was about 5, very similar to control stations. The general diversity was near 1 until the diversion and dilution. After closure of Grand Canal it was near 2 or close to control stations. During the period of maximum discharge the evenness component was extremely

Table 7. Comparison of diversity indices (d_1 , \bar{H} , e) for individual taxa and composite of all taxa. Data from 7 stations sampled in August 1972

Station	Taxa	No. of species ^{1/}	No. of individuals	d_1	\bar{H}	e
SE I Biscayne Bay	Pisces	8	28	2.1007	1.8586	.8938
	Molluska	2	5	.6213	.6730	.9710
	Crustacea	5	57	.9894	1.3537	.8411
	Polychaeta ^{1/}	1	69	.0000	.0000	.0000
	Porifera	0	0	-	-	-
	Coelenterata	0	0	-	-	-
	Echinoderma	2	5	.6213	.5004	.7219
	Misc. vermes	1	1	.0000	.0000	1.0000
	Tunicata & Bryozoa	1	1	.0000	.0000	1.0000
	COMBINED	20	166	3.7168	2.1184	.7071
G Biscayne Bay	Pisces	0	0	-	-	-
	Molluska	0	0	-	-	-
	Crustacea	2	4	.7213	.6931	1.0000
	Polychaeta	3	3	1.8205	1.0986	1.0000
	Porifera	0	0	-	-	-
	Coelenterata	0	0	-	-	-
	Echinoderma	2	30	.2940	.1461	.2108
	Misc. vermes	0	0	-	-	-
	Tunicata & Bryozoa	0	0	-	-	-
	COMBINED	7	37	1.6616	.8968	.4608
0104 Card Sound	Pisces	2	2	1.4427	.6931	1.0000
	Molluska	17	159	3.1565	1.8753	.6619
	Crustacea	6	16	1.8034	1.5607	.8710
	Polychaeta	5	94	.8804	.7298	.4534

Table 7. Continued

Station	Taxa	No. of species ^{1/}	No. of individuals	d_1	\bar{H}	e
0104 Card Sound (cont.)	Porifera	11	68	2.3699	1.7262	.7199
	Coelenterata	1	4	.0000	.0000	.0000
	Echinoderma	3	6	1.1162	.8676	.7897
	Misc. vermes	2	4	.7213	.5623	.8117
	Tunicata & Bryozoa	1	2	.0000	.0000	.0000
	COMBINED	48	375	7.9299	2.8934	.7474
0503	Pisces	3	3	1.8205	1.0986	1.0000
	Molluska	22	167	4.1032	1.6724	.5410
	Crustacea	10	42	2.4079	1.1968	.5197
	Polychaeta	6	18	1.7299	1.5380	.8584
	Porifera	13	34	3.4029	2.3793	.9270
	Coelenterata	0	0	-	-	-
	Echinoderma	5	28	1.2004	1.4903	.9259
	Misc. vermes	1	1	.0000	.0000	1.0000
	Tunicata & Bryozoa	0	0	-	-	-
	COMBINED	60	293	10.3870	2.9599	.7229
0504 Card Sound	Pisces	4	8	1.4427	1.3862	1.0000
	Molluska	18	100	3.6915	2.3263	.8048
	Crustacea	6	74	1.1617	1.1765	.6566
	Polychaeta	6	26	1.5346	1.7028	.9504
	Porifera	13	92	2.6538	2.2415	.8739
	Coelenterata	0	0	-	-	-
	Echinoderma	6	128	2.6538	1.5494	.8648
	Misc. vermes	1	2	.0000	.0000	.0000
	Tunicata & Bryozoa	1	1	.0000	.0000	1.0000

Table 7. Continued

Station	Taxa	No. of species ^{1/}	No. of individuals	d_1	\bar{P}	e
0504 Card Sound (cont.)	COMBINED	55	431	8.9019	3.4229	.8542
0603 Card Sound	Pisces	4	7	1.5417	1.1537	.8322
	Molluska	14	85	2.9262	1.8165	.6883
	Crustacea	6	18	1.7299	1.3031	.7273
	Polychaeta	9	41	2.1543	1.5565	.7084
	Porifera	8	48	1.8082	1.2967	.6236
	Coelenterata	0	0	-	-	-
	Echinoderma	7	52	1.5185	1.4145	.7269
	Misc. vermes	1	2	.0000	.0000	.0000
	Tunicata & Bryozoa	1	1	.0000	.0000	1.0000
	COMBINED	50	254	8.8490	3.1647	.8090
0604 Card Sound	Pisces	4	7	1.5417	1.2770	.9212
	Molluska	25	323	4.1539	2.1619	.6716
	Crustacea	11	118	2.0961	1.4022	.5847
	Polychaeta	6	69	1.1809	1.6877	.9419
	Porifera	14	90	2.8890	2.3904	.9058
	Coelenterata	2	6	.5581	.6365	.9183
	Echinoderma	7	185	1.1493	1.7313	.8897
	Misc. vermes	1	5	.0000	.0000	.0000
	Tunicata & Bryozoa	2	2	1.4427	.6931	1.0000
	COMBINED	72	805	10.6115	3.4659	.8104

^{1/} Polychaetes identified to family

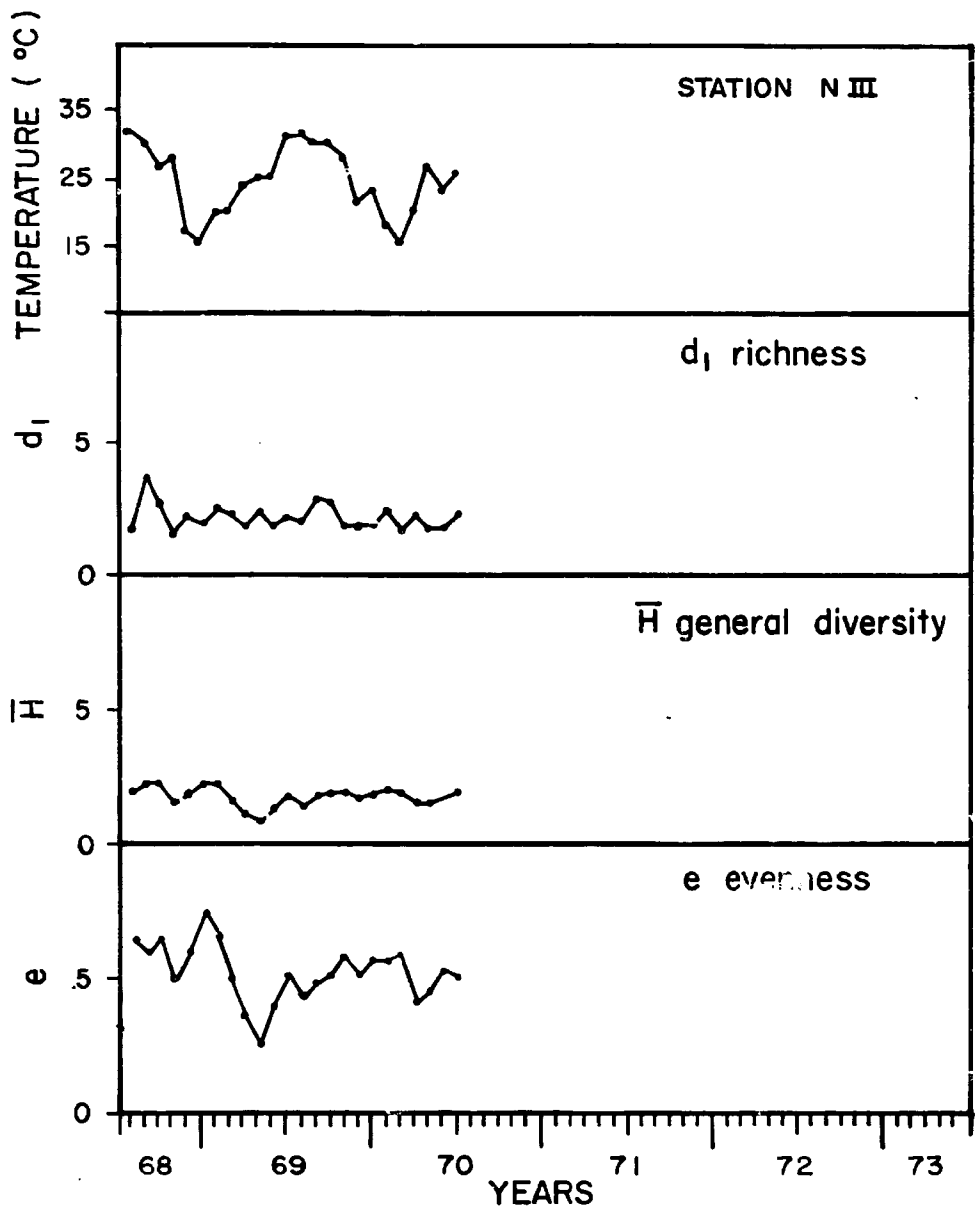


FIGURE 28A. Diversity and temperature at unaffected inshore Biscayne Bay stations.

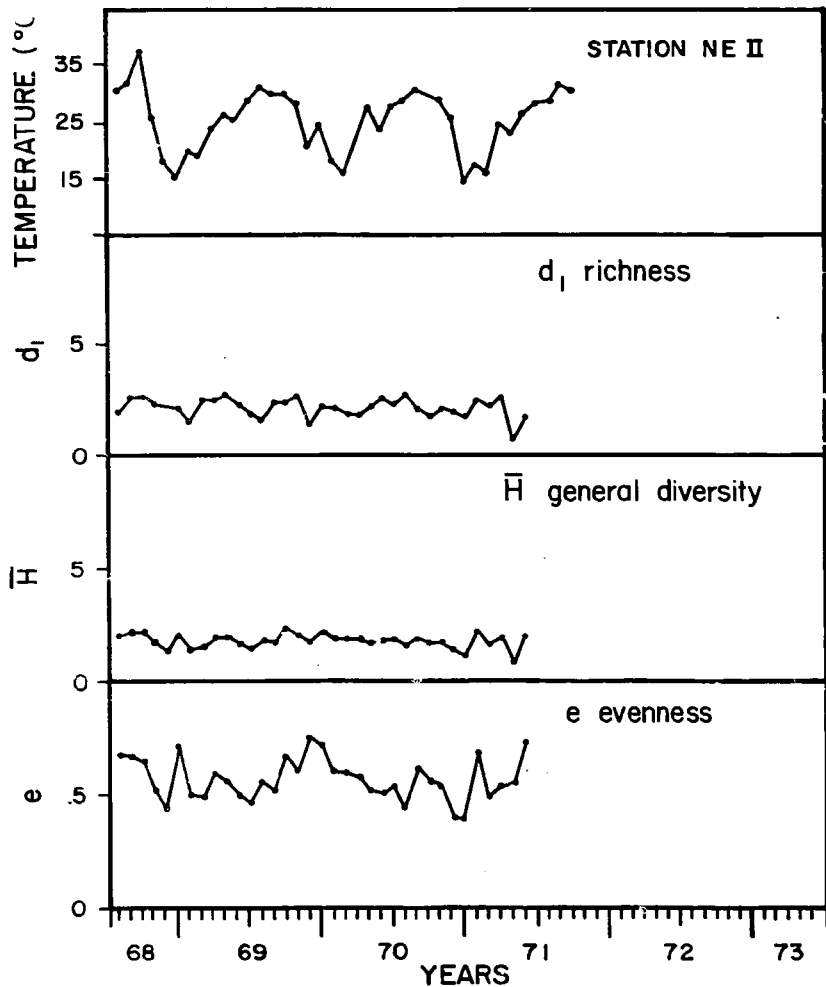


FIGURE 28B.

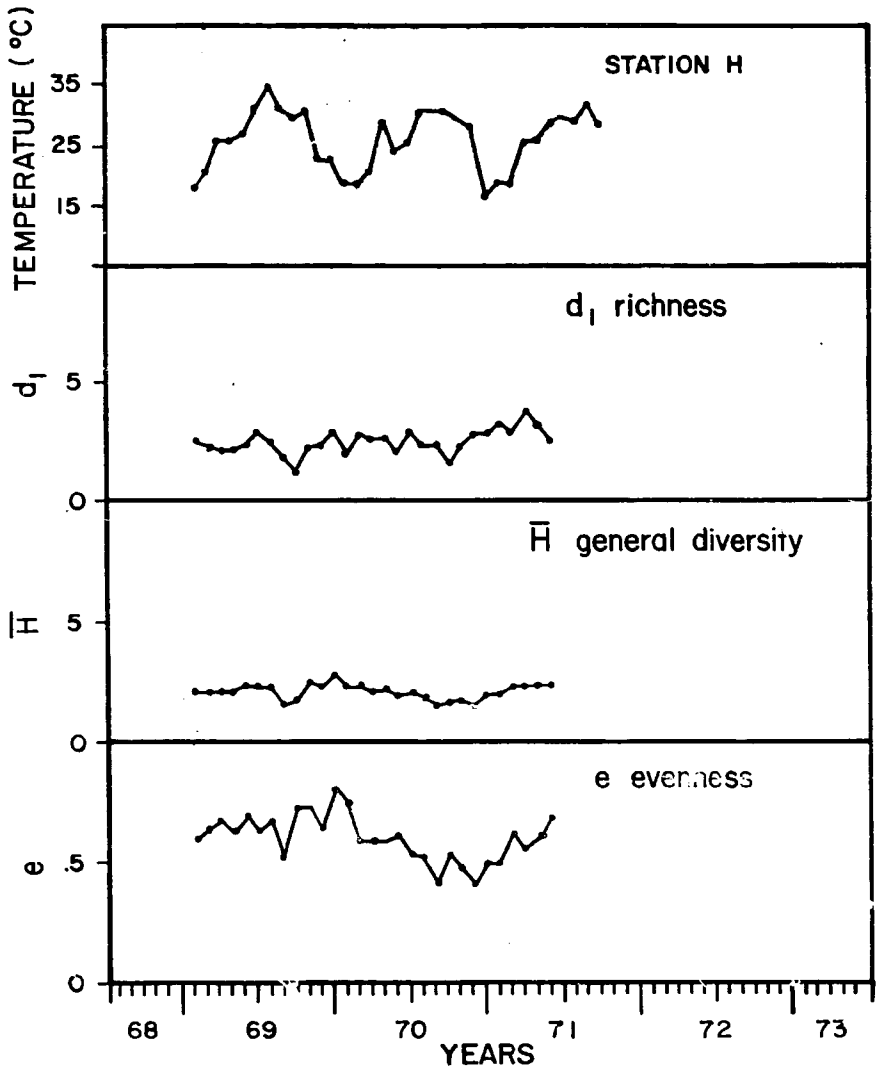


FIGURE 28C.

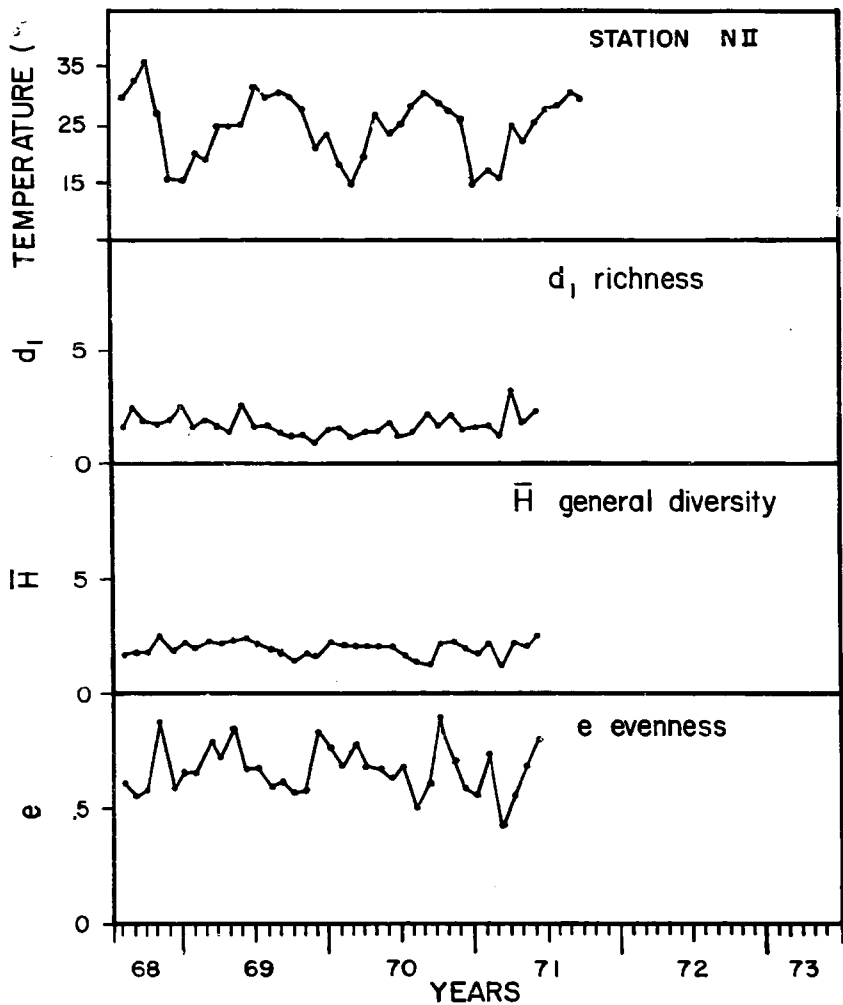


FIGURE 28D.

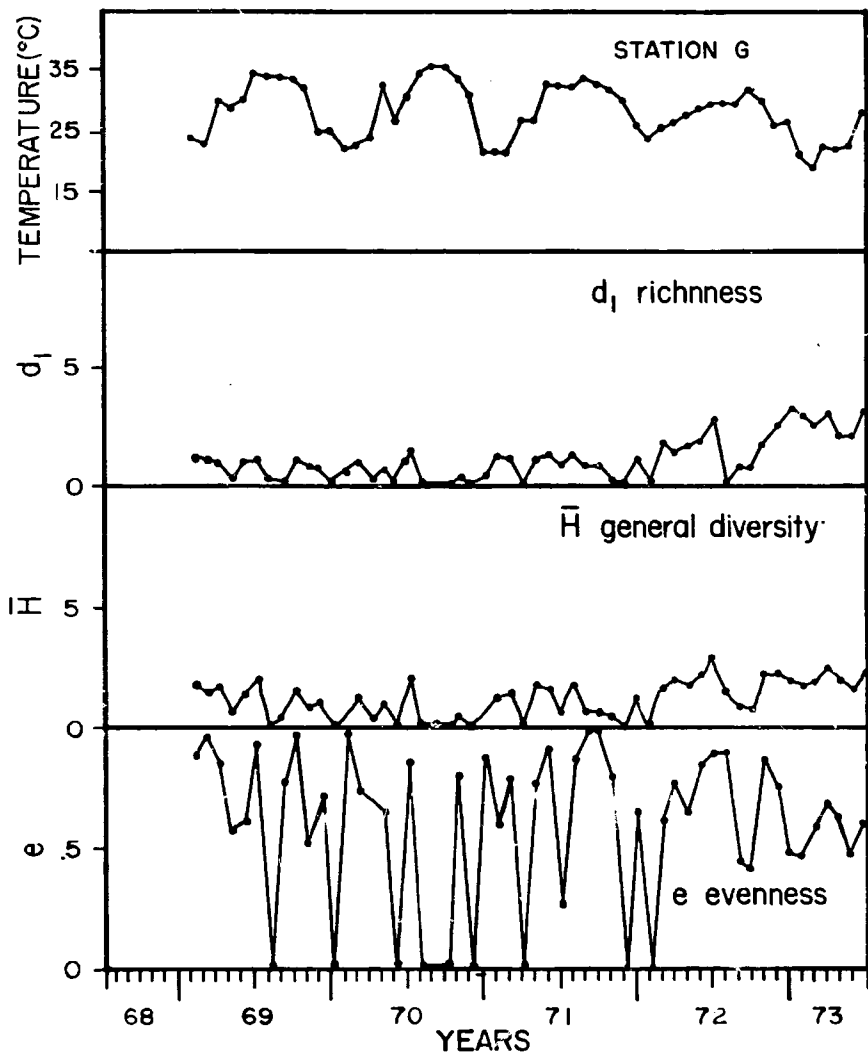


FIGURE 29A. Diversity and temperature at affected inshore stations in Biscayne Bay

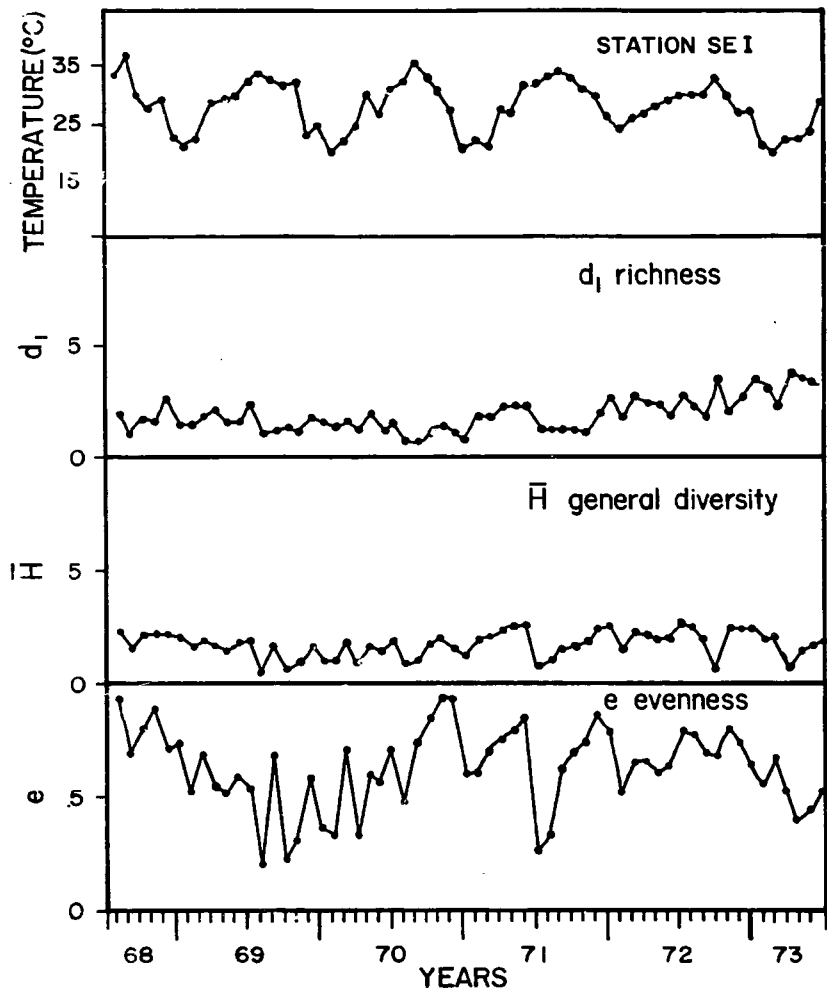


FIGURE 29B.

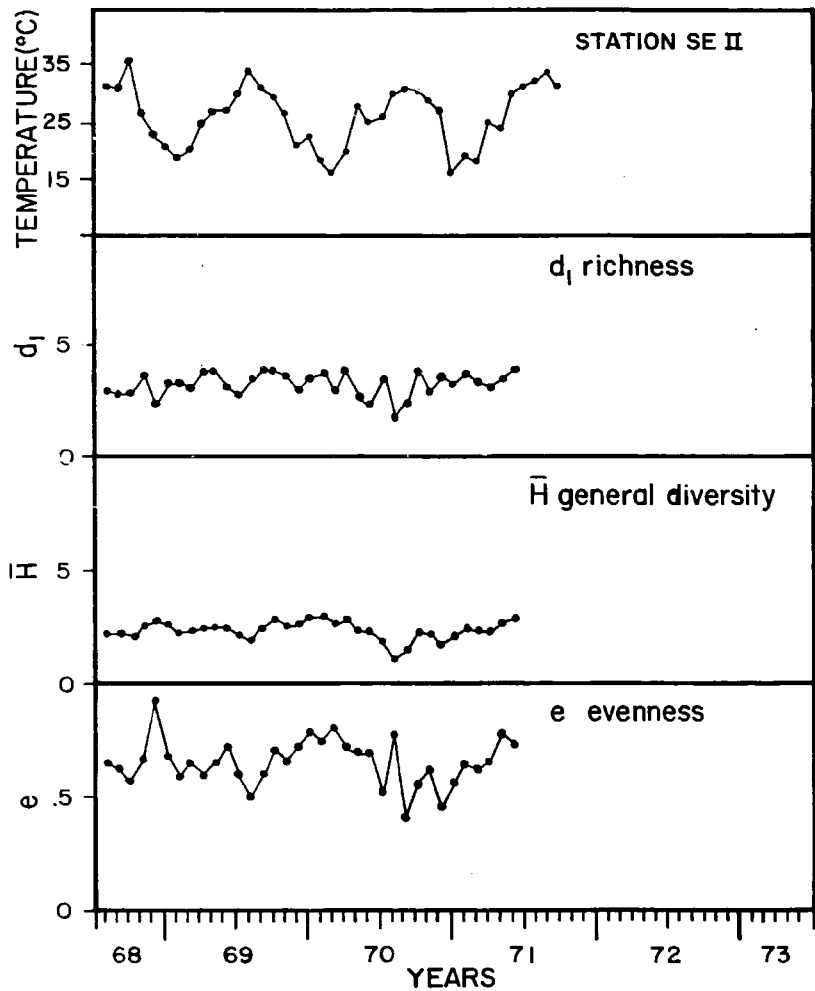


FIGURE 29C.

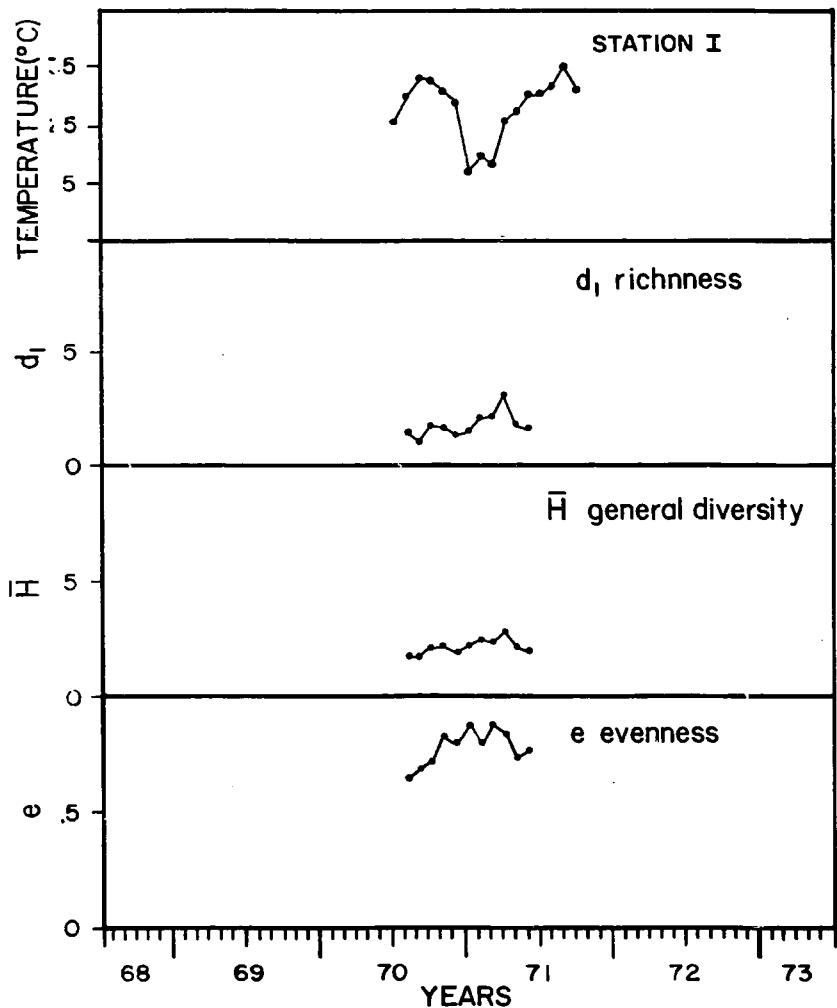


FIGURE 29D.

erratic but after diversion and dilution and after closing Grand Canal it approached 0.5. Station SE I averaged about 3-4°C above ambient. The species richness was about 3 until diversion and dilution when it increased to about 4. After Grand Canal was closed richness increased to 6. At SE I the general diversity was about 1.5, while the Grand Canal was operating fully, but increased to about 2 after dilution and diversion. The pattern of evenness was cyclic and difficult to interpret. Station SE II was elevated between 2 and 3°C in the period sampled. The richness index was near 7, which is high for nearshore or shallow soft sediment stations, but similar to offshore stations. The general diversity was near 2.5 again similar to mid-Bay and offshore stations. The evenness index was quite variable but was near 0.7.

In Figure 30, three mid-Bay stations and one eastern Bay station are compared. None are seriously effected by temperature anomalies. Station D was used as a temperature control and is located in shallow water on a bar covered with Thalassia in mid-Bay. Here richness averaged about 5, general diversity about 2 and the evenness was variable but was near 0.6-0.7. The two high peaks in evenness occurred in spring to summer when natural solar heating may have driven some species from the shallows. Station SE III is also shallow, but is associated with an island. The richness is near 6, general diversity near 2.5 and the evenness near 0.65. Station S III is also a mid-Bay station, in deeper water and has harder, coarser substrate than the previous stations. It has a richness index near 6, a general diversity near 2-2.5, and an evenness of about 0.6. The evenness component is more stable than the shallow stations. Although only scattered data are available for the eastern Bay station S V, it is obvious that richness is higher (near 9) than inshore and mid-Bay stations; general diversity is higher (near 3) than inshore stations and evenness also tends to be high compared to inshore stations.

Card Sound stations with salinity values are shown in Figure 31. Effluent was discharged from February 1972-February 1973. The thermal anomaly was only 1-2°C at station 0603. At all stations, richness was considerably higher than in Biscayne Bay. General diversity and evenness also tended to be higher. No effect of the effluent was evident at any of the stations examined. Generally, hypersaline conditions at inshore stations during the first half of the study depressed the richness component. After return to salinities between 25-35 ppt richness increased, the fall in the evenness component during the winter and spring of 1973 was due to a large influx of Tricolia affinis.

Examination of species richness, general diversity and evenness indicate that only the most severely affected stations, i.e., those elevated 3-4°C above ambient or more showed deviations.

4. Total Counts

In July 1968-June 1970, 3360 samples produced about 288,000 animals from Biscayne Bay in the vicinity of the Turkey Point power plant. The catch of each species at each station was reported by Roessler, Tabb, Rehner and Garcia (1974) and Bader and Roessler (1971, Tables V-1 and V-2). Analysis of the data must be separated into two time periods because of differences in station locations and sorting techniques. A summary of

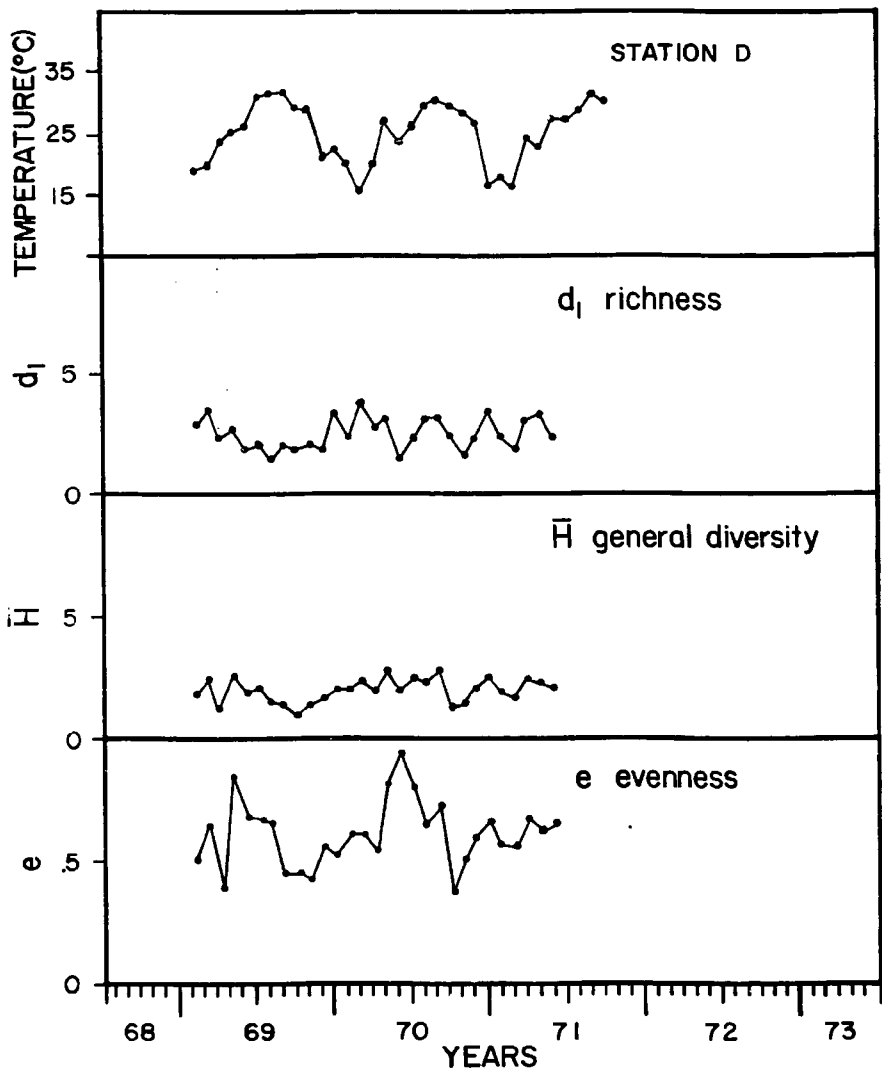


FIGURE 30A. Diversity and temperature at mid and eastern Biscayne Bay stations

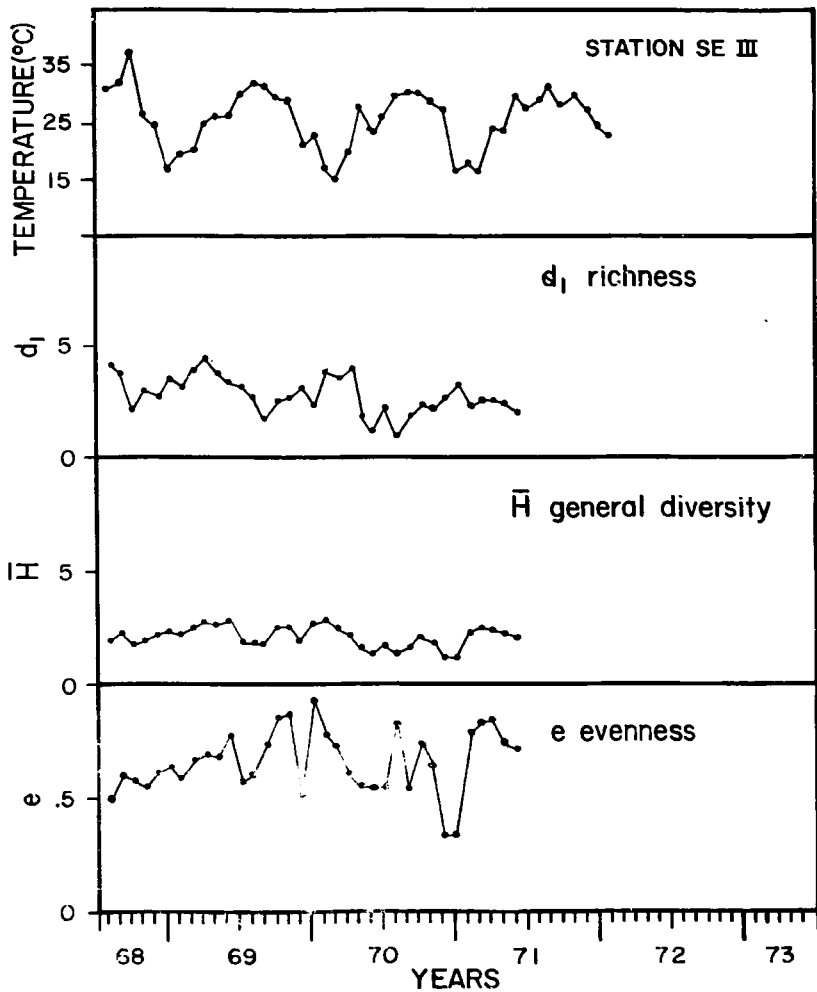


FIGURE 30B.

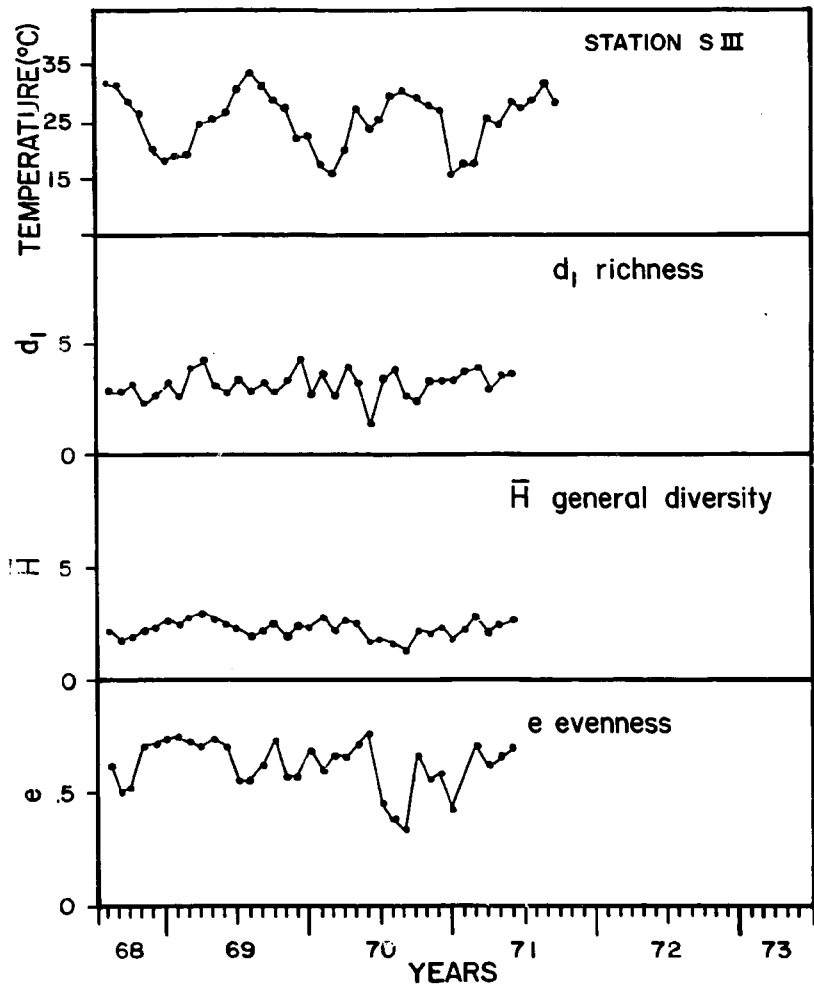


FIGURE 30C.

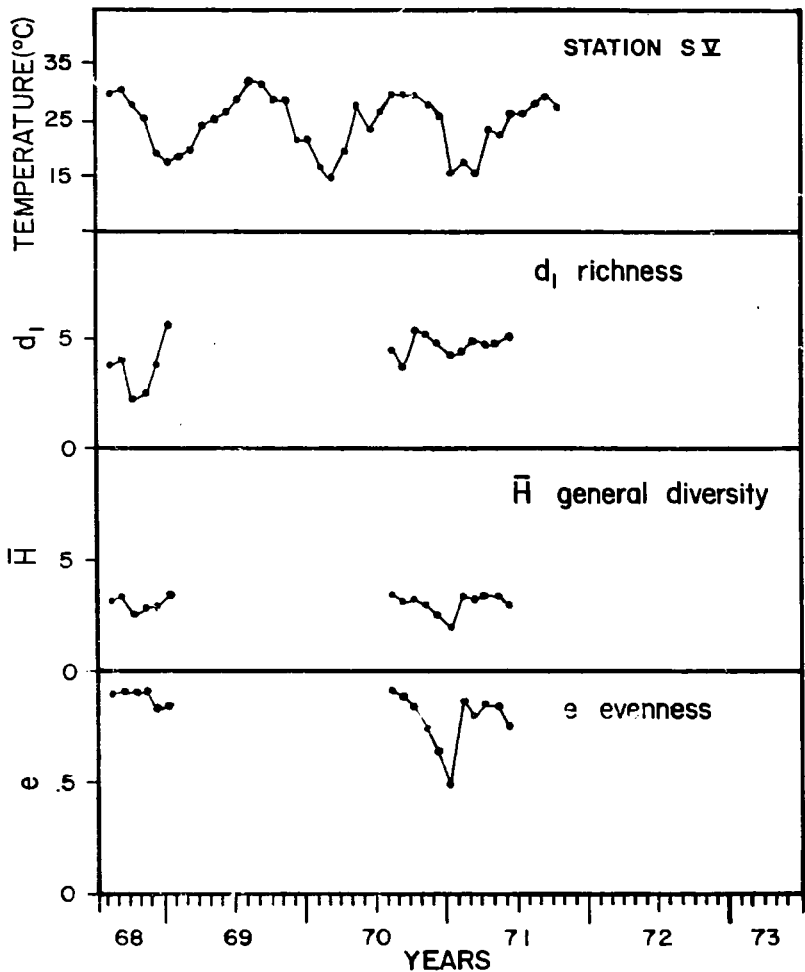


FIGURE 30D.

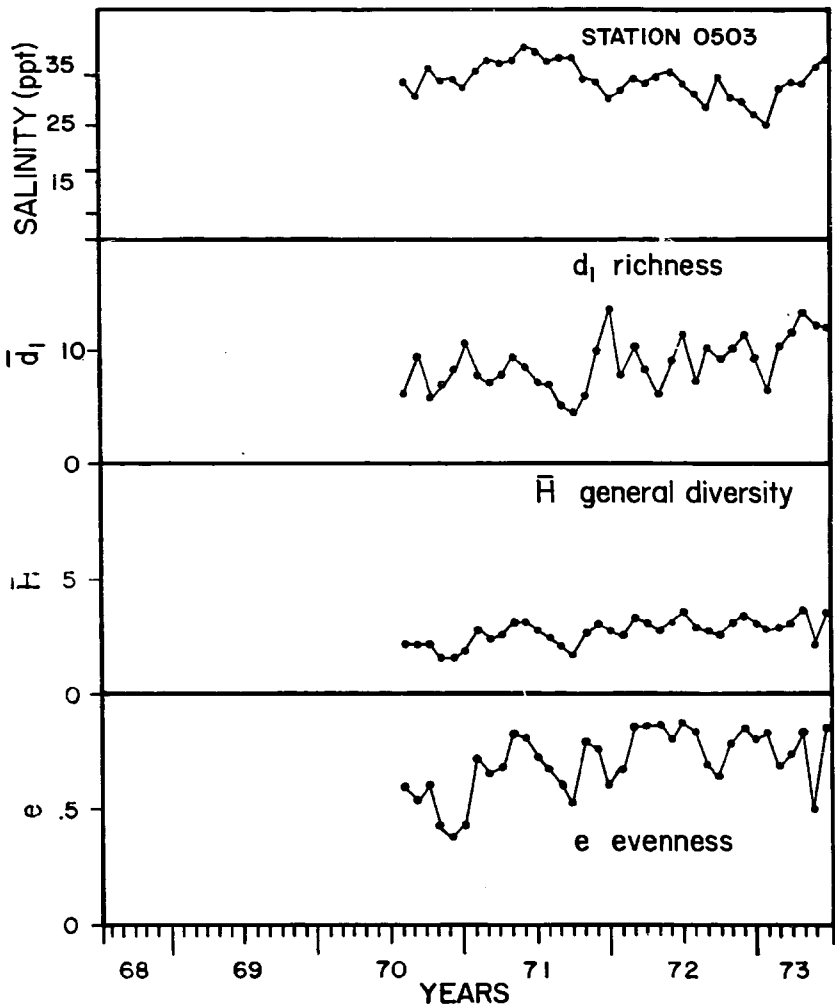


FIGURE 31A. Diversity and salinity at Card Sound stations

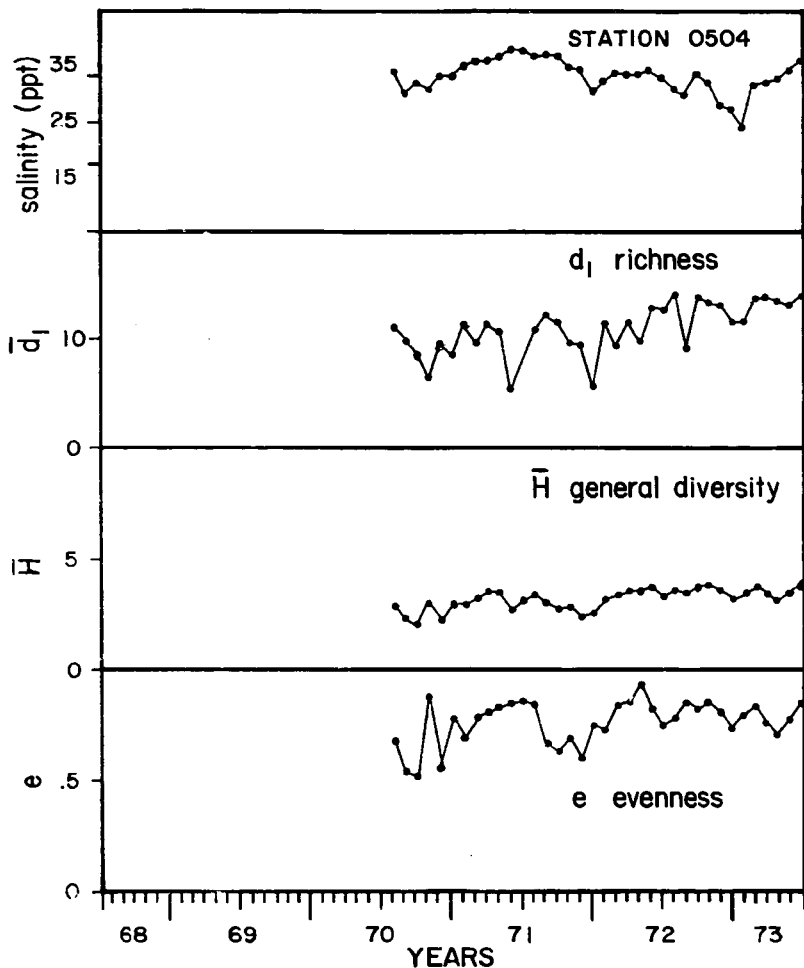


FIGURE 31B.

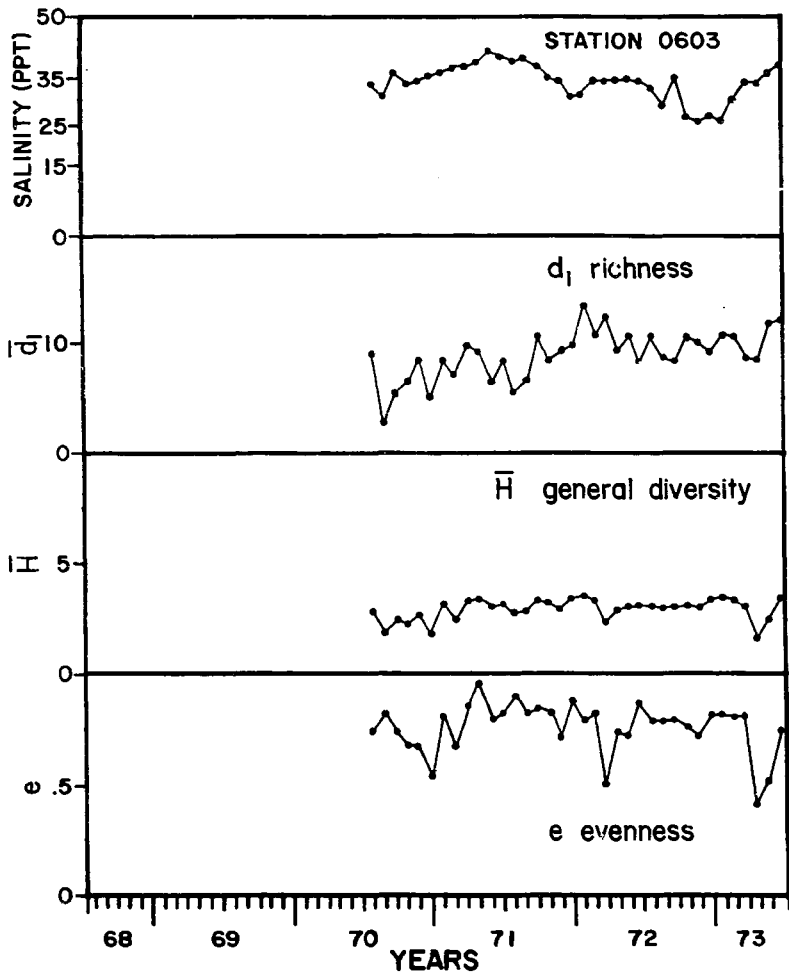


FIGURE 31C.

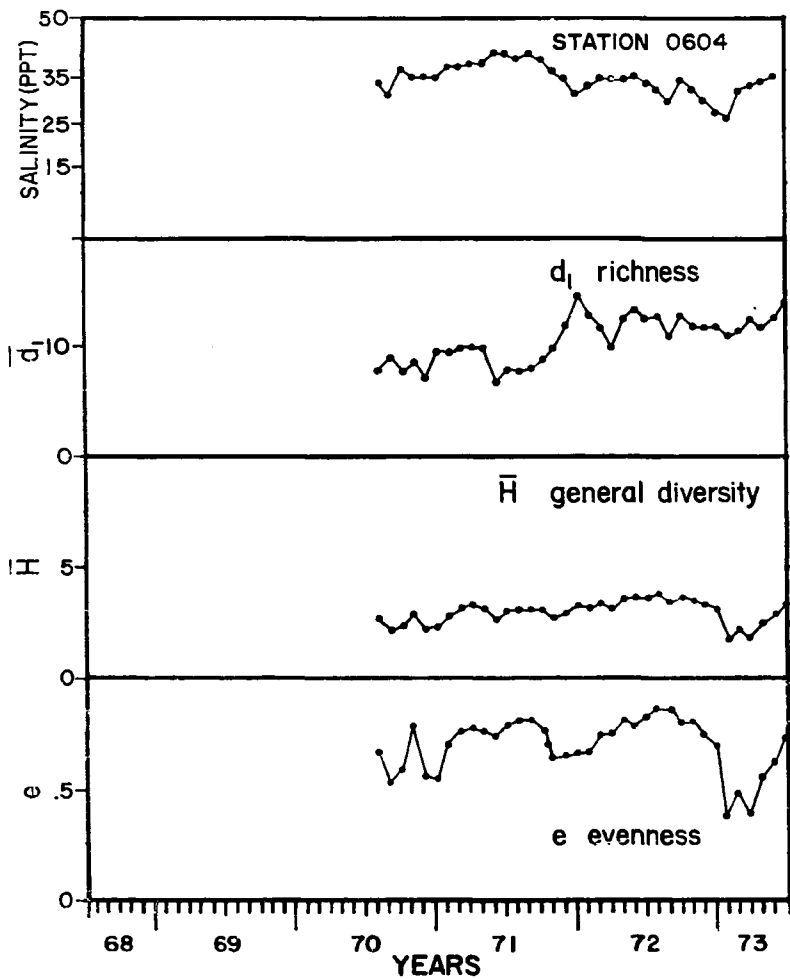


FIGURE 31D.

effort by station by year is presented in Table 8.

Analysis of the 20 stations sampled from July 1968-December 1968 indicated that a total of 48,128 animals were collected (Poessler, Tabb, Rehrer and Garcia, 1974). Nonparametric analysis of variance indicated that the abundance of organisms at the 20 stations was not homogeneous, catches were significantly higher than the average (57 animals per drag) at stations N V, SE II and SE III. Table 9 summarizes the vegetation type and abundance for each of the stations and examination of these tables indicates that the three stations with greatest abundance of animals share large catches of vegetation, principally Laurencia or Digenia. Seasonal distribution of vegetation in trawl samples at Biscayne Bay stations N II, F, SE I and G is shown in Figure 32 and vegetation at Card Sound stations O104, O504, O603 and O604 is shown in Figure 33.

Catches were below average at stations N II, NE IV, NE V, SE I, SE IV, SE V, S I and S V. These stations all produced low catches of vegetation as well as low animal catches. There appears to be three major causes for low catches of vegetation at certain stations. First, Zieman (1970), Roessler and Zieman (1970) and Thorhaug (1971), have shown that in an area of about 300 acres from the mouth of the Turkey Point effluent canal the amount of algae and sea grass is seasonally reduced by temperature effects. At stations N II and N V located near the mouth of the Florida City Canal and Moody Canal the vegetation is killed during periods of freshwater discharge. This was particularly evident at station N II located 150 m from the mouth of Florida City Canal and less so at N V located 300 m from the mouth of Moody Canal. However, at N V the dense Digenia growth observed in July and August 1968 was totally killed in September, but quickly replaced by Laurencia. The freshwater influence at station N V was also indicated by the presence of the pelecypods Crassostrea virginica, Amygdalum papyria, Congeria leucophaeta, and Anomalocardia cuneimeris. The third reason for low catches of vegetation is due to stations located on Thalassia flats. The otter trawl does not uproot the Thalassia but only catches the dead fragments of the blades. The Thalassia beds are dominant on the shallows near the Arsenicker Keys on Pelican Bank and near the Florida Keys on the eastern side of the Bay.

Thus, we believe the low abundance of animals at stations S I and SE I which were in the thermal plume and were elevated 5.26 and 5.25°C above ambient, was the direct result of temperature increases or indirect result of temperature which adversely affected the algae and sea grass, used as food and shelter by the animals. Further study is needed to separate these alternatives. The low catches at station N II are probably caused by fresh water discharge from a point source at the mouth of the Florida City Canal, and low catches at stations NE IV, NE V, SE IV, SE V and S V result because these off-shore stations have sparse vegetation or nearly pure Thalassia communities with little unattached vegetation.

After January 1969, a washing technique was used in field sorting which made the collection of small molluscs and other animals more efficient. In the period January 1969-June 1971, the mean catch per tow was 91.8 animals per tow with a 95% confidence interval of 66.1 to 117.5 for stations N I, N II, N III, NE I, NE II, NE III, SE II, SE III, S I, S II and S III. Stations N III, and S II, were above average in catch and stations N I and S I were below average. Station SE I with a catch per unit of 67.0 for the period January 1969-June 1973, was within the confidence limits but was at the low end of the range (Table 10).

Table 8. Summary of distribution of effort (number of tows)

Station	7/68- 6/69	7/69- 6/70	7/70- 6/71	7/71- 6/72	7/72- 6/73	Total
N I	84	86	77	0	0	247
N II	84	86	77	0	0	247
N III	84	86	77	0	0	247
N IV	48	12	0	0	0	60
N V	48	12	0	0	0	60
NE I	84	86	77	0	0	247
NE II	84	86	77	0	0	247
NE III	84	86	77	0	0	247
NE IV	48	12	0	0	0	60
NE V	48	12	0	0	0	60
SE I	84	86	84	84	84	422
SE II	84	86	77	0	0	247
SE III	84	86	77	21	0	268
SE IV	48	12	0	0	0	60
SE V	48	12	0	0	0	60
S I	84	86	77	0	0	247
S II	84	86	77	0	0	247
S III	84	86	77	0	0	247
S IV	48	12	77	0	0	137
S V	48	12	77	0	0	137
A	70	86	77	0	0	233
B	42	86	0	0	0	128
C	42	86	0	0	0	128
D	42	86	77	0	0	205
E	42	86	77	0	0	205
F	42	86	84	42	0	254
G	42	86	84	84	84	380
H	42	86	77	0	0	205
I	0	0	77	0	0	77
J	0	0	77	21	0	98
K	0	0	77	0	0	77
0104	0	0	84	84	84	252
0204	0	0	63	0	0	63
0208	0	0	77	49	0	126
0304	0	0	70	28	0	98
0306	0	0	63	28	0	91
0403	0	0	70	49	0	119
0404	0	0	70	49	0	119
0405	0	0	84	49	0	133
0503	0	0	84	84	84	252
0504	0	0	84	84	84	252
0602	0	0	84	84	84	252
0604	0	0	84	84	84	252
0606	0	0	63	28	0	91
0608	0	0	77	0	0	77
0703	0	0	84	49	0	133

Table 8. Continued

Station	7/68- 6/69	7/69- 6/70	7/70- 6/71	7/71- 6/72	7/72- 6/73	Total
0704	0	0	63	28	0	91
0803	0	0	63	0	0	63
0804	0	0	63	0	0	63
0805	0	0	63	28	0	91
1003	0	0	77	0	0	77

Table 9. Temperature and vegetation data for Biscayne Bay and Card Sound trawling stations

BISCAYNE BAY July - December 1968						
Station	Bottom Temp.		t	Dominant Vegetation	Average Pounds/Tow	
	Max.	Min.				
N I	37.6	13.5	-0.17	<u>Laurencia</u> , <u>Thalassia</u>	7.32	
N II	36.6	15.7	-0.68	<u>Laurencia</u> , <u>Diplanthera</u>	6.68	
N III	30.4	15.4	-25.08*	<u>Laurencia</u> , <u>Thalassia</u>	5.70	
N IV	30.7	13.8	-0.85	<u>Laurencia</u> , <u>Thalassia</u>	3.77	
N V	37.3	14.2	-0.02	<u>Digenia</u> , <u>Laurencia</u> & <u>Thalassia</u>	17.29	
NE I	30.4	14.2	-0.76	<u>Laurencia</u> , <u>Diplanthera</u> & <u>Thalassia</u>	7.69	
NE II	38.1	14.8	-0.35	<u>Laurencia</u> , <u>Thalassia</u>	9.46	
NE III	32.3	15.3	-0.11	<u>Laurencia</u> , <u>Thalassia</u>	5.23	
NE IV	30.4	15.4	-0.41	<u>Udotea</u> , <u>Penicillus</u> & sponges	1.33	
NE V	30.5	15.6	-0.63	<u>Thalassia</u>	0.01	
SE I	37.5	22.4	+5.25	<u>Digenia</u> & peat	1.78	
SE II	36.3	20.4	+2.20	<u>Laurencia</u> , <u>Batophora</u> & <u>Thalassia</u>	4.13	
SE III	37.8	16.5	+1.17	<u>Laurencia</u> , <u>Thalassia</u>	6.31	
SE IV	31.4	17.6	+1.31	<u>Thalassia</u> , <u>Laurencia</u>	1.29	
SE V	38.7	17.7	+0.37	<u>Thalassia</u>	0.23	
S I	38.0	22.7	+5.26	<u>Diplanthera</u>	1.23	
S II	32.9	18.0	+2.25	<u>Laurencia</u> , <u>Thalassia</u>	3.75	
S III	31.8	18.1	+0.93	<u>Laurencia</u> , <u>Thalassia</u>	1.43	
S IV	30.1	20.0	+1.05	Some <u>Thalassia</u> & sponges	0.73	
S V	30.8	18.2	+0.41	<u>Alcyonarians</u> & sponges	0.03	
January 1969 - June 1970						
N I	30.2	15.0	+0.35	<u>Laurencia</u> , <u>Thalassia</u>	11.46	
N II	32.0	15.0	+0.29	<u>Laurencia</u> , <u>Diplanthera</u>	9.36	
N III	31.5	15.0	+0.24	<u>Laurencia</u> , <u>Thalassia</u>	20.67	

* Average ambient temperature

Table 9. Continued

Station	Bottom Temp.		t	Dominant Vegetation	Average Pounds/Tow
	Max.	Min.			
NE I	30.9	15.5	+0.57	<u>Laurencia</u> , <u>Thalassia</u> & <u>Diplanthera</u>	10.70
NE II	31.0	15.8	+0.60	<u>Laurencia</u> , <u>Thalassia</u>	13.25
NE III	30.7	15.1	+0.27	<u>Laurencia</u> , <u>Thalassia</u>	9.87
SE I	34.1	19.8	+3.59	<u>Diplanthera</u> , <u>Laurencia</u> & peat	3.12
SE II	34.0	16.1	+0.74	<u>Laurencia</u> , <u>Thalassia</u> & <u>Batophora</u>	7.91
SE III	32.1	14.8	+0.26	<u>Thalassia</u> , <u>Laurencia</u>	4.97
S I	35.3	21.0	+3.65	<u>Diplanthera</u>	1.30
S II	34.2	19.4	+2.39	<u>Laurencia</u> , <u>Thalassia</u>	11.16
S III	34.1	16.1	+0.75	<u>Laurencia</u> , <u>Thalassia</u>	6.09
A	31.5	15.8	+1.48	<u>Laurencia</u> , <u>Thalassia</u>	6.06
B	31.1	15.9	+0.89	<u>Thalassia</u> , <u>Laurencia</u> & sand	4.53
C	31.9	15.4	+0.18	<u>Udotea</u> , <u>Penicillus</u>	3.69
D	31.0	15.2	24.13*	<u>Thalassia</u>	2.00
E	32.0	15.1	+0.31	<u>Laurencia</u> , <u>Thalassia</u>	3.66
F	35.0	15.8	+1.82	<u>Thalassia</u> , <u>Digenia</u> & <u>Laurencia</u>	15.79
G	34.5	22.5	+4.56	<u>Acetabularia</u> (winter) & blue-green diatom mat	0.09
H	35.0	18.2	+1.46	<u>Laurencia</u> , <u>Thalassia</u>	9.91

July 1970 - June 1971

Station	Bottom Temp.		Ave. Temp.	Dominant Vegetation	Average Pounds/Tow
	Max.	Min.			
N I	30.8	15.1	24	<u>Laurencia</u> , <u>Thalassia</u>	8.50
N II	30.6	15.1	24	<u>Laurencia</u> , <u>Diplanthera</u>	7.38
NE II	31.3	15.2	25	<u>Laurencia</u> , <u>Thalassia</u>	10.48
SE I	36.0	20.6	29	<u>Diplanthera</u> , <u>Laurencia</u>	4.36
SE II	30.8	15.7	26	<u>Laurencia</u> , <u>Thalassia</u>	4.47
SE III	30.4	16.1	25	<u>Laurencia</u> , <u>Thalassia</u>	3.53

* mean ambient temperature

Table 9. Continued

Station	<u>Bottom Temp.</u>		Ave. Temp.	Dominant Vegetation	Average Pounds/Tow
	Max.	Min.			
S I	36.0	21.9	29	<u>Diplanthera</u>	1.43
S II	35.4	21.1	28	<u>Laurencia</u>	4.72
S III	30.6	16.2	26	<u>Laurencia</u>	7.48
S IV	30.1	16.1	25	<u>Laurencia</u> , <u>Thalassia</u>	3.17
S V	30.3	16.0	25	<u>Laurencia</u> , <u>Thalassia</u>	4.59
A	32.3	15.2	26	<u>Thalassia</u> , <u>Laurencia</u>	5.65
D	30.1	15.9	24	<u>Thalassia</u> , <u>Laurencia</u>	2.89
E	30.3	15.6	25	<u>Thalassia</u> , <u>Laurencia</u>	3.62
F	33.0	16.0	27	<u>Laurencia</u>	5.42
G	36.0	21.7	30	microalgae	0.37
H	31.2	17.3	26	<u>Laurencia</u>	9.87
I	32.7	17.0	27	<u>Thalassia</u> , <u>Diplanthera</u>	2.22
J	33.2	16.0	26	<u>Laurencia</u> , <u>Thalassia</u>	6.90
K	32.0	15.1	26	<u>Thalassia</u> , <u>Laurencia</u>	2.47
<u>July 1971 - June 1973</u>					
SE I	34.1	19.3	28	<u>Laurencia</u> , <u>Diplanthera</u>	3.68
G	34.0	19.3	28	microalgae	1.08
CARD SOUND					
<u>July 1970 - June 1973</u>					
0104	31.1	13.5	25	<u>Thalassia</u>	3.4
0503	32.0	16.5	26	<u>Laurencia</u>	5.7
0504	31.8	16.3	26	<u>Laurencia</u>	4.1
0603	33.5	16.5	26	<u>Diplanthera</u> , <u>Laurencia</u>	3.9
0604	32.0	16.5	26	<u>Laurencia</u>	8.9

Table 9. Continued

Station	Bottom Temp.		Ave. Temp.	Dominant Vegetation	Average Pounds/Tow
	Max.	Min.			
<u>July 1970 - December 1971</u>					
0208	30.4	14.2	26	<u>Thalassia</u>	0.4
0405	30.9	16.2	26	<u>Laurencia</u>	3.6
0703	31.3	16.8	26	<u>Laurencia</u>	2.4
<u>July 1970 - May 1971</u>					
0608	30.7	15.1	25	<u>Thalassia</u>	0.7
1004	30.3	16.8	25	<u>Laurencia, Thalassia</u>	3.5
<u>September 1970 - May 1971</u>					
0204	27.9	16.4	23	<u>Thalassia, Laurencia</u>	5.7
0304	28.0	16.5	23	<u>Laurencia, Thalassia</u>	21.2
0306	27.9	14.8	23	<u>Thalassia</u>	4.7
0403	27.9	16.2	24	<u>Laurencia, Thalassia</u>	11.6
0404	27.9	16.6	23	<u>Laurencia</u>	11.7
0606	28.1	16.2	23	<u>Thalassia, Laurencia</u>	10.3
0704	28.0	16.5	23	<u>Laurencia, Thalassia</u>	11.8
0803	27.9	16.6	24	<u>Laurencia, Thalassia</u>	5.6
0804	28.0	16.8	23	<u>Laurencia, Thalassia</u>	18.2
0805	28.0	16.8	23	<u>Laurencia</u>	10.8

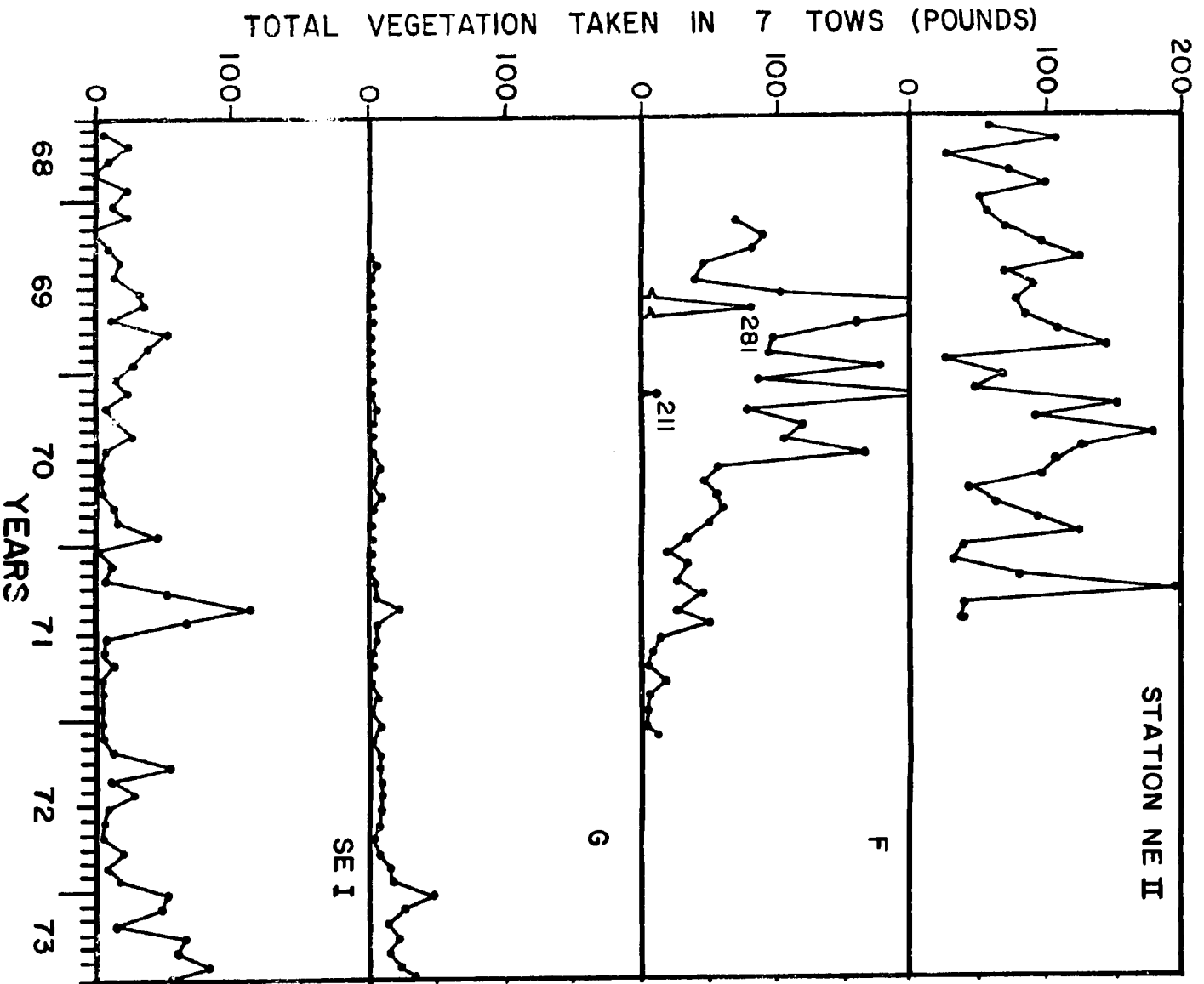


FIGURE 32. Seasonal distribution of vegetation at stations N II, SE I, F and G.

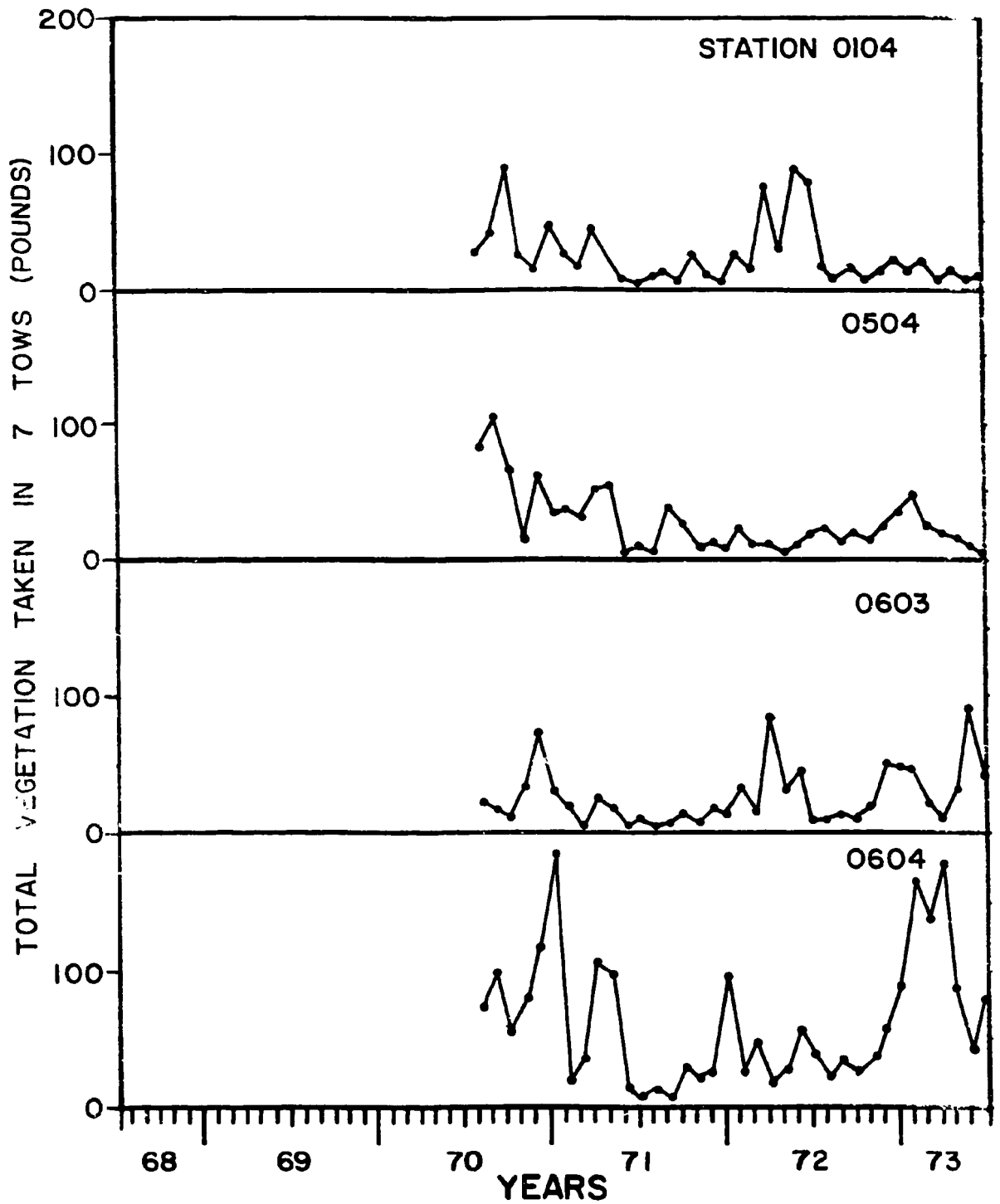


FIGURE 33. Seasonal distribution of vegetation at stations 0104, 0504, 0603 and 0604.

Table 10. Catch per tow of all species combined at selected stations in Biscayne Bay and Card Sound

Station	C/e July 1968- June 1971	Station	C/e Jan. 1969- June 1971	Station	C/e July 1970- June 1973
N I	62.4	A	57.1	0104	70.4
N II	99.5	D	51.1	0503	104.2
N III	159.1	E	60.1	0504	116.2
NE I	68.9	F	163.7	0603	94.1
NE II	103.4	H	161.2	0604	208.0
NE III	76.2				
SE II	105.8				
SE III	82.2				
S I	13.9				
S II	138.6				
S III	99.5				
SE I	67.0 ^{1/}	G	19.1 ^{2/}		
\bar{x}	11.7		26.1		23.6
\bar{x}	91.8		98.6		118.6
	<u>95% CI</u>		<u>95% CI</u>		<u>95% CI</u>
	66.1 ≤ 91.8 ≤ 117.5		25.5 ≤ 98.6 ≤ 171.7		52.5 ≤ 118.6 ≤ 184.6

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

The mean catch per tow for stations A, D, E, F and H for the period January 1969-June 1971 was 98.6 animals per tow. The 95% confidence limits were 25.5 to 171.7. All of the stations were within this range. Station G had a mean catch of 19.1 for the period January 1969-June 1973. It therefore, had significantly low catches.

The mean catch/tow for Card Sound stations 0104, 0503, 0504, 0603 and 0604 was 118.6. The 95% confidence interval was from 52.6 to 184.6. Station 0604 produced high catches while the other stations fell within the expected range.

Above average catches occurred at stations where vegetation predominantly Laurencia spp. was abundant. Low catches occurred at stations G (the Biscayne Bay effluent mouth), station S I (185 m east-southeast of the effluent) and station N I (north of the intake canal). Station SE I (185 m east-northeast of the effluent) was within the 95% confidence interval, but at the low end of the range. This catch per tow includes a year of samples after the effluent was diverted to Card Sound and when this year was not included, the catch per tow at SE I was significantly low.

Therefore, we conclude that stations elevated between 3-4°C above ambient and those between 4-5°C above ambient had significantly less animal biomass than other stations in the Bay and Sound system.

While total counts of animals per tow and community diversity are instructive, it is of considerable importance to examine the various taxa to see how each is affected and for the most abundant species or those of economic importance it is essential to examine the changes in the species itself.

Fish

Fishes were poorly represented in trawl samples and the 8479 trawl hauls produced 14,173 individuals or 1.8% of the animal catch. The total fishes taken in Biscayne Bay was 10,097 in 5784 drags or 1.7 fishes per tow were taken, while in Card Sound 4076 fishes were taken in 2695 drags or 1.5 fishes per tow were taken. Hence, the catch per tow of fishes in both areas was similar.

Examination of fish catches in the period July-December 1968 indicated significantly higher than average catches (3.27 fish/tow) at station N V and lower than average catches at stations SE I and S I (Roessler, Tabb, Rehner and Garcia, 1974). The low catches at stations S I and SE I are probably the result of elevated temperatures and the resulting lack of algae and sea grasses (Table 9).

During the period July 1968-June 1971, the catch per tow of fishes for stations N I, N II, N III, NE I, NE II, NE III, SE III, S I, S II, S III (basic stations) was 1.7 fishes per tow. The 95% confidence limits were between 1.2 and 2.3. Stations N II and N III produced above average catches while S I elevated 3.5°C above ambient produced below average catches. Considering the 5 year study period, catches at station SE I were within the 95% confidence interval despite the fact that it was elevated 3.5°C during the period July 1968-February 1972.

The average catch per tow at stations A, D, E, F and H (added Biscayne Bay stations) for the period January 1969-June 1971 was 1.43 fishes per tow. The 95% confidence interval encompassed a range from 0.8 to 2.1 fishes per tow. Station H produced above average catches, station G, sampled between

January 1969 and June 1973, had an average catch of 0.3 fishes per tow and was significantly below average.

Stations 0104, 0503, 0504, 0603, and 0604 (Card Sound) were sampled from July 1970-June 1973 and produced 1.3 fishes per tow. Catches at station 0104 (0.82) were below the 95% confidence limits (0.84-1.74) and station 0604 (1.75) had catches above average (Table 11).

Ninety-nine species of fishes were collected, but no species comprised as much as 1% of the total catch. Cowfish (Acanthostracion quadricornus), code gobies (Gobiosoma robustum), rainwater killifish (Lucania parva), fringed pipefish (Micrognathus crinigerus) and Gulf toadfish (Opsanus beta) were the dominant fishes contributing 7, 15, 15, 19 and 15% of the total fish catch respectively, or a total of 71% of the numbers of fish.

The cowfish was represented by 1024 individuals. The average catch per tow in Biscayne Bay was 0.06 cowfish per tow and varied from a low of 0 at N V, A and I, to a high of 0.65 at SE I. Generally, catches were highest near the Florida Keys and low near the mainland. In Card Sound the average catch per tow was 0.23 with a range from a low of 0.12 at station 0403 to a high of 0.88 at 0608. Again in Card Sound, catches were low near the mainland shore and higher near the Florida Keys. Cowfish appear to be back reef forms which enter the Bay areas. Their greatest abundance occurs where Lee and Rooth (1971) indicate tidal exchange is greatest. The low relative abundance (0.008 at station G, 0.004 at S I and 0.002 at SE I) may be attributed to the inshore nature of these stations and variability of salinity rather than thermal additions.

The code goby was represented by 2143 individuals. In Biscayne Bay the average catch was 0.35 individuals per tow. The low was (0.00) at NE V and SE V and the high was 14.82 at N V. In Card Sound the average catch per tow was 0.04. The low was (0.00) at 0208 and 0703. In general, this is an inshore sediment wedge species adapted to variable salinity. Thus, the low catches at G (0.02 fish/tow), at SE I (0.09) and at S I (0.02), were significant compared to other inshore stations. The code goby appears to be most abundant at temperatures near 30°C although 90% of the individuals were collected at temperatures below 32°C.

The rainwater killifish was represented by 210 individuals. The average catch in Biscayne Bay was 0.37 individuals per tow. The low was 0.00 at NE IV, NE V, SE IV, SE V and C and the high was 2.66 at N II. Only 11 specimens were taken in Card Sound. This species was abundant only along the north (N) transect and at a few other inshore stations subject to occasional fresh water inputs from drainage canals. It is primarily a fresh water species which is carried in great abundance to the Bay during the rainy season. Ecologically, it is important as a link between fresh water marsh production and the estuary but it has little value as an indicator of thermal stress.

The fringed pipefish was represented by 2688 individuals and was the most abundantly caught fish in the survey. The average catch in Biscayne Bay was 0.28 individuals per tow. They were taken at all Biscayne Bay stations. The catch per tow was low at stations N II (0.04) and N V (0.01), which were influenced by fresh water discharge. Stations NE V (0.07), SE V (0.03) and S V (0.07) were offshore stations with low catches. Stations SE I (0.36), S I (0.03), F (0.06), G (0.16) and I (0.01) had low catches, probably as a result of thermal stress which limited the amount of vegetative cover. Station B

Table 11. Catch per tow of fishes at selected stations in Biscayne Bay and Card Sound

Station	C/e July 1968- June 1971	Station	C/e Jan. 1969- June 1971	Station	C/e July 1970- June 1973
N I	1.36	A	1.04	0104	0.82
N II	3.54	D	1.05	0503	1.35
N III	3.11	E	1.21	0504	1.48
NE I	1.38	F	1.56	0603	1.07
NE II	1.83	H	2.28	0604	1.75
NE III	1.49				
SE II	1.41				
SE III	1.52				
S I	.83				
S II	1.34				
S III	1.22 ^{1/}				
SE I	1.92 ^{1/}	G	0.27 ^{2/}		
$s\bar{x}$.25		.23		.16
\bar{x}	1.73		1.43		1.29
	<u>95% CI</u>		<u>95% CI</u>		<u>95% CI</u>
	1.18 ≤ 1.73 ≤ 2.28		.79 ≤ 1.43 ≤ 2.07		.84 ≤ 1.29 ≤ 1.74

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

(0.06) also produced low catches and had small amounts of Laurencia. It was not, however, thermally stressed. Two inshore stations N IV (0.88) and H (0.85) produced the highest catches.

In Card Sound the average catch was 0.39 individuals per tow (Table 12). No fringed pipefish were taken at offshore station 0608 and only a single individual was taken at 0208. The highest catch (1.63 individuals per tow) was taken at 0304. The species prefers shoreline areas with a large amount of red algae, Laurencia spp. Catches are depressed in areas of thermal stress and in areas where fresh water is discharged into the Bay via drainage canals.

The Gulf toadfish Opsanus beta is known to hybridize with O. tau in Biscayne Bay (Schultz and Reid, 1937) and some of the 1124 individuals reported here may be hybrids. Examination of pectoral fin pigment pattern indicates the incidence of hybrids was low. Opsanus was present at all stations but was most numerous where red algae Laurencia spp. or Digenia simplex was abundant. The catch rate was 0.25 individuals per tow, 0.24 fish per tow in Biscayne Bay and 0.28 in Card Sound. In Biscayne Bay catches were low at the most severely stressed stations G (0.01), S I (0.05), SE I (0.06), I (0.09) and K (0.04). They were also low at stations located offshore: NE I (0.10), SE IV (0.08), SE V (0.02) and S V (0.04) and in areas where Laurencia spp. was not common: N I (0.09), B (0.07) and D (0.09). The highest catch occurred at station N V (3.98) during a period of heavy Digenia growth. The small mussel, Brachidontes exustus, probably served as food and the heavy algal growth protected them from predators such as cormorants. Almost all of the fishes were small (15 gm wet weight) and large individuals which dwell in holes were mostly missed by the trawl.

In Card Sound catches were low at inshore stations 0104 (0.10), 0603 (0.08), 0703 and 0803 (0.02) and 0208 (0.03) near the Broad Creek Channel. The widespread low catch rate at inshore stations implies the effluent at 0603 was not the cause of low catch rate. Stations 0304 (1.18) and 0804 (0.43) produced high catch rates and were also producers of large quantities of red algae (Table 12).

Fishes of sport or commercial importance collected included 4 silverperch, Bairdiella chrysura, 14 porgy, Calamus calamus, 2 spotted seatrout, Cynoscion nebulosus, 15 sand perch, Diplectrum formosum, 77 grunts, Haemulon spp., 10 pigfish, Orthopristis chrysopterus, 5 hogfish, Lachnolaimus maximus, 583 pinfish, Lagodon rhomboides, 133 snappers, Lutjanus spp., 8 bagrids, Meroperca microlepis, 73 flounder, Laralichthys spp. and 5 barracuda, Sphyræna barracuda.

Lagodon rhomboides does not appear to be adversely affected on an annual basis by the temperatures observed. Too few specimens were available to examine seasonal patterns. Nugent (1970) trapped these fish in the effluent canals. He found that pinfish were more abundant in the heated canals in winter and less abundant in summer than in his control station. The dependence of this species on the sea grasses or attached algae is well documented and Caldwell (1957), Darnell (1958) and Springer and Woodburn (1960) indicated that these fishes feed on vegetation.

Mollusks

Mollusks were the most abundant group of animals in our collections. We trapped 363,753 individuals comprised of 199 species. This represented 40% of the total annual catch. Brachidontes exustus, Bitium varium and Hydrobia spp. were excluded from the counts.

Table 12. Catch and catch per tow of fishes, and catch per tow of cowfish, code goby, rainwater killifish, fringed pipefish and toadfish

Station	CATCH			CATCH PER TOW			
	Fishes	Fishes	Cowfish	Code Goby	Rainwater Killifish	Fringed Pipefish	Toadfish
N I	336	1.36	.008	.069	.814	.202	.085
N II	875	3.54	.004	.287	2.656	.040	.223
N III	767	3.11	.004	.753	1.453	.198	.490
N IV	214	3.57	.150	.917	.283	.883	.700
N V	1328	22.13	0.000	14.817	2.450	.050	0.980
NE I	340	1.38	.008	.186	.563	.275	.158
NE II	453	1.83	.073	.320	.356	.615	.202
NE III	368	1.49	.057	.170	.057	.660	.312
NE IV	72	1.20	.333	.050	0.000	.450	.050
NE V	47	0.78	.233	0.000	0.000	.067	.100
SE I	811	1.92	.002	.085	.443	.036	.062
SE II	347	1.41	.073	.154	.008	.749	.097
SE III	406	1.52	.041	.172	.078	.608	.358
SE IV	82	1.37	.100	.017	0.000	.267	.083
SE V	140	2.33	.650	0.000	0.000	.033	.017
S I	206	0.83	.004	.024	.012	.028	.046
S II	332	1.34	.133	.389	.041	.326	.251
S III	300	1.22	.073	.061	.049	.506	.211
S IV	139	1.02	.051	.117	.022	.118	.109
S V	190	1.39	.584	.007	.015	.066	.044
A	242	1.04	0.000	.146	.382	.515	.150
B	116	0.91	.016	.125	.383	.063	.070
C	200	1.56	.227	.031	0.000	.719	.250
D	215	1.05	.024	.010	.005	.156	.088
E	247	1.21	.083	.012	.005	.283	.166
F	396	1.56	.004	.571	.059	.055	.713
G	104	0.27	.008	.018	.003	.016	.003
H	467	2.28	.010	.644	.137	.849	.478
I	226	2.94	0.000	.455	1.300	.013	.091
J	95	0.97	.041	.122	.039	.276	.102
K	36	0.47	.039	.026	.117	.429	.039
0104	207	0.82	.123	.040	.032	.147	.095
020	83	1.32	.206	.016	0.000	.540	.159
020	94	0.74	.246	0.000	0.000	.008	.032
0304	357	3.64	.184	.061	.010	1.633	1.173
0304	100	1.10	.308	.033	0.000	.099	.242
0403	123	1.03	.118	.034	0.000	.387	.210
0404	206	1.73	.235	.017	0.000	.580	.336
0405	160	1.20	.338	.008	0.000	.120	.256
050	339	1.35	.246	.056	0.000	.102	.183
0504	373	1.48	.294	.028	0.000	.317	.200
0603	270	1.07	.250	.036	.004	.179	.079
0604	440	1.75	.282	.016	0.000	.444	.321
0604	214	2.35	.165	.022	0.000	.901	.758

Table 12. Continued

Station	CATCH		CATCH PER TOW				
	Fishes	Fishes	Cowfish	Code Goby	Rainwater Killifish	Fringed Pipefish	Toadfish
0608	211	2.74	.883	.013	0.000	0.000	.117
0703	85	0.64	.233	0.000	0.000	.098	.045
0704	171	1.88	.220	.066	0.000	.824	.297
0803	45	0.71	.143	.016	0.000	.413	.016
0804	246	3.91	.222	.302	0.000	1.175	1.429
0805	235	2.58	.286	.121	0.000	.670	.516
1003	118	1.53	.351	.091	.013	2.60	.156

In the period July 1968-June 1971, the average catch per tow at the 11 original Biscayne Bay stations was 44 mollusks per tow. The 95% confidence interval was from 24 to 64. Stations N II, N III and S II were above average, while S I produced low catches. Station SE I sampled through June 1973 produced 34 mollusks per tow and hence, falls within the confidence limits.

The added Biscayne Bay stations sampled from January 1969-June 1971 produced an average catch of 43 mollusks per tow. Catches at station F were above the 95% confidence limits ($11 \leq 43 \leq 76$). If station G, sampled through June 1973, is compared to the above 5 stations the catch per tow is significantly lower than expected.

The five Card Sound stations sampled July 1970-June 1973 produced an average catch of 53 mollusks per tow. The 95% confidence interval was from 18 to 89. Station 0604 produced above average catches (Table 13).

Only three species of mollusks were taken which are considered of sport or commercial value. These were the oyster Crassostrea virginica and the scallops Argopecten irradians and A. gibbus nucleus. Several other species are eaten, but are seldom used or are rare in the study area.

The scallop Argopecten gibbus nucleus was represented by 222 specimens. Most, 81%, of these came from Card Sound and of these most came from the effluent canal station 0603. Most specimens in Biscayne Bay came from near Caesar's Inlet, but SE I near the Biscayne Bay effluent produced nearly as many.

The more common bay scallop, Argopecten irradians, was represented by 3385 individuals. Together these 3607 scallops made up 1% of the mollusk catch and 0.5% of the total animal catch. The catch per tow for Argopecten spp. is shown in Table 14. In Biscayne Bay the catch averaged 0.29 individuals per tow. Catches were low at N II and N V, influenced by freshwater canals; NE IV, NE V, S V and C, offshore stations; S I, S II and C, influenced by heat; A and H, near shore; and I, J and K, occupied after scallops became scarce in the area. Over 93% of the scallops caught in Biscayne Bay were caught between July 1968 and June 1970, thus, stations I, J and K, sampled from July 1970-June 1971, would not be expected to produce many scallops when control areas were not producing. The highest catch (5.3 scallops per tow) occurred at N IV.

In Card Sound scallop catches averaged 0.72 per tow. Catches were low at 0204, 0208, 0306, 0403, 0405, 0608 and 0803. High catches occurred at 0603 and 0604. The spotty distribution is common in scallops and the high catches at 0603 and 0604 indicate no damage caused by the Card Sound discharge.

Juvenile oysters, Crassostrea virginica, were represented by 1524 individuals. Station N V, off Moody Canal, accounted for 1470 or 96% of the catch. N V received heavy fresh water in the summer of 1968 when those animals were taken. Oysters are scarce at all other stations reflecting the lagoon nature of the Bay and lack of suitable substrate for attachment at the sampling stations.

Table 13. Catch per tow of mollusks at selected stations in Biscayne Bay and Card Sound

Station	C/e July 1968- June 1971	Station	C/e Jan. 1969- June 1971	Station	C/e July 1970- June 1973
N I	23.6	A	30.0	0104	37.5
N II	64.6	D	21.4	0503	54.8
N III	112.3	E	23.6	0504	28.9
NE I	29.3	F	77.8	0603	44.3
NE II	37.9	H	64.3	0604	101.1
NL III	26.7				
SE II	41.8				
SE III	37.1				
S I	4.1				
S II	76.0				
S III	31.9				
SE I	34.2 ^{1/}	G	8.6 ^{2/}		
\bar{s}_x	9.0		11.6		12.7
\bar{x}	44.1		43.4		53.3
	<u>95% CI</u>		<u>95% CI</u>		<u>95% CI</u>
	24.3 ≤ 44.1 ≤ 63.9		10.9 ≤ 43.4 ≤ 75.9		17.7 ≤ 53.3 ≤ 88.9

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

Table 14. Catch and catch per tow of mollusks and catch per tow of Argopecten spp., Crassostrea and Acmaea sp.

Station	CATCH		CATCH PER TOW		
	Mollusks	Mollusks	<u>Argopecten</u> spp.	<u>Crassostrea</u> <u>virginica</u>	<u>Acmaea</u> sp.
N I	5832	23.6	.11	.02	.01
N II	15948	64.6	.01	.01	.01
N III	27741	112.3	.89	.08	0
N IV	7421	123.7	5.30	.08	0
N V	26942	449.0	.07	24.50	0
NE I	7246	29.3	.14	.03	0
NE II	9379	28.0	.20	0	0
NE III	6593	26.7	.22	.01	0
NE IV	535	8.9	.08	0	0
NE V	155	2.6	.02	0	0
SE I	14442	34.2	.20	.01	.01
SE II	10330	41.8	.72	0	0
SE III	9943	37.1	.68	0	0
SE IV	969	16.2	1.42	.02	0
SE V	97	1.6	.58	0	.02
S I	1002	4.1	0	.01	0
S II	18773	76.0	.07	0	0
S III	7884	31.9	.33	0	0
S IV	1336	9.3	.89	0	.01
S V	1022	7.5	.03	0	.13
A	6986	30.0	.03	0	0
B	1805	14.1	.19	0	0
C	1909	14.9	.08	0	0
D	4380	21.4	.13	0	.01
E	4831	23.6	.21	0	.01
F	19769	77.8	.17	0	.01
G	3280	8.6	.01	.01	.01
H	13188	64.3	.03	0	.01
I	695	9.0	0	0	0
J	2805	28.6	0	0	.01
K	415	5.4	0	0	0
0104	9441	27.4	.95	0	.30
0204	2134	23.9	.05	0	.05
0208	133	1.1	.04	0	.07
0304	19568	129.7	.29	0	.10
0306	655	7.3	.03	0	.54
0403	9437	79.3	.05	0	.40
0404	4279	36.0	.20	.02	.56
0405	3105	23.3	.05	0	1.56
0503	13817	54.8	.51	0	.33
0504	7287	28.9	.58	0	.50
0603	11169	44.3	2.61	0	.53
0604	25479	101.1	2.25	0	.26

Table 14. Continued

Station	<u>CATCH</u>		<u>CATCH PER TOW</u>		
	Mollusks	Mollusks	<u>Argopecten</u> spp.	<u>Crassostrea</u> <u>virginica</u>	<u>Acmaea</u> sp.
0606	5232	57.5	.14	0	4.28
0608	265	3.4	.03	.03	.27
0703	1893	14.2	.11	0	.05
0704	3078	33.8	.09	0	.45
0803	2642	41.9	.05	0	.02
0804	5704	90.5	.84	0	.18
0805	3854	42.4	.28	0	.66
1004	918	11.9	.14	0	.05

The limpet, Acmaea sp., was represented by 1443 individuals. Thirty-five came from Biscayne Bay and 1408 from Card Sound. In Card Sound the catch rate was 0.52 individuals per tow. Catches were low at stations 0204, 0208, 0703, 0803 and 1004. Catches were high at 0606 and 0405 (Table 14). Stations in the middle part of the Sound appeared to be favored. The catches at 0603 and 0604 were not significantly low and there is no evidence to indicate the discharge affected Acmaea.

The paper mussel, Amygdalum papyria, was represented by 3785 individuals. Ninety-seven percent of these were taken at N V during low salinity periods (Table 15). None were taken in Card Sound. The restricted distribution and apparent dependence on Digenia simplex makes this a poor indicator species.

The dove shell, Anachis pulchella was represented by 1623 individuals. In Biscayne Bay the catch rate was 0.15 individuals per tow. None were taken at N III, N V, SE V, B, D, G, I and K. High catches occurred at SE III, S III and E. Relative abundance is related to the presence of red algae, Laurencia spp., and catches are low where the algae is scarce and high where the algae is most abundant. In Card Sound the catch rate was 0.27 individuals per tow. Catches were low at stations 0208, 0306, 0405, 0606, 0608, 0703, 0704, 0803, 0804, 0805 and 1004. High catches occurred at 0104 and 0304. The distribution of A. pulchella is related to the availability of red algae.

The well-ribbed dove shell, Anachis translirata, was represented by 1528 individuals. In Biscayne Bay A. translirata was uncommon and the catch rate was only 0.05 individuals per tow. Twenty-seven percent of the 283 animals occurred at NE III and if we include the catches made at SE III, S IV, S V, D and E we account for 71% of the catch (Table 15). In Card Sound the catch rate was 0.46 individuals per tow. Catches were low at 0208 and high at 0304, 0604 and 0606.

The Adam's miniature arc, Arcopsis adamsi, was represented by 1057 specimens. In Biscayne Bay the catch rate was 0.18 while in Card Sound it was 0.27 individuals per tow. The species was absent from Biscayne Bay stations N I, NE I, NE II, NE IV, NE V, SE IV, SE V, B, D and I. Generally, those were stations with low vegetation catches. Catches were high at N III and N IV which had high vegetation catches. In Card Sound the species was not taken on 0403, 0803 and 1004. These too, were stations with little red algae. Stations 0304 and 0805 produced the highest catches, 1.09 and 1.86 individuals per tow respectively.

Bulla umbilicata, the striate bubbleshell, was one of the dominant mollusks chosen as an indicator species. This species together with Cerithium eberneum, C. muscarum, Mitrella lunata, Modulus modulus, Prunum apicinum, Rissoina chesneli and Tricolia affinis are discussed in detail in a later section.

Bittium varium (variable bittium) and the scorched mussel, Brachidontes exustus, were not counted. The former was so numerous and small that most were lost through the net. The latter when small, are firmly attached to Digenia simplex and the time needed to separate and count them was greater than our resources. After the first two years Brachidontes became scarce,

Table 15. Catch per tow of Amygdalum papyria, Anachis pulchella, Anachis translirata, Arcopsis adamsi, Cardita floridana from Biscayne Bay and Card Sound

Station	<u>Amygdalum</u> <u>papyria</u>	<u>Anachis</u> <u>pulchella</u>	<u>Anachis</u> <u>translirata</u>	<u>Arcopsis</u> <u>adamsi</u>	<u>Cardita</u> <u>floridana</u>
N I	.01	.05	0	0	0
N II	.05	.01	0	.06	0
N III	.27	0	.01	.33	0
N IV	.08	.03	0	.23	.02
N V	61.30	0	0	.02	0
NE I	0	.01	0	0	0
NE II	.01	.01	.01	0	0
NE III	0	.15	.31	.05	.01
NE IV	0	.30	.07	0	0
NE V	0	.02	.15	0	0
SE I	.01	.11	.02	.01	.01
SE II	.01	.10	.06	.13	.06
SE III	0	.61	.10	.01	1.52
SE IV	0	.05	0	0	0
SE V	0	0	0	0	0
S I	.02	.01	0	.01	0
S II	.03	.01	.04	.14	.02
S III	.01	.88	.02	.14	.10
S IV	0	.27	.15	.06	.18
S V	0	.15	.15	.04	.01
A	0	.01	.03	.02	0
B	.01	.01	0	0	0
C	0	.38	.10	.01	0
D	0	.32	.15	0	.08
E	0	.83	.13	.14	.01
F	.01	.01	.02	.11	0
G	0	0	.01	.01	.01
H	.01	.03	0	.01	.02
I	0	0	0	0	0
J	0	.01	.01	.08	0
K	0	0	0	.04	0
0104	0	1.14	.10	.02	3.62
0204	0	.11	.21	.03	.05
0208	0	.01	.02	.02	0
0304	0	3.45	2.37	1.09	.02
0306	0	0	.43	.01	0
0403	0	.46	.10	0	.02
0404	0	.07	.56	.36	0
0405	0	0	.41	.08	0
0503	0	.05	.11	.06	.01
0504	0	.02	.41	.59	.01
0601	0	0	0	.11	0
0602	0	.04	1.33	.42	0

Table 15. Continued

<u>Station</u>	<u>Amgydalum</u> <u>papyria</u>	<u>Anachis</u> <u>pulchella</u>	<u>Anachis</u> <u>translirata</u>	<u>Arcopsis</u> <u>adamsi</u>	<u>Cardita</u> <u>floridana</u>
0606	0	0	1.18	.63	0
0608	0	0	.08	.04	0
0703	0	0	.06	.02	0
0704	0	.01	.29	.40	0
0803	0	.02	.18	0	0
0804	0	0	.56	.08	0
0805	0	0	.44	1.86	0
1004	0	0	.40	0	0

generally, throughout the area.

Cardita floridana, the broad ribbed cardita, was represented by 1256 individuals. Ninety-one percent of the individuals occurred at stations SE III in Biscayne Bay and 0104 in Card Sound. Both of these stations were on sediment banks associated with mid-Bay islands and this seems to be the preferred habitat of Cardita.

Small chitons (Ishnochitonidae) were represented by 3611 individuals. The catch rate in Biscayne Bay was 0.24 individuals per tow. Catches were low at N I, N II, N III, N V, NE I, NE III, NE IV, NE V, SE I, SE IV, SE V, S I and G (Table 16). The stations S I, SE I and G elevated above 3.5°C are among others with low catches. However, other inshore stations N I, N II, N III, etc. also have low catch rates. Catches at A, B, D, E, H and I were high. These animals prefer pure Thalassia on which they are attached and stations with lush stands of the seagrass had numerous chitons. This included I in the minor discharge which was subject to +5°C water on the ebbing tide. In Card Sound the catch rate was 0.83 individuals per tow. Low catches occurred at 0204 and 0208, while high catches were taken at 0603, 0606, 0704 and 0804. Station 0603 was in the outfall canal and hence, the effluent in Card Sound did not adversely affect this species.

Columbellids were represented by 240 C. mercatoria (common dove shell), 3683 C. rusticoides (rusty dove shell) and 7315 juveniles which could not be assigned to species. Thus, Columbella spp. was represented by 11,238 individuals which is 1.4% of the total catch or 3.1% of the mollusks. The catch rate in Biscayne Bay was 1.08 individuals per tow. Catches were low at N I, N II, N III, N V, NE I, NE V, SE I, SE V, S I, A, F, G, I and K. Catches were high at NE III, SE II, S III, D and E. Generally, catches are related to the presence of red algae, Laurencia spp. In Card Sound the catch rate was 1.86 individuals per tow. Catches were low at 0208, an offshore station, and high at 0604 and 0804, inshore stations with high catches of Laurencia spp. The low catches at SE I, S I, F, G, I and 0603 indicate thermal stress was effective in limiting this species group.

The turret, Crassispira leucocyma, was represented by 1041 individuals. In Biscayne Bay only 179 specimens were taken for a catch rate of 0.03 individuals per tow. In Card Sound 862 individuals were taken representing a catch rate of 0.32 individuals per tow. The highest catch was 2.62 at station 0304.

The spotted slipper-shell Crepidula maculosa, was represented by 1398 individuals. Of these 1283 or 92% were taken in Biscayne Bay. The catch rate was 0.22 individuals per tow. Catches were greatest at N II and at I. None were taken at stations N V, NE III, NE IV, NE V, C and E. The species appears to prefer inshore stations and was rare in Card Sound where only 115 specimens were taken for a catch rate of 0.04 individuals per tow.

The Cayenne keyhole limpet, Diodora cayenensis, was represented by 2041 individuals. In Biscayne Bay the catch rate was 0.16 individuals per tow. The species was absent at stations SE V, S I and D. Catches were low at N V, NE V, SE I, A, B, C, G and I; and high at N IV, E and H. In Card Sound the catch rate was 0.42 individuals per tow. It was taken

Table 16. Catch per tow of Ischnochitoridae, Columbella spp., Crassispira leucocyma, Crepidula maculosa, Diodora cayenensis and Haminoea spp. from Biscayne Bay and Card Sound

Station	<u>Ischnochitoridae</u>	<u>Columbella</u> spp.	<u>Crassispira</u> <u>leucocyma</u>	<u>Crepidula</u> <u>maculosa</u>	<u>Diodora</u> <u>cayenensis</u>	<u>Haminoea</u> spp.
N I	.03	.01	0	.01	.09	.05
N II	.01	0	.01	2.06	.15	1.03
N III	.02	.03	0	.01	.19	1.15
N IV	.18	2.73	.07	.28	1.15	.85
N V	0	.03	0	0	.02	.37
NE I	.03	.02	.01	.10	.05	.13
NE II	.19	.19	.01	.16	.18	.14
NE III	.05	3.62	.08	0	.30	.02
NE IV	0	1.32	.02	0	.22	.07
NE V	0	.08	0	0	.03	0
SE I	.10	.04	.01	.55	.04	.13
SE II	.13	6.22	.13	.02	.37	.05
SE III	.36	1.96	.06	.11	.06	.02
SE IV	.05	.97	.05	.05	.07	0
SF V	.03	.02	0	.02	0	0
S I	.01	.01	0	.01	0	.04
S II	.12	1.10	.01	.11	.23	.40
S III	.17	6.60	.10	.03	.34	.02
S IV	.36	.39	.02	.06	.39	0
S V	.10	.25	.04	.03	.09	0
A	.80	.07	0	.64	.04	.09
B	.92	.20	0	.13	.04	.02
C	.11	1.38	.18	0	.04	0
D	.95	2.88	.13	.04	0	.03
E	2.20	4.95	.17	0	.94	.01
F	.23	.02	.01	.09	.25	1.26
G	.05	.01	0	.01	.02	.24
H	2.97	.69	.16	.68	.86	.34
I	.55	0	0	1.40	.03	.01
J	.30	.10	.02	.01	.28	.01

Table 16. Continued

Station	Ischnochitonidae	<u>Columbella</u> spp.	<u>Crassispira</u> <u>leucocyma</u>	<u>Crepidula</u> <u>maculosa</u>	<u>Diodora</u> <u>cayenensis</u>	<u>Haminoea</u> spp.
K	.32	.04	0	.01	.08	0
0104	.58	1.07	.44	.02	.02	<.01
0204	.02	.79	.60	.05	.10	0
0208	.09	.01	0	.01	.01	0
0304	.63	3.48	2.62	.04	.65	.01
0306	.77	.66	.04	.01	.12	.02
0403	.57	.40	.34	.01	.03	.01
0404	.87	.73	.29	0	.43	0
0405	.65	1.13	.14	.05	.39	0
0503	.92	2.89	.52	.06	.14	<.01
0504	.68	1.42	.14	.08	.47	.01
0603	1.66	.90	.29	.08	.46	.02
0604	.94	6.28	.09	.02	.57	.07
0606	1.68	7.12	.13	.16	1.69	0
0608	.22	0	0	.04	.22	0
0703	.48	.90	.02	.01	.13	0
0704	1.04	1.74	.14	.06	.57	0
0803	.62	1.54	.13	.03	.38	0
0804	2.41	6.05	.14	.05	1.73	0
0805	.98	1.50	.58	.02	1.44	.07
1004	.82	.78	.03	.01	.25	0

at all stations and was most abundant at 0608, 0804 and 0805. The stations 0603 and 0604, most affected by the effluent, were at the average and thus, the Card Sound discharge did not appear to reduce this species.

The paper-bubble, Haliotea sp., was represented by 1383 individuals. Biscayne Bay stations accounted for 97% of these individuals. The catch rate was 0.23 individuals per tow. N II, N III and F had high catches and accounted for 64% of the Biscayne Bay specimens. Adding S II and G brings the percent accounted for to 78. There is a trend which indicates intermediate temperature rises (2.0-3.5°C above ambient) encourage this species.

The knave marginella, Hyalina torticula, was represented by 2256 individuals. In Biscayne Bay the catch rate was 0.14 individuals per tow. The species was absent at stations N V, NE V, SE I, SE IV, SE V, S I, G, I and K. These are offshore stations except for S I, SE I, G, I and K, which were affected by the effluent. Station N V was also an inshore station but subject to low (0 ppt) salinity. Catches were highest at N IV and H, both inshore stations with high catches of red algae. In Card Sound the catch rate was 0.52 individuals per tow. The species was absent at offshore station 0208 and most abundant at inshore station 0804. Catches at 0603 were below the average but at 0604 the catches were average (Table 17). The relative abundance of this species was reduced by the effluent in Biscayne Bay and in Card Sound.

An unidentified hydrobiid was represented by 2103 individuals. All of the specimens collected were from Biscayne Bay. Eighty-seven percent were taken at station N V. SE I also produced high catches and contributed another 11% of the hydrobiid catch.

The Antillean limn, Lima pellucida, was represented by 7881 individuals. This represented 1.0% of the total catch and 2.2% of the mollusk catch. The catch rate in Biscayne Bay was 0.32 individuals per tow. Catches were low at N I, N II, N V, NE I, SE I, SE IV, SE V, S I, S IV, A, B, G, I and K. Catches were high at stations NE III and SE II. The species appears to prefer mid-Bay stations where red algae are common. It is not abundant at any inshore stations. In Card Sound the catch rate was 2.24 individuals per tow. Catches were low at 0104, 0204, 0208, 0306, 0403, 0405, 0608 and 1004. All of these stations were low in the production of Laurencia. The highest catches occurred at 0604 and 0804 where Laurencia spp. was abundant.

The Antillean scallop, Lyropecten antillarum, was rare in Biscayne Bay where only 7 specimens were collected. Six of these were taken at S V on the border between Biscayne Bay and Card Sound. In Card Sound 833 specimens were taken and the catch rate was 0.31 individuals per tow. None were taken at 0204, 0403, 0608, 0703, and single individuals were taken at 0208 and 0803. Catches were high at 0404 and 0604. These scallops occur where Laurencia is common.

A variety of nudibranchs contributed 3096 individuals. In Biscayne Bay the catch rate was 0.41 individuals per tow. If we add the 996 Tridachia crispata taken at G and SE I during the spring of 1973, the catch rate of nudibranchs increases to 0.58 individuals per tow. Catches were low at N V, NE V, SE I, SE V, S I, G, (except for the T. crispata taken in

Table 17. Catch per tow of Hyalina torticula, Hydrobiidae, Lima pellucida, Lyropecten antillarum, Nudibranchia, Parviturboides interruptus from Biscayne Bay and Card Sound

Station	<u>Hyalina torticula</u>	Hydrobiidae	<u>Lima pellucida</u>	<u>Lyropecten antillarum</u>	Nudibranchia	<u>Parviturboides interruptus</u>
N	.04	.05	.01	0	.32	0
N I	.02	.01	.07	0	.46	0
N II	.08	.03	.27	0	.43	0
N IV	1.43	.03	.40	0	1.50	0
N V	0	30.38	.02	0	.02	0
N VI	.40	0	.02	0	.75	0
NE I	.48	.01	.15	0	1.97	0
NE II	.11	0	1.11	0	.70	0
NE IV	.03	.05	.23	0	.13	.02
NE V	0	0	.27	0	.08	0
SE I	0	.55	.06	.01	.07	0
SE II	.10	.01	1.77	0	.47	0
SE III	.09	.01	.22	0	.16	0
SE IV	0	0	.08	0	.15	0
SE V	0	0	.02	0	0	0
S I	0	.02	.02	0	.03	.01
S II	.03	.01	.36	0	.70	0
S III	.27	.01	.85	0	.48	0
S IV	.04	.01	.07	0	.10	0
S V	.02	0	.37	.04	.19	.25
A	.12	0	.02	0	.36	0
B	.06	0	.03	0	.26	0
C	.12	0	.40	0	.26	0
D	.02	.05	.38	0	.25	0
E	.11	0	.78	0	1.12	0
F	.01	0	.58	0	.39	0
G	0	0	.05	0	.01	.01
H	1.29	.02	.29	0	2.46	0
I	0	0	.01	0	.03	0
J	.06	0	.19	0	.25	0
K	0	0	.04	0	.01	0

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Table 17. Continued

Station	<u>Hyalina</u> <u>tortricula</u>	Hydrobiidae	<u>Lima</u> <u>pellucida</u>	<u>Lyropecten</u> <u>antillarum</u>	Nudibranchia	<u>Parviturboidea</u> <u>interius</u>
0104	.22	0	.19	.03	.05	0
0204	.18	0	.33	0	.08	0
0208	0	0	.01	.01	.03	0
0304	1.40	0	4.40	.40	.57	.14
0306	.12	0	.14	.06	.21	.06
0403	.20	0	.64	0	.13	0
0404	.39	0	3.42	1.00	.49	.02
0405	.11	0	.36	.46	.41	6.38
0503	.53	0	1.43	.03	.08	.06
0504	.20	0	1.93	.51	.15	.06
0603	.14	0	3.43	.06	.08	0
0604	.59	0	7.33	1.16	.54	.72
0606	1.15	0	2.52	.52	.74	3.14
0608	0	0	.17	0	.20	.27
0703	.06	0	1.04	0	.05	0
0704	1.13	0	2.29	.28	.55	.02
0803	.52	0	1.00	.02	.11	0
0804	6.05	0	10.56	.29	.86	0
0805	.97	0	1.19	.73	.91	.09
1004	.35	0	.25	.03	.13	0

the recovery period), I and K. Catches were high at stations N IV, NE II and E. Thus, nudibranchs appear to be relatively common inshore species which have lowered abundance at the stations elevated 3.5°C or more above ambient temperature. The large influx of T. crispata during the spring of 1973 occurred at G after the effluent was diverted to Card Sound.

In Card Sound the catch rate was lower than Biscayne Bay and was 0.27 individuals per tow. Catches were low at 0104, 0204, 0208, 0503 and 0603. Generally, these are stations with low catches of vegetation. Station 0603 was in the effluent plume and may indicate thermal or current velocity induced stress.

Parviturboides interruptus, was represented by 1437 individuals. Thirty-seven were taken in the 5784 tows made in Biscayne Bay and 1400 were taken in Card Sound. Three stations 0405 (848 specimens), 0606 (286 specimens) and 0604 (181 specimens) accounted for 94% of the Card Sound catch.

The Atlantic pearl oyster, Pinctada radiata, was represented by 2821 individuals. The catch rate in Biscayne Bay was only 0.07 individuals per tow. The highest catch rate was 0.40 per tow at station E (Table 18). In Card Sound the catch rate was 0.90 individuals per tow. Catches were low at 0104, 0204 and 0208. Catches were high at 0304, 0404, 0405, 0604, 0606, 0704, 0804 and 0805. The highest catches were associated with high relative abundance of Laurencia to which the spiny oyster was attached as juveniles.

The smooth Atlantic tegula, Tegula fasciata, was represented by 1593 individuals. In Biscayne Bay the catch rate was 0.13 individuals per tow. Catches were highest at stations D and E. In Card Sound the catch rate was 0.31 individuals per tow. Station 0104 produced the highest yield.

The black lined trifora, Triphora nigrocincta, was represented by 2067 individuals. Eighty-eight percent of these were taken in Biscayne Bay, and stations F and H accounted for 59% of the Biscayne Bay catch. The numbers taken at other stations are too few to discuss.

The chestnut turbon, Turbo staneus, was represented by 5084 individuals. The catch rate in Biscayne Bay was 0.59 individuals per tow. Two stations, SE III and D produced 68% of this total catch. In Card Sound the catch rate was 0.72 individuals per tow. Station 0104 produced 80% of the catch. The three stations which produced high catches of Turbo were mid-Bay stations in very shallow water with Thalassia. Two stations, 0104 and SE III, were associated with the Arsenicker Keys while D was on the shallow Pelican Bank.

The tulip mussel, Velosella (= Modiolus) americanus was represented by 1294 individuals. Only 118 individuals were taken in Biscayne Bay, and most of these were taken at mid-Bay or offshore stations. In Card Sound the catch rate was 0.44 individuals per tow. The species was absent from stations 0204 and 0208. It was most common at mid-Bay stations 0606, 0804 and 0805. The relatively low catches at 0603 may well be due to the inshore location of the station; catches at 0604 are not depressed. Therefore, effects from the discharge cannot be demonstrated.

Table 18. Catch per tow of Pinctada radiata, Tegula fasciata, Triphora nigrocincta, Turbo castaneus, VolSELLa americana from Biscayne Bay and Card Sound

Station	<u>Pinctada radiata</u>	<u>Tegula fasciata</u>	<u>Triphora nigrocincta</u>	<u>Turbo castaneus</u>	<u>VolSELLa americana</u>
N I	.07	.02	.03	.15	0
N II	.11	.02	.07	.06	.01
N III	.08	.01	.68	.02	.01
N IV	.22	0	.77	0	.13
N V	.03	0	.02	.02	0
NE I	.03	0	.12	.11	0
NE II	.14	.31	.39	.24	.03
NE III	.09	.31	.21	.07	.05
NE IV	.12	.35	.02	0	.03
NE V	.05	0	0	0	.02
SE I	.06	.09	.09	.58	.01
SE II	.16	.13	.10	.47	.08
SE III	.13	.21	.09	4.80	0
SE IV	.07	.03	.05	.37	0
SE V	0	.02	0	.07	.05
S I	0	0	0	.01	0
S II	.07	.01	.27	.03	.02
S III	.07	.04	.20	.64	.04
S IV	.04	.12	0	.34	.03
S V	.07	.05	.01	.07	.09
A	.03	0	.28	.02	0
B	.01	.01	.17	.02	.01
C	.06	.31	.06	.01	.05
D	.08	1.38	0	13.29	.07
E	.40	2.43	0	1.96	.14
F	.06	.01	2.23	.03	0
G	.02	.14	.01	.18	.01
H	.22	.04	6.48	.04	0
I	.01	0	0	.01	0
J	.01	.07	.03	.25	0
K	.01	.01	0	.70	0

Table 18. Continued

Station	<u>Pinctada radiata</u>	<u>Tegula fasciata</u>	<u>Triphora nigrocincta</u>	<u>Turbo castaneus</u>	<u>Volvella americana</u>
0104	.12	1.95	0	5.34	.05
0204	.10	.02	.05	.02	0
0208	.03	0	0	0	0
0304	1.53	.50	.20	0	.35
0306	.66	0	.01	.01	.14
0403	.34	.12	.03	.56	.04
0404	1.23	.06	.02	.34	.35
0405	1.49	.02	.13	.30	.59
0503	.50	.43	.05	.21	.15
0504	.85	.07	.06	.04	.53
0603	.68	.50	.08	.60	.15
0604	1.50	.09	.21	.13	.62
0606	3.46	.01	1.07	.01	2.26
0608	.30	0	.03	.01	.14
0703	.22	.03	0	.01	.11
0704	1.28	.01	.03	0	.47
0803	.27	.03	0	0	.08
0804	3.48	.02	0	.03	1.51
0805	1.76	0	.08	0	2.59
1004	.34	0	0	.01	.21

Crustaceans

The second most abundant group of organisms were the crustaceans. Amphipods, Isopods and Pagurapseudes were not identified nor counted. Even without these numerous small animals the 80 species of crustaceans produced 264,078 individuals, nearly 34% of the total animal catch. The catch rate in Biscayne Bay was 32 individuals per tow which is very similar to the 29 individuals per tow taken in Card Sound.

Analysis of the crustacean catch data indicated significant differences in catch among stations during the period July-December 1968 (Pr < .01). Catches at N II, NE IV, NE V, SE I, S IV and S V were below the mean catch of 27.5 mollusks per tow. Station N II, located off the mouth of Florida City Canal, experienced periods of low salinity. Stations SE I and S I were elevated 5°C above ambient. The remaining stations were eastern Bay stations which produced little red algae and low numbers of animals.

Catches were above average at stations N I, N IV, N V, NE I, NE II, SE II and SE III. These were generally inshore stations which also had high catches of the red algae, Laurencia or Digenia. The high catches at station N V (off Moody Canal) were primarily the result of Alpheus heterochaelis, Neopanope packardii, Pagurus bonairensis, Palaemonetes intermedius and Hippolyte pleuracantha, which were abundant in July-September 1968, when N V was covered with dense stands of Digenia simplex. The remaining stations with high catches generally had high catches of Laurencia spp. (Roessler, Tabb, Rehrer and Garcia, 1974).

In the period July 1968-June 1971, the original Biscayne Bay stations produced an average of 40 crustaceans per tow. The 95% confidence limits were 31 to 50 individuals. Station N II, influenced by Florida City Canal, and S I, elevated about 3.5°C above ambient, had low catch rates (Table 19). Stations NE II, SE II, S II and S III produced high catches. Station SE I, sampled from July 1968-June 1973, was significantly less productive than average. This sampling period includes approximately 1.5 years of recovery time after the closing of Grand Canal. The new Biscayne Bay stations sampled between January 1969 and June 1971 also produced 40 crustaceans per tow. The range was between 10 at D and 84 at H. Both of these are considered control stations in regard to temperature. However, D yielded low catches of vegetation, whereas H was consistently a producer of heavy catches of red algae. Station H produced catches of 84 individuals per tow which is above the 95% confidence limits of 0-80 individuals. Station G elevated 4.5°C above ambient during the discharge period produced 2 crustaceans per tow. Due to the high standard deviation in catch rates, this catch was not significantly below average. In Card Sound the average catch rate was 17 crustaceans per tow. The 95% confidence limit was 10-25. Station 0604, located 1/2 mile from the discharge in Card Sound, produced catches significantly above the 95% confidence interval. Station 0603, located in the mouth of the effluent, produced low catches (10.5) but this was not significant considering the variance (Table 19).

Four species of crustacea were abundant enough to be used as indicator organisms. They were the caridean shrimp, Hippolyte pleuracantha and Thor floridanus, the mud crab, Neopanope packardii and the hermit crab, Pagurus

Table 19. Catch per tow of crustacea at selected stations in Biscayne Bay and Card Sound

Station	C/e July 1968- June 1971	Station	C/e Jan. 1969- June 1971	Station	C/e July 1970- June 1973
N I	34.3	A	17.1	0104	11.6
N II	26.7	D	9.7	0503	20.9
N III	43.0	E	24.2	0504	17.9
NE I	37.1	F	63.7	0603	10.5
NE II	58.8	H	83.8	0604	25.4
NE III	44.3				
SE II	51.2				
SE III	39.3				
S I	5.5				
S II	51.9				
S III	52.2				
SE I	13.7 ^{1/}	G	2.1 ^{2/}		
\bar{Sx}	4.5		14.4		2.8
\bar{x}	40.4		39.7		17.3
<u>95% CI</u>		<u>95% CI</u>		<u>95% CI</u>	
30.5 ≤ 40.4 ≤ 50.3		.0 ≤ 39.7 ≤ 80.0		9.5 ≤ 17.3 ≤ 25.1	

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

bonairensis. In addition to these, 5 species were in excess of 1000 individuals and 6 species are of significant commercial interest to include a brief discussion of their distribution.

Several crustaceans of commercial value were collected in the study. These included the blue crab, Callinectes sapidus, stone crab, Menippe mercenaria, spiny lobster, Panulirus argus and shrimps of the genus Panaeus. Most of the shrimp collected were juveniles of less than 10 mm carapace length. Without careful morphometric analysis these animals are impossible to identify (Chensuri, 1968 and Farfante, 1970). Panaeus aztecus (7), P. braziliensis (8), and P. duorarum (1105) were the species collected; all of these are "grooved" shrimp. The 1190 juveniles probably also are mainly P. duorarum, although as shown by Costello and Allen (1966) the bait shrimp catches in Biscayne Bay may contain nearly 50% brown shrimp at some seasons. Due to the nocturnal habits of grooved shrimp, our estimates are minimal. The catch rate of Penaeid shrimp in Biscayne Bay was 0.38 individuals per tow. Catches were highest at SE I, S I and I. All of these stations were elevated 3.5°C or more above ambient. All were in soft mud substrate which seasonally produced Diplanthera growth, with subsequent summer die off and detritus production. In Card Sound the catch rate was 0.04 individuals per tow. The harder substrate and lack of estuarine conditions in Card Sound resulted in few penaeid shrimp (Table 20). Thus, shrimp do not appear to be limited by the temperatures experienced in Biscayne Bay.

Thorhaug, et al. (1971) experimentally established critical upper temperatures for larval and postlarval shrimp. These were: nauplii, 30.5-31.5; first protozoa, 36.0-37.6; third protozoa, 36.8-37.8; third mysis, 36.8-37.8; first postlarvae, 37.9-40.7; juvenile, 36.3-38.5. However, since shrimp do not enter the estuary before they are advanced postlarvae, temperature does not appear to be critical.

The portunid crabs, primarily the blue crab, Callinectes sapidus, provide a small commercial fishery in Biscayne Bay and Card Sound. They are also subject to sport fishing. During this study we collected 263 C. sapidus, 1251 C. ornatus, 44 C. similis, 348 juvenile Callinectes spp., as well as 46 Portunus depressifrons, 3 P. gibbessi, 1 P. ordwayi, 1 P. sebae and 43 P. spinimanus. The catch rate in Biscayne Bay for C. sapidus was 0.04 individuals per tow. The highest catches occurred at SE I, S I and G, the stations most affected by the effluent. Catches were lowest at offshore stations where Portunus appeared more common (Table 21). The combined Callinectes spp. catch rate was 0.30 individuals per tow in Biscayne Bay. The spacial distribution was similar to that for C. sapidus. Catches of Callinectes were low in Card Sound (0.01 C. sapidus per tow and 0.07 combined Callinectes per tow) but the Portunus catches were higher in Card Sound (0.02 Portunus per tow) than in Biscayne Bay (0.01 per tow).

Callinectes sapidus appears to prefer a slightly elevated temperature approximately 3°C above Biscayne Bay summer ambient (ca. 28°C) and survives up to 39°C (Tagatz, 1969 and Hoberg, 1975). The preference for near shore habitat has also been demonstrated for mid-Biscayne Bay by Park (1969). Thus, the effluent does not seem to adversely affect Callinectes and in fact, appears to attract C. similis, since 81% of those collected in Biscayne Bay were taken at the three hottest stations.

Table 20. Catch and catch per tow of Penaeid shrimp in Biscayne Bay and Card Sound

Station	<u>Penaeus</u> <u>aztecus</u>	<u>Penaeus</u> <u>brasiliensis</u>	<u>Penaeus</u> <u>duorarum</u>	<u>Penaeus</u> spp. (juv.)	e	C/e
<u>BISCAYNE BAY</u>						
N I	0	0	1	11	247	0.05
N II	0	0	27	38	247	0.26
N III	2	0	9	21	247	0.13
N IV	0	0	2	6	60	0.13
N V	0	1	4	35	60	0.67
NE I	0	0	4	22	247	0.11
NE II	0	1	5	7	247	0.05
NE III	0	0	4	8	247	0.05
NE IV	0	0	1	2	60	0.05
NE V	0	0	0	2	60	0.03
SE I]	0	0	424	536	422	2.28
SE II	0	0	7	11	247	0.07
SE III	1	1	2	11	268	0.06
SE IV	0	0	0	3	60	0.05
SE V	1	0	1	2	60	0.07
S I	0	0	130	234	247	1.47
S II	0	0	8	15	247	0.09
S III	1	0	11	27	247	0.16
S IV	1	0	9	9	137	0.14
S V	0	0	1	0	137	0.01
A	0	0	6	4	233	0.04
B	0	1	14	2	128	0.13
C	1	0	7	2	128	0.08
D	0	0	9	0	205	0.12
E	0	0	8	3	205	0.14
F	0	0	8	8	254	0.06
G	0	1	44	88	380	0.35
H	0	0	15	28	205	0.56
I	0	1	274	12	77	3.73
J	0	0	4	0	98	0.04
K	0	1	3	0	77	0.05
SUB TOTAL	7	7	1042	1147	5784	0.38
<u>CARD SOUND</u>						
0104	0	0	6	2	252	0.03
0204	0	0	0	0	63	0.00
0208	0	0	9	3	126	0.10
0304	0	1	2	1	98	0.04
0308	0	0	0	0	91	0.00

Table 20. Continued

Station	<u>Penaeus</u> <u>aztecus</u>	<u>Penaeus</u> <u>brasiliensis</u>	<u>Penaeus</u> <u>duorarum</u>	<u>Penaeus</u> <u>spp.</u> <u>(juv.)</u>	e	C/e
0403	0	0	1	1	119	0.02
0404	0	0	1	0	119	0.01
0405	0	0	1	2	133	0.02
0503	0	0	4	3	252	0.03
0504	0	0	3	0	252	0.01
0603	0	0	7	13	252	0.08
0604	0	0	5	9	252	0.06
0606	0	0	1	1	91	0.02
0608	0	0	9	0	77	0.12
0703	0	0	0	2	133	0.02
0704	0	0	3	0	91	0.03
0803	0	0	1	2	63	0.05
0804	0	0	1	0	63	0.02
0805	0	0	4	2	91	0.07
1004	0	0	5	2	77	0.09
SUB TOTAL	0	1	63	43	2695	0.04
TOTAL	7	8	1105	1190	8479	0.27

Table 21. Catch of Portunid crabs and catch per tow of Callinectes sapidus and total Callinectes

Station	Catch <u>C.</u> <u>sapidus</u>	C/e	<u>C.</u> <u>ornatus</u>	<u>C.</u> <u>similis</u>	Juvenile <u>C.</u> spp.	Combined C/e	Catch <u>Portunus</u> spp.
N I	9	0.04	50	0	9	0.30	1
N II	19	0.08	36	0	2	0.23	0
N III	5	0.02	6	0	5	0.07	0
N IV	0	0.00	2	0	0	0.03	0
N V	2	0.03	27	2	8	0.65	0
NE I	4	0.02	33	0	24	0.25	0
NE II	7	0.03	33	0	24	0.26	0
NE III	0	0.00	29	1	6	0.15	1
NE IV	0	0.00	3	0	0	0.05	1
NE V	0	0.00	2	0	0	0.03	1
SE I	76	0.18	403	3	74	1.32	0
SE II	3	0.01	15	0	5	0.09	2
SE III	0	0.00	19	1	6	0.10	2
SE IV	0	0.00	0	0	0	0.00	0
SE V	0	0.00	4	0	0	0.07	5
S I	35	0.14	153	6	61	1.03	2
S II	6	0.02	32	2	12	0.21	0
S III	2	0.01	27	0	2	0.13	3
S IV	0	0.00	11	0	0	0.08	1
S V	0	0.00	0	0	1	0.01	1
A	4	0.02	6	0	0	0.04	0
B	1	0.01	0	0	0	0.01	0
C	0	0.00	18	1	4	0.17	6
D	0	0.00	1	0	2	0.04	1
E	0	0.00	1	0	0	0.01	0
F	6	0.02	30	1	14	0.20	0
G	39	0.10	149	25	32	0.65	0
H	3	0.02	31	0	24	0.75	1
I	5	0.07	10	0	0	0.20	0
J	2	0.02	4	0	0	0.06	0
K	0	0.00	2	0	0	0.03	0
SUB TOTAL (Biscayne Bay)	228	0.04	1137	42	315	0.30	28
0104	1	0.01	4	0	1	0.02	0
0204	0	0.00	5	0	0	0.08	1
0208	0	0.00	8	0	0	0.06	17
0304	0	0.00	5	0	2	0.07	4
0306	0	0.00	1	0	0	0.01	2
0403	0	0.00	6	0	5	0.09	1
0404	0	0.00	7	0	0	0.06	1
0405	0	0.00	2	0	1	0.02	4
0503	0	0.00	3	0	0	0.04	0
0504	0	0.00	3	0	1	0.02	7
0603	0	0.00	10	0	10	0.28	7

Table 21. Continued

Station	Catch <u>C.</u> <u>sapidus</u>	C/e	<u>C.</u> <u>ornatus</u>	<u>C.</u> <u>similis</u>	Juvenile <u>C.</u> spp.	Combined C/e	Catch <u>Portunus</u> spp.
0604	0	0.00	1	0	3	0.03	6
0606	0	0.00	1	0	1	0.02	3
0608	1	0.01	5	0	0	0.08	4
0703	2	0.02	5	0	3	0.08	1
0704	0	0.00	5	0	0	0.06	0
0803	0	0.00	2	0	1	0.05	0
0804	0	0.00	2	0	0	0.03	2
0805	1	0.01	10	0	0	0.12	5
1003	0	0.00	7	1	0	0.10	1
SUB TOTAL (Card Sound)	35	0.01	114	2	33	0.07	66
TOTAL	263	0.03	1251	44	348	0.22	94

One other commercial crab, the stone crab Menippe mercenaria, was collected. In Biscayne Bay 55 juveniles were collected and in Card Sound 77 juveniles were taken. The hole dwelling nature of adults and juveniles of this species limits the efficiency of the trawl. Hagan and Purkerson (1970) reported numerous stone crabs were killed in Grand Canal when temperatures exceeded 37°C. Once settled in burrows, Hoberg (1975) found these animals generally failed to move in thermal gradients even when temperature approaches the lethal level. He further found death occurred when increasing gradients reached approximately 41°C. Thorhaug, et al. (1971) have experimentally determined lethal limits for juvenile and larval stone crabs and these were: eggs, 36.3-38.5°C; first zoea, 34.4-36.0°C; second zoea, 33.1-34.2°C; fifth zoea, 34.7-35.5°C; megalopa, 36.0-37.0; juveniles, 28.9-30.5°C.

The spiny lobster, Panulirus argus, was represented by 345 individuals. In Biscayne Bay 160 individuals were taken for a catch rate of 0.03 per tow. Approximately 60% of the Biscayne Bay catch was taken at S IV, S V and D, which are mid-Bay to eastern Bay stations. Adding the 30 individuals taken at NE V and F, also mid-Bay stations, would account for 78% of the catch. In Card Sound the highest catches occurred at 0603 and 0604 indicating that the discharge into Card Sound did not adversely affect the spiny lobsters. As with the stone crab the cryptic daytime habits of spiny lobster makes the trawl inefficient and the catch per tow does not reflect the abundance of spiny lobsters in the Bay or Sound.

Although, as previously stated, Pagurus bonairensis was the dominant hermit crab yielding over 90,000 individuals; in Card Sound, a second hermit crab, Paguristes tortugae, became important. In addition, a large but uncounted number of Pagurapseudes sp. were present and in competition with hermit crabs for small shells.

P. tortugae were represented by 4205 individuals. In Biscayne Bay the catch rate was 0.17 individuals per tow. None were taken at N V, NE I, S I, B, I and K. Generally, numbers were low at inshore stations except N II which produced 0.31 per tow. Catches were high at NE IV, C and E which were mid-Bay stations. In Card Sound the catch rate was 1.19 per tow. Catches were low at 0104, 0204, 0208, 0213, 0405, 0606, 0608, 0703 and high at 0305, 0704 (Table 22). Vegetation, especially red algae, abundance was correlated with catches.

The caridean shrimp Libinia americana was represented by 1274 individuals. The catch rate in Biscayne Bay was 0.12 and in Card Sound it was 0.18 individuals per tow. The species was not taken at N V, G, I, J and K. Catch rates were lower than 0.015 at NE I, SE I and S I. Thus, the stations most affected by the effluent: G, S I, SE I and I, produced below average catches. At several other inshore stations (NE I, N V) were also low producers. Stations C and K, as well as I, were only sampled for about 1 year and may reflect a natural period of low abundance or may reflect the effect of the effluent. Catches were high at stations SE III and D; shallow-mid-Bay stations with Thalassia substrate. Station SE III also had abundant Laurencia. In Card Sound catches were low at 0104, 0204, 0405, 0405, 0503, 0608, 0703, 0704 and 0803, they were highest at 0805.

Table 22. Catch and catch per tow of Periclimenes and Paguristes from Biscayne Bay and Card Sound

Station	<u>Periclimenes americanus</u>		<u>Pagurus tortugae</u>	
	Catch	Catch/Tow	Catch	Catch/Tow
N I	5	.02	14	.06
N II	12	.05	76	.31
N III	8	.03	1	.01
N IV	10	.17	8	.13
N V	0	0	0	0
NE I	2	.01	0	0
NE II	6	.02	4	.02
NE III	79	.32	106	.43
NE IV	23	.38	102	1.70
NE V	34	.57	16	.28
SE I	3	.01	9	.02
SE II	38	.15	127	.51
SE III	283	1.06	116	.43
SE IV	3	.05	11	.18
SE V	2	.03	1	.02
S I	3	.01	0	0
S II	6	.02	13	.05
S III	17	.07	67	.27
S IV	9	.07	9	.07
S V	19	.14	5	.04
A	5	.02	1	.01
B	2	.02	0	0
C	58	.45	182	1.42
D	111	1.44	15	.20
E	15	.20	74	.96
F	20	0	16	.06
G	0	.08	5	.01
H	3	.04	3	.04
I	0	0	0	0
J	0	0	6	.06
K	0	0	0	0
0104	4	.02	78	.31
0204	2	.03	107	1.70
0208	18	.14	0	0
0304	10	.10	665	6.79
0306	32	.35	5	.06
0403	4	.03	37	.31
0404	8	.07	197	1.66
0405	8	.06	10	.08
0503	22	.09	345	1.37
0504	43	.17	202	.80
0603	106	.42	208	.83
0604	92	.37	674	2.68
0606	54	.59	30	.33
0608	5	.07	0	0

Table 22. Continued

Station	<u>Periclimenes americanus</u>		<u>Pagurus tortugae</u>	
	Catch	Catch/Tow	Catch	Catch/Tow
0703	3	.02	54	.41
0704	8	.09	158	1.74
0803	0	0	60	.95
0804	14	.22	292	4.64
0805	51	.56	54	.59
1004	14	.18	42	.55

Polychaetes

Polychaete worms were not counted nor identified at the beginning of the study. After January 1971, they were identified to family and counted. For this reason, the effort for polychaetes is unequal to that for other animals and some Biscayne Bay stations (N III, N IV, N V, NE III, NE IV, NE V, SE IV, SE V, B and C) were not sampled at all for polychaetes. Others (N I, N II, NE II, SE II, S I, S II, S III, S IV, S V, A, D, E, H, I, J, K, O204, O803, O804 and 1003) were only sampled for 5 months (winter to summer) and still others (SE III, J, O304, O306, O606, O704 and O805) were sampled for only 8 months -- January-August 1972. Despite the lower effort expended to catch and sort polychaetes, they were represented by 55,533 individuals, which is about 7% of the total catch. The total catch in Biscayne Bay was 7972 taken in 1141 tows, or 6.99 individuals per tow. If 5784 tows were taken the catch should have been 40,412, assuming an even distribution at the unsampled stations existed. In Card Sound 47,561 worms were taken in 1925 tows, or 24.71 individuals per tow. If all 2695 tows had been sorted and had the same average catch per tow, the total would have been 66,585. Thus, the total polychaete catch would have been 106,991, the total animals caught would have been 834,135, and thus the polychaetes would represent 13% of the total animal catch, a significant portion of the biomass.

Comparing ten of the original Biscayne Bay stations (Table 23) we found the average catch per tow was 3.6. The 95% confidence interval was from 2 to 5. Catches at N I and SE III were low, and those at S II and S III were high. Station SE I (sampled for 30 months) was high compared to the other stations. Part of the high catch resulted during the period of recovery, after the Grand Canal was diverted and closed. Even so, the average catch, 3.4 individuals per tow, at station S I indicates polychaetes were not adversely affected by the latter period of effluent discharge and had either recovered from the earlier discharge or were never depressed significantly.

Analysis of 8 additional Biscayne Bay stations showed a catch rate of 6 worms per tow with a 95% confidence interval from 3 to 9. Catches at station F were high while those at I and K were low. Catches at station G (sampled for 30 months) were similar to the average of other stations. Again, this indicates recovery at the hottest station.

The average catch rate at the Card Sound stations was 23 worms per tow. The 95% confidence intervals were 6 to 39. Generally, worms were more abundant in Card Sound.

The dominant families in the worm catches were Nereidae (43%), Syllidae (25%), Eunicidae (7%), Serpulidae (5%), Lumbrineridae (5%), Hesionidae (3%) and Dorvilleidae (2%). The other 10% were represented by 28 families.

Porifera

The Porifera were represented by 36,146 sponge colonies of 27 species, plus an unidentified category which contained 629 individual colonies. Of these sponges, 932 were of the genus Spongia and 38 were Hippospongia.

Table 23. Catch per tow and number of tows sorted for Polychaete worms from selected stations in Biscayne Bay and Card Sound

Station	C/e	tows	Station	C/e	tows	Station	C/e	tows
N I	1.6	35	A	7.7	35	0104	8.0	210
N II	4.5	35	D	3.3	35	0503	13.4	210
NE II	2.7	35	E	5.7	35	0504	35.6	210
SE II	2.6	35	F	11.3	84	0603	19.3	210
SE III	.1	56	H	7.7	35	0604	36.8	210
S I	3.4	35	I	2.3	35			
S II	6.3	35	J	6.2	56			
S III	7.3	35	K	1.5	35			
S IV	3.5	35						
S V	3.7	35						
SE I	13.7 ^{1/}	210	G	6.8 ^{2/}	210			
\overline{sx}	.7			1.2			5.8	
\bar{x}	3.6			5.7			22.6	
	<u>95% CI</u>			<u>95% CI</u>			<u>95% CI</u>	
	2.1 ≤ 3.6 ≤ 5.1			2.8 ≤ 5.7 ≤ 8.6			6.4 ≤ 22.6 ≤ 38.8	

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

Thus, 970 commercial sponges were taken. In 1968 and 1969, an active fishery for these sponges was in progress by expatriated Cuban fishermen. Their principle activities occurred on the shallows north of station NE IV, on Pelican Bank, on the Arsenicker Banks near station SE III and SE IV, and in Card Sound. Of these commercial species the grass sponge, Spongia graminea, was most abundant in our samples. Smith (1973) has discussed growth of this species and distribution of sponges in Card Sound. In Biscayne Bay only 97 specimens were taken and 63 colonies or 65% of these were taken at SE III, S IV and S V. In Card Sound the catch rate was 0.26 colonies per tow. Catches were low at 0208, 0104, 0803, 0403, 1003 and 0204. Except for 0208 located near Angelfish Creek entrance, in a shallow Thalassia area, these were near shore stations. Catches were greatest at stations 0604, 0504 and 0805, stations near the mainland, but 1-1.5 miles from shore.

A non-parametric analysis of variance indicated a significant difference in the catch of sponges among the 20 stations sampled from July-December 1969 (Roessler, Tabb, Rehrer and Garcia, 1974). Sponges were absent from inshore stations N II, N III, SE I, S I, S II and S III. Except for the last two stations, these were all located along the shoreline and were subjected to salinity fluctuations beyond the range tolerated by marine sponges. The few sponges taken in the inshore area were the chicken liver sponge, Chondrilla nucula, the "brown bay sponge", Oligoceras hemorrhages the fire sponge, Tedania ignis, or drifting sponges of other species usually found attached in mid-Bay stations. Sponge catches were above average at stations NE IV, S IV and S V. These stations were far enough from the mainland to receive little influence from runoff and were generally subjected to oceanic water exchange through the tidal passes (see Lee and Rooth, 1971).

In the period July 1968-June 1971, the original Biscayne Bay stations produced 0.82 sponge colonies per tow. The 95% confidence range was from 0.48-1.16. Catches were high at N I, SE II, SE III and S II (Table 24). Catches were low at N II, N III, NE III and S I. The low catches reflect inshore locations and salinity variation. If one compares the 1968-1973 catch rate of 0.11 at SE I, influenced by the thermal effluent, it is low compared to the average for other stations. The added Biscayne Bay stations produced 5.20 sponges per tow. A very high variance makes the 95% confidence limit 0-13. Catches at D were significantly higher than other stations. When one compares the catches made at G (0.01 colonies per tow), including the recovery period, it is low but not significant due to the large variability among other stations. In Card Sound the catch rate of sponges was 9.65 colonies per tow. The 95% confidence interval was 4.6-14.7. Catches were higher at the mid-Bay stations 0504 and 0604 and lower at inshore stations 0104, 0503 and 0603. Smith (1973) has discussed the abundance, diversity and growth of sponges in Card Sound, with reference to the effluent.

In this study the most abundant species of sponge was the chicken liver sponge, Chondrilla nucula. It is discussed below as an indicator species. The brown bay sponge, Oligoceras hemorrhages produced 1621 specimens. In Biscayne Bay the catch rate was 0.17 per tow. This common sponge was most abundant at N I, N IV and H. It was absent at inshore stations S I, SE I and I; those most affected by the effluent. It was also

Table 24. Catch per tow of sponges at selected stations in Biscayne Bay and Card Sound

Station	C/e July 1968- June 1971	Station	C/e Jan. 1969- June 1971	Station	C/e July 1970- June 1973
N I	1.33	A	1.38	0104	9.56
N II	.05	D	14.75	0503	6.39
N III	.47	E	.52	0504	13.88
NE I	.79	F	8.45	0603	4.95
NE II	.96	H	1.37	0604	13.47
NE III	.47				
SE II	1.53				
SE III	1.33				
S I	.03				
S II	1.26				
S III	.82				
SE I	.11 ^{1/}	G	.01 ^{2/}		
\bar{s}_x	.16		2.76		1.81
\bar{x}	.82		5.20		9.65
	<u>95% CI</u>		<u>95% CI</u>		<u>95% CI</u>
	.48 ≤ .82 ≤ 1.16		.0 ≤ .20 ≤ 12.93		4.59 ≤ 9.65 ≤ 14.71

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

absent or rare at mid-Bay and offshore stations (Table 25). In Card Sound the catch rate was 0.23. The highest catch rate (1.8 per tow) occurred at 0104 located in shallow water near the Arsenicker Keys.

The blue colored finger sponge, Dysidea etheria, was represented by 1381 colonies. Only 84 were taken from Biscayne and these generally were taken at the mid-Bay and offshore stations. In Card Sound the catch rate was 0.48 colonies per tow. The highest catches 1.1 and 2.0 occurred at 0504 and 0604. Generally, catches were lowest along the shore and highest 1/2-1 mile from the mainland.

The hard white sponge, Geodia gibberosa, was represented by 1288 specimens. Stations S IV and S V produced 85% of the 274 specimens collected in Biscayne Bay. In Card Sound the catch rate was 0.38 colonies per tow. Highest catches occurred at 0504 and 0604. Low catches occurred at 0306, 0703, 0803 and 1004. Except for 0306 these were in the inshore area protected from tidal exchange by Card Bank.

The green sponge, Haliclona viridis, is usually found growing over the above G. gibberosa. Hence, the numbers of distribution of H. viridis and G. gibberosa is almost identical. A few additional free colonies or fragments increased the total numbers of H. viridis to 1308. Of these, 285 were taken in Biscayne Bay. Stations S IV and S V in the eastern Bay produced 85% of the catch. In Card Sound the catch rate was 0.38 colonies per tow. Distribution was similar to Geodia.

The purple finger sponge, Haliclona molitba (may include other purple Haliclona), was represented by 1230 specimens. Catch rates were low in Biscayne Bay (0.01 colonies per tow) with most specimens coming from the eastern Bay. In Card Sound the catch rate was higher (0.43 colonies per tow). The affected stations 0603, 0604 and controls 0503 and 0504 were all high producers.

The finger sponge, Ircinia fasciculata, was represented by 2329 colonies. The catch rate in Biscayne Bay was 0.08. Catches from NE IV, SE III, S IV, S V and D accounted for 80% of the 465 specimens. These were all mid to eastern Bay stations. The catch rate in Card Sound was 0.69 colonies per tow. Catches were high at 0304, 0504, 0604, 0606 and 0805 again the mid-Bay stations. Catches were low at 0104, 0208 and 0803, stations close to the mainland or islands.

The green ball sponge, Tethya diploderma, produced 1559 colonies. In Biscayne Bay 254 specimens were taken. Station D produced 67% of these. In Card Sound the catch rate was 0.48 colonies per tow. Catches were low at 0208, 0306, 0405, 0608 and 1004. This sponge appeared more commonly near the mainland than at offshore stations. All stations near the Card Sound effluent had average to high catch rates.

Coelenterates

Coelenterates were not abundant and jellyfish, alcyonarians, corals and anemones produced only 1593 specimens. The firmly attached corals and alcyonarians are not adequately sampled by trawls. Mr. L. Purkerson

Table 25. Catch per tow of abundant sponges

Station	<u>Oligoceras</u> <u>hemorrhages</u>	<u>Dysidea</u> <u>etheria</u>	<u>Geodia</u> <u>gibberosa</u>	<u>Haliclona</u> <u>molitba</u> (complex)	<u>Haliclona</u> <u>viridis</u>	<u>Ircinia</u> <u>fasciculata</u>	<u>Tethya</u> <u>diploderma</u>
N I	1.14	0	0	0	0	0	0
N II	.03	0	0	0	0	0	.01
B III	.06	0	0	0	0	0	.01
N IV	1.05	0	0	0	0	0	0
N V	0	0	0	0	0	0	0
NE I	.54	0	0	0	0	.01	0
NE II	.53	0	0	0	0	0	0
NE III	.06	.02	.01	.02	0	.02	.01
NE IV	.05	.08	.12	.07	.12	.48	0
NE V	.02	.02	.02	.17	.02	.17	0
SE I	0	.01	0	0	.01	0	.01
SE II	.26	0	.01	.02	.01	.02	.01
SE III	.04	.02	.03	0	.04	.20	.01
SE IV	.05	.02	.13	.05	.12	.22	.02
SE V	0	0	.02	.03	.02	.17	0
S I	0	0	0	0	0	0	0
S II	.11	0	0	0	0	.01	.04
S III	.22	0	.01	0	.01	.03	.02
S IV	.04	.09	1.10	.18	1.17	.99	.05
S V	.02	.30	.61	.13	.66	.94	.07
A	.10	0	0	0	0	0	.01
B	.04	0	0	.01	0	0	0
C	.12	.02	.04	.02	.06	.17	0
D	.04	.04	0	.01	.01	.33	2.21
E	.26	.07	.01	.01	0	.16	.05
F	.02	0	0	0	0	0	.09
G	.02	0	0	0	0	0	0
H	1.36	0	0	0	.01	0	0
I	0	0	0	0	0	0	0
J	.11	0	.02	0	0	0	.17

Table 25. Continued

Station	<u>Oligoceras</u> <u>hemorrhages</u>	<u>Dysidea</u> <u>etheria</u>	<u>Geodia</u> <u>gibberosa</u>	<u>Haliclona</u> <u>molitba</u> (complex)	<u>Haliclona</u> <u>viridis</u>	<u>Ircinia</u> <u>fasciculata</u>	<u>Tethya</u> <u>diploderma</u>
K	0	0	0	0	0	0	.03
0104	1.79	.07	.38	.41	.44	.14	.45
0204	0	.62	.44	.06	.44	.44	.22
0208	.02	.13	.24	0	.18	.18	.02
0304	0	.47	.52	.36	.54	1.09	.35
0306	.02	.18	.03	.19	.09	.60	.07
0403	.05	.17	.20	.13	.12	.35	.35
0404	.05	.35	.39	.75	.46	.76	.94
0405	0	.14	.09	.38	.17	.69	.09
0503	.31	.26	.38	.44	.37	.46	.82
0504	.04	1.10	.72	.79	.71	1.45	.90
0603	.17	.40	.16	.70	.10	.21	.61
0604	.03	2.00	1.08	.85	1.00	1.64	.47
0606	.02	.30	.11	.73	.20	1.13	.26
0608	0	.17	.09	.03	.22	.51	.04
0703	.06	.07	.85	.01	.07	.23	.12
0704	.03	.45	.52	.21	.51	.60	.97
0803	0	.06	.08	.02	.11	.14	.13
0804	.02	.43	.48	.35	.49	.86	.84
0805	.02	.14	.29	.29	.36	1.18	.45
1004	0	.04	.01	.01	.03	.60	.08

is studying these animals and additional studies have been reported by Clark, Joy and Rosenthal (1970) and Chesher (1971) for specimens located near a desalinization plant in Key West, which also discharges heated effluents. The work of Mayer (1914) should also be consulted.

In general, the corals and cyanarians were more abundant in the eastern half of the Bay and scarce on the western side. This reflects the salinity tolerances of these animals.

In Biscayne Bay the catch rate was 0.09 colonies per tow for the combined 17 species and in Card Sound it was 0.39 individuals per tow. The original Biscayne Bay stations produced an average of 0.05 per tow, the 5 additional stations 0.08 individuals per tow. The 5 Card Sound stations most frequently trawled produced 0.60 individuals per tow with 0603 being the largest producer (Table 26). No species was of commercial value and none was of sufficient abundance to warrant individual analysis.

Echinoderms

Echinoderms, composed of 26 species of sea cucumbers, starfish and brittlestars produced 42,573 individuals. This represented 5.4% of the animal catch. During the period July-December 1968 echinoderms were represented by 8079 individuals, comprised of 23 species. They represented 2.4% of the animal catch. During the period July-December 1968, the mean catch for the 20 stations was 3.56 echinoderms per tow. Echinoderms were absent from stations N I, N II, N V and SE I. Catches were low at N IV, NE II, NE V, SE I, SE IV and S I ($P < .05$), (Roessler, Tabb, Rehrer and Garcia 1974). These are generally inshore stations which are subjected to wide ranges of salinity. The low catches at NE V may reflect the low amount of vegetation and sponges which appear to be habitats favored by echinoderms. The Biscayne Bay stations occupied from July 1968-June 1971 produced an average of 2.1 individuals per tow. The 95% confidence limits were 0.3 to 3.8. Catches were low at inshore stations N I, N II, N III, NE I and S I. Catches were high at SE II and S III. Comparing the catch at SE I for the period July 1968-June 1973 to the above we find the catch was within the confidence range. This reflects high catches after the effluent was diverted.

The added Biscayne Bay stations had an average catch rate of 1.47 with a 95% confidence range from 0-3.75. Catches at D were above the range. Comparing G to the above stations it produced close to the average catch rate. Salinity rather than temperature appeared to control echinoderm distribution.

The Card Sound stations produced an average of 11.93. The variation was large and the 95% confidence interval was 0-24 (Table 27). Catches at station 0604 were extremely high while those at the control station near Arsenicker Key were low.

The very abundant sea cucumber, Leptosynapta parvipatina, will be discussed as an indicator species. It was represented by 13,445 individuals, which comprised 1.7% of the total catch.

Table 26. Catch per tow of coelenterates from selected stations in Biscayne Bay and Card Sound

Station	C/e July 1968- June 1971	Station	C/e Jan. 1969- June 1971	Station	C/e July 1970- June 1973
N I	.10	A	.01	0104	.23
N II	.04	D	.20	0503	.30
N III	.01	E	.12	0504	.50
NE I	.01	F	.02	0603	1.29
NE II	.04	H	.06	0604	.69
NE III	.07				
SE II	.11				
SE III	.07				
S I	.01				
S II	.01				
S III	.05				
SF I	.07 ^{1/}	G	.02 ^{2/}		
\bar{Sx}	.01		.04		.19
\bar{x}	.05		.08		.60
<u>95% CI</u>		<u>95% CI</u>		<u>95% CI</u>	
.03 ≤ .05 ≤ .07		.00 ≤ .08 ≤ .18		.07 ≤ .60 ≤ 1.13	

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

Table 27. Catch per tow of echinoderms from selected stations in Biscayne Bay and Card Sound

Station	C/e July 1968- June 1971	Station	C/e Jan. 1969- June 1971	Station	C/e July 1970- June 1973
N I	.07	A	.04	0104	1.52
N II	.08	D	.66	0503	6.35
N III	.18	E	4.59	0504	16.62
NE I	.27	F	.54	0603	8.40
NE II	.85	H	1.52	0604	26.75
NE III	3.02				
SE I	6.90				
SE IV	2.84				
S I	.03				
S II	.54				
S III	5.85 ^{1/}				
SE I	1.41 ^{2/}	G	.87 ^{2/}		
\bar{Sx}	.80		.82		4.43
\bar{x}	2.06		1.47		11.93
	<u>95% CI</u>		<u>95% CI</u>		<u>95% CI</u>
	.30 ≤ 2.06 ≤ 3.82		.0 ≤ 1.47 ≤ 3.75		.0 ≤ 11.93 ≤ 24.33

^{1/} July 1968 - June 1973

^{2/} January 1968 - June 1973

The starfish, Echinaster sentus, produced 1433 specimens. In Biscayne Bay the catch rate was 0.24 individuals per tow. None were taken at N V, NE , S I, A, I and K (Table 28). Catches were also low at N I, N II, N III, NE V, SE V, S II, S IV, S V, B, F and G. Catches were high at N IV, NE III, C, E and H. Most of the catch was taken where the red algae, Laurencia spp. or Pigeria simplex was abundant. Only 45 specimens were collected in Card Sound and 69% of these came from station 0104.

Although much research on the dynamics of the urchin, Lytechinus variegatus has been done by H. B. Moore and his students and it was abundant in the samples, we can say little about the distribution of the species except that it appears to be limited by salinity and the presence of tides which bring oceanic water. Out of the 732 animals taken in Biscayne Bay, 98% occurred at eastern Bay stations NE V, SE V, S IV and S V. The highest catch rate, 7.1 individuals per tow, occurred on a Thalassia bed near Ceasar's Creek Inlet. In Card Sound the catch rate was 0.41 individuals per tow. The high catch rate at 0208 (Broad Creek Inlet) was expected, but the high catches at 0604 and 0504 (about 1/2 mile east of the shoreline) near the Model Land Company Canal discharge were unexpected. Perhaps the current from the power plant effluent and relative stable salinity during the study allowed these animals to move into the area. Such invasions and disappearances do not appear unnatural. Before the initiation of the Card Sound sampling, the area of 0104 had numerous urchins. During one rainy season they disappeared and only 1 was taken at 0104 in 252 net hauls during the study.

The brittlestar, Ophiactis savignyi, was represented by 7385 specimens. In Biscayne Bay the catch rate was 0.25 individuals per tow. Catches were high at stations N IV, SE II, S III, S V and E. Generally, these stations produced high vegetation catches or at S V high catches of sponges. The species appeared to avoid inshore stations along the mainland. In Card Sound the catch rate was 2.21 individuals per tow. Catches were low at 0104, 0204, 0208, 0608, 0803 and 1004. Catches were highest at 0805, 0804 and 0304. Thus, the species appears to be a mid-Bay species which avoids the edges of the Sound.

Another brittlestar, Ophioderma brevispinum, was represented by 1622 individuals. The catch rate in Biscayne Bay was 0.05 individuals per tow. Seventy percent of the 271 individuals came from stations SE II, C and E with abundant red algae and where sponges were common. In Card Sound the catch rate was 0.50 individuals per tow. Catches were high at 0304, 0404, 0604 and 0804. Catches were low at 0104, 0204, 0208, 0306, 0403, 0608, 0703 and 1004. The species tends to avoid shallow areas and is most common in sponge or red algae.

Ophiopsila riisei was represented by 10941 individuals, which is 1.4% of the animals caught. Had it been more abundant in Biscayne Bay where only 537 individuals were taken, it would have been chosen as an indicator organism. However, the low catch rate of 0.09 individuals per tow, in the area most influenced by the effluent, made it an unlikely indicator of thermal affects. The species was common at NE IV, S IV, S V and C and abundant at station E. The former stations are eastern Bay stations and C and E are mid-Bay stations. The catches at all inshore stations were very low or zero. In Card Sound the catch rate was 3.86 individuals per tow. Brittlestar catches were high at stations 0304,

Table 28. Catch per tow of Echinaster, Lytechinus, Ophiactis, Ophioderma, Ophiopsila, Ophiostigma and Ophiothrix

Station	<u>Echinaster</u> <u>sentus</u>	<u>Lytechinus</u> <u>variegatus</u>	<u>Ophiactis</u> <u>savignyi</u>	<u>Ophioderma</u> <u>brevispinum</u>	<u>Ophiopsila</u> <u>riisei</u>	<u>Ophiostigma</u> <u>isacanthum</u>	<u>Ophiothrix</u> <u>orstedii</u>
N I	.01	0	0	0	0	0	0
N II	.03	0	<.01	0	<.01	0	0
N III	.02	0	0	0	0	0	0
N IV	2.52	0	2.43	.03	0	0	0
N V	0	0	0	0	0	0	0
NE I	0	0	<.01	0	0	0	0
NE II	.13	0	.01	0	<.01	0	0
NE III	1.28	0	.12	.07	.07	.02	.36
NE IV	.13	.10	.60	.07	.78	.23	1.22
NE V	.02	.60	.25	0	.27	.02	.18
SE I	.08	0	.01	<.01	.01	.01	0
SE II	.53	0	1.21	.22	.07	.03	.04
SE III	.40	.01	.26	.02	.03	.02	.21
SE IV	.07	.05	.10	.08	.10	0	.12
SE V	.02	7.08	.03	0	0	0	0
S I	0	0	0	0	0	0	0
S II	.02	0	.22	0	0	.01	0
S III	.46	<.01	1.37	.07	.01	.02	0
S IV	.01	1.38	.27	.03	.77	.09	.45
S V	.04	.47	1.12	.07	.58	.20	.53
A	0	0	.01	0	.01	0	.01
B	.02	0	.01	0	.01	0	0
C	.91	.01	.26	.65	.35	.06	.89
D	.33	.07	.14	.08	0	.03	.12
E	1.08	0	1.97	.70	2.31	.12	.02
F	<.01	0	.01	.01	.02	0	0
G	.03	0	<.01	.02	.01	.01	0
H	^ .71	0	.12	0	.01	0	0
I	0	0	0	0	0	0	0
J	.13	0	.19	.01	0	0	0

Table 28. Continued

Station	<u>Echinaster</u> <u>sentus</u>	<u>Lytechinus</u> <u>variegatus</u>	<u>Ophiactis</u> <u>savignyi</u>	<u>Ophioderma</u> <u>brevispinum</u>	<u>Ophiopsila</u> <u>riisei</u>	<u>Ophiostigma</u> <u>isacanthum</u>	<u>Ophiothrix</u> <u>orstedii</u>
K	0	0	0	0	0	0	0
0104	.12	<.01	.35	.03	.18	.11	.02
0204	0	0	.65	.08	.48	.05	.05
0208	0	.98	.07	0	0	0	.02
0304	0	.05	4.92	1.15	6.74	1.39	.18
0306	0	0	1.04	0	.28	.04	.15
0403	0	.02	1.56	.03	.13	.13	.05
0404	.01	.05	3.14	1.13	10.24	1.98	.20
0405	0	.03	1.61	.17	1.72	.11	.50
0503	0	.29	1.24	.22	1.27	.89	.04
0504	0	.89	2.58	.64	5.31	2.71	.50
0603	0	.31	1.46	.55	2.67	2.39	.02
0604	<.01	1.88	3.30	1.62	8.16	5.58	.53
0606	0	.39	2.88	.54	1.68	.79	.20
0608	0	.10	.30	.07	.39	.13	.47
0703	0	.03	1.52	.08	1.26	.39	.09
0704	0	.03	4.57	.74	17.04	2.29	.21
0803	0	.02	.84	.27	1.13	.38	.14
0804	0	.08	5.76	1.10	15.08	1.70	.30
0805	.03	.47	10.45	.92	9.56	1.75	.54
1004	.12	.31	.40	0	.06	.01	.16

0404, 0504, 0604, 0704, 0804 and 0805 and low at 0104, 0204, 0208, 0306, 0403, 0608 and 1004. Those stations close to shore or in relatively pure Thalassia produced few specimens while those in mid-Bay areas, where sponges and red algae were abundant, produced large catches.

Ophiostigma isacanthum was represented by 4085 individuals. It too, was not common in Biscayne Bay where the catch rate was 0.02 individuals per tow. Again, stations NE IV, S IV, S V, C and E produced most (88%) of these brittlestars. In Card Sound the catch rate was 1.48 individuals per tow. Catches were greatest at 0604 which had large amounts of Laurencia spp. plus numerous sponges. Stations 0504 and 0603 also produced high catches. Low catches occurred at 0104, 0204, 0208, 0306, 0403, 0405, 0608 and 1004.

Ophiothrix orstedii was represented by 1090 individuals. The catch was about evenly distributed between Biscayne Bay and Card Sound, but the catch rate was lower in Biscayne Bay (0.09) than in Card Sound (0.22 individuals per tow). In Biscayne Bay, relative abundance was high at NE III, NE IV, SE III, S IV, S V and C. All of these stations yielded larger sponges. In Card Sound the mid-Bay stations with sponges yielded high catches, while the shoreline and Thalassia stations yielded less brittlestars.

All of the echinoderms seem to be salinity dominated and all of the brittlestars appear to be associated with larger sponges, such as Ircinia, Geodia, Spongia and Speciospongia. The smaller dominant sponges Chondrilla, Oligoceras and Tedania are less stenohaline and enter inshore areas. They do not grow as massively and provide little shelter for brittlestars. Either lack of shelter or less stable salinity excludes the majority of brittlestars.

Other

Other groups of animals -- Platyhelminthes, Sipunculids, Hirudinea, Nemertinea, Bryozoa and Ascidiacea were not specifically sorted and were represented by 4828 individuals or 0.62% of the animals collected. They will not be discussed here.

The dominant species in order of decreasing abundance were the caridean shrimp, Thor floridanus; the checkered pheasant shell, Tricolia affinis; the hermit crab, Pagurus bonairensis; the lunate dove shell, Mitrella lunata; the Chesnel's rissoina, Rissoina chesneli; the fly-speckled cerith, Cerithium muscarum; the polychaete family Neriidae; the chicken liver sponge, Chondrilla nucula; the Atlantic modulus, Modulus modulus; the worm shell gastropod, Vermicularia spirata; the miter, Mitra gemmata; the polychaete family, Syllidae; the small sea cucumber, Leptosynapta parvipatina; the striate bubble shell, Bulla umbilicata; the caridean shrimp, Hippolyte pleurocantha; the rusty dove shell, Columbella rusticoides (and unidentified juveniles); the brittlestar, Ophicpsila rissei; the mud crab, Neopanope packardii; the Antillean lima, Lima pellucida, the ivory cerith, Cerithium eberneum, and the brittlestar, Ophiactis savignyi. These 21 taxa (4%) produced 632,255 individuals or 81% of the total catch. The remaining 469 taxa produced 150,422 or 19%

of the catch. Other dominant species were the mussel, Brachidontes exustus, and the variable bittium, Bittium varium, amphipods and isopods. However, these animals were not sorted and counted.

From the above list, 7 mollusc species were chosen as indicator species for analysis of spacial and temporal distribution and the importance of environmental variables on the catch rate. These were Bulla umbilicata (12,890 individuals - 1.8% of total excluding polychaetes), Cerithium eberneum (7,474 - 1.0%), Cerithium muscarum (25,829 - 3.6%), Mitrella lunata (50,253 - 6.9%), Modulus modulus (18,254 - 2.5%), Tricolia affinis (93,709 - 12.9%) and Vermicularia spirata (16,252 - 2.2%). In addition, Mitra gemmata (14,320 - 2.0%) and Rissoina chesneli (33,461 - 4.6%) were examined for spacial and temporal distribution. Two additional species, the paper mussel, Amygdalum papyria (3,785 - 0.5%) and Atlantic marginella, Prunum apicinum (5,639 - 0.8%) were chosen as indicators because of their importance in Biscayne Bay, especially early in the study. Columbella rusticooides and unidentified juveniles, together with Lima pellucida were dominant in Card Sound and were not selected as indicators. A total of 9 indicator molluscs were analyzed.

The crustaceans, Hippolyte pleuracantha (11,335 - 1.6%), Neopanope packardii (9,110 - 1.3%), Pagurus bonairensis (90,648 - 12.5%) and Thor floridanus (140,567 - 19.3%) were selected as indicators.

None of the polychaetes were used because of systematic problems and the unequal effort used to catch, sort and count polychaetes.

The chicken liver sponge, Chondrilla nucula (19,932 - 1.4%) and the sea cucumber, Leptosynapta parvipatina (13,445 - 1.8%) brought the indicator species to 15. The brittlestars, Ophiopsila riisei and Ophiactis savignyi were not considered because of their scarcity in Biscayne Bay and dominance in Card Sound.

Table 29 shows the sum of the transformed data ($\Sigma \log(\text{catch} + 1)$) for each Biscayne Bay station for the periods July 1968 - December 1968; January 1969 - June 1970 and July 1970 - May 1971. The 99% confidence limits of the station totals is given. In the first two periods, zero catches at a given station were considered significantly low and the station was not used to compute geometric means nor was the effort used in the analysis of variance or confidence limits. In the period July 1970 - May 1971, all effort and catches were included in the analysis and confidence limits. Table 30 gives similar data for Card Sound for the periods July 1970 - May 1971, July 1970 - December 1971 and July 1970 - June 1973. Here all effort was used in the analysis and in calculating the 99% confidence intervals.

In the first 6 months of the study, station S I located in the thermal plume and 5.25° above the ambient temperature recorded at station N III produced low catches of Cerithium muscarum (fly-speckled cerithium), Vermicularia spirata (worm shell gastropod), Hippolyte pleuracantha (caridean shrimp), Thor floridanus (caridean shrimp) and Pagurus bonairensis (hermit crab). Station SE I also elevated 5.25° by the thermal plume produced low catches of Bulla striata (strait bubble shell), Modulus modulus (Atlantic modulus), Vermicularia spirata, Hippolyte pleuracantha,

Table 29A. Summary of catches, $\Sigma \text{Log}(\text{Catch} + 1)$, in Biscayne Bay (July 1968 - December 1968)^{1/}

Species	N I	N II	N III	N IV	N V	NE I	NE II	NE III	NE IV	NE V	99% C.I.	
											Low	Upper
<u>Amygdalum papyria</u>	0.60	1.20	0.60	0.90	43.20	0.00	0.30	0.00	0.00	0.00	0.00	10.50
<u>Bulla umbilicata</u>	2.90	11.53	7.82	11.24	4.38	9.74	8.95	3.42	0.90	1.50	0.00	11.76
<u>Cerithium muscarum</u>	8.84	9.31	12.27	8.68	12.44	10.84	8.53	8.25	1.50	1.00	1.68	15.12
<u>Mitrella lunata</u>	8.17	7.62	4.14	6.86	13.32	10.83	5.75	1.90	0.30	0.00	0.00	9.24
<u>Modulus modiolus</u>	10.60	4.03	9.46	26.26	0.60	9.59	7.43	2.98	1.08	0.60	0.84	11.76
<u>Prunum apicinum</u>	5.52	6.39	3.15	2.58	3.76	2.28	1.68	1.30	0.00	0.00	0.00	8.40
<u>Tricolia affinis</u>	1.08	0.60	0.00	0.00	1.08	0.30	2.98	8.23	5.56	1.00	0.00	8.82
<u>Vermicularia spirata</u>	0.60	0.78	0.30	7.68	0.00	0.00	2.88	4.96	10.09	2.52	3.78	13.86
<u>Hippolyte pleuracantha</u>	15.14	1.43	7.39	5.40	6.94	13.84	11.67	3.16	1.08	0.00	0.00	10.50
<u>Thor floridanus</u>	26.14	7.70	16.25	24.96	1.50	26.47	34.58	27.83	12.18	4.68	8.40	29.40
<u>Neopanope packardii</u>	18.56	1.85	18.93	30.97	52.96	20.78	28.09	18.47	8.26	1.98	7.14	22.26
<u>Pagurus bonairensis</u>	49.31	17.44	44.53	55.38	13.53	44.43	48.27	30.57	17.69	1.64	15.12	36.96
<u>Chondrilla nucula</u>	0.00	0.00	0.00	0.30	0.30	0.60	4.90	2.04	0.00	0.00	0.00	4.20
<u>Leptosynapta parvipatina</u>	0.00	0.00	0.90	16.83	0.00	5.33	9.46	7.45	7.95	2.58	1.26	16.38
Δ^t/D	-0.17	-0.68	25.08	-0.85	-0.02	-0.76	-0.35	-0.11	-0.41	-0.63		
Veg. lb/tow	7.3	6.7	5.7	3.8	17.3	7.7	9.5	5.2	1.3	0.0		

^{1/} Confidence intervals do not consider stations with 0 catch

Table 29A. Continued^{1/}

Species	SE I	SE II	SE III	SE IV	SE V	S I	S II	S III	S IV	S V	99% C.I.	
											Low	Upper
<u>Amygdalum papyria</u>	0.60	0.30	0.00	0.00	0.00	0.60	0.78	0.30	0.00	0.00	0.00	10.50
<u>Bulla umbilicata</u>	0.30	10.99	6.97	0.60	0.00	3.81	18.90	3.30	1.80	0.00	0.00	11.76
<u>Carithium muscarum</u>	9.00	15.88	14.23	4.94	0.30	1.68	29.10	7.03	6.52	0.30	1.68	15.12
<u>Mitrella lunata</u>	5.72	0.90	0.90	0.30	0.00	4.79	2.58	0.90	0.30	0.00	0.00	9.24
<u>Modulus modulus</u>	1.68	6.44	15.57	3.34	0.30	2.64	14.00	2.28	5.10	0.60	0.84	11.76
<u>Prunum spicinum</u>	0.60	4.38	12.94	0.00	0.00	0.30	7.30	0.60	0.00	0.00	0.00	8.40
<u>Tricolia affinis</u>	0.78	5.74	15.69	6.32	0.90	0.78	0.30	1.80	1.68	0.90	0.00	8.82
<u>Vermicularia spirata</u>	0.90	29.01	8.62	2.28	1.30	2.28	31.81	13.53	21.70	2.38	3.78	13.86
<u>Hippolyte pleuracantha</u>	0.60	3.70	4.54	0.30	0.00	0.60	0.78	0.00	0.30	0.30	0.00	10.50
<u>Thor floridanus</u>	5.89	41.58	49.93	17.36	2.98	5.58	26.52	25.75	14.93	4.26	8.40	29.40
<u>Neopanope packardii</u>	9.98	15.57	19.85	3.78	0.78	9.19	16.18	4.68	3.60	0.00	7.14	22.26
<u>Pagurus bonairensis</u>	13.98	41.36	36.23	8.60	1.15	8.73	48.12	32.09	4.56	0.90	15.12	36.96
<u>Chondrilla nucula</u>	1.38	1.20	6.53	0.30	0.60	0.90	2.10	0.60	0.78	1.38	0.00	4.20
<u>Leptosynapta parvipatina</u>	0.00	29.10	13.25	6.84	0.48	0.60	16.13	21.65	1.68	3.06	1.26	16.38
Δ^t/D	+5.25	+2.20	+1.17	+1.31	+0.37	+5.26	+2.25	+0.93	+1.05	+0.41		
Veg. lb/tow	1.8	4.1	6.3	1.3	0.2	1.2	3.8	1.4	0.7	0.0		

^{1/} Confidence intervals do not consider stations with 0 catch

Table 29B. Summary of catches, E Log (Catch +1), in Biscayne Bay (January 1969 - June 1970)^{1/}

Species	N I	N II	N III	NE I	NE II	NE III	SE I	SE II	SE III	S I	99% C.I.	
											Low	Upper
<u>Amygdalum papyria</u>	0.00	2.28	10.84	0.00	0.00	0.00	0.00	0.30	0.00	0.48	--	--
<u>Bulla umbilicata</u>	37.09	40.51	54.00	89.73	54.19	12.96	17.98	23.31	16.82	5.65	17.64	47.88
<u>Cerithium eberneum</u>	3.02	8.42	4.55	0.60	2.76	13.08	12.16	25.14	5.46	1.08	2.52	22.68
<u>Cerithium muscarum</u>	6.98	102.4	151.97	44.02	59.71	13.94	79.53	25.08	33.64	19.61	37.80	70.56
<u>Mitrella lunata</u>	78.02	72.89	182.42	103.32	97.06	33.77	70.77	20.00	10.67	32.30	40.32	78.12
<u>Modulus modulus</u>	77.97	50.49	38.34	82.82	63.82	29.43	3.64	46.35	27.67	2.76	31.50	59.22
<u>Prunum apicinum</u>	29.46	16.37	84.52	30.07	24.61	14.85	11.59	15.91	7.42	0.78	13.86	39.06
<u>Tricolia affinis</u>	20.11	1.20	4.94	12.63	32.61	50.28	1.68	24.04	46.77	0.60	7.56	35.28
<u>Vermicularia spirata</u>	0.90	0.48	5.08	1.50	4.56	54.07	0.00	83.62	15.57	1.50	12.60	37.80
<u>Hippolyte pleuracantha</u>	87.46	61.85	99.93	92.94	94.29	35.37	11.42	22.44	16.61	2.76	27.77	55.44
<u>Thor floridanus</u>	30.07	4.56	70.92	59.57	112.70	110.35	13.78	121.58	85.82	4.68	46.62	86.94
<u>Neopanope packardii</u>	12.00	8.10	39.08	31.39	29.98	43.62	12.64	29.43	29.71	5.06	11.34	31.50
<u>Pagurus bonairensis</u>	152.03	95.18	195.33	167.36	176.62	150.45	65.41	134.86	103.10	46.26	93.24	133.56
<u>Chondrilla nucula</u>	1.38	0.60	3.33	1.68	1.90	9.45	2.88	27.95	20.87	0.00	7.56	27.72
<u>Leptosynapta parvipatina</u>	0.0	0.30	0.30	0.00	0.00	26.07	0.00	54.44	34.70	0.00	11.34	34.02
Δ^E/D	+0.35	+0.29	+0.24	+0.57	+0.60	+0.27	+3.59	+0.74	+0.26	+3.65		
Veg. lb/tow	11.5	9.4	20.7	10.7	13.3	9.9	3.2	7.9	5.0	1.3		

^{1/} Confidence intervals do not consider stations with 0 catch

Table 29B. Continued^{1/}

Species	S II	S III	A	B	C	D	E	F	G	H	99% C.I.	
											Lower	Upper
<u>Amygdalum papyria</u>	0.90	0.00	0.00	0.30	0.00	0.00	0.00	0.30	0.00	0.60	--	--
<u>Bulla umbilicata</u>	61.63	24.67	42.57	17.96	4.26	0.78	10.91	40.21	0.90	61.29	17.64	47.88
<u>Cerithium eberneum</u>	87.26	12.43	3.45	1.08	5.51	0.00	5.94	15.40	0.00	14.07	2.52	22.68
<u>Cerithium muscarum</u>	113.44	18.74	64.02	19.61	2.98	5.73	5.60	141.74	1.20	113.00	37.80	70.56
<u>Mitrella lunata</u>	102.82	22.62	61.31	50.23	5.86	4.44	3.88	134.17	3.24	94.86	40.32	78.12
<u>Modulus modiolus</u>	83.79	18.18	65.36	50.53	14.16	3.66	14.78	96.79	0.00	49.52	31.50	59.22
<u>Prunum apicinum</u>	29.39	6.24	25.75	16.21	2.94	0.00	1.08	55.99	0.00	40.67	13.86	39.06
<u>Tricolia affinis</u>	12.07	32.88	15.06	12.76	30.71	46.17	33.32	27.23	0.90	10.53	7.56	35.28
<u>Vermicularia spirata</u>	58.05	72.25	1.20	11.99	33.02	7.09	48.80	31.49	0.00	10.45	12.60	37.80
<u>Hippolyte pleuracantha</u>	26.43	29.71	35.80	33.14	17.20	12.54	13.61	47.16	0.00	58.74	27.72	55.44
<u>Thor floridanus</u>	115.47	113.67	48.41	36.29	70.46	39.16	64.51	142.40	0.30	79.58	46.62	86.94
<u>Neopanope packardii</u>	42.69	12.97	7.24	6.69	21.94	8.24	5.76	62.58	0.78	18.13	11.34	31.50
<u>Pagurus bonaiensis</u>	172.60	107.12	83.50	89.08	67.07	33.93	63.29	307.77	14.10	141.37	93.24	33.56
<u>Chondrilla nucula</u>	9.86	14.10	20.91	3.34	3.98	110.52	3.00	77.09	0.00	1.68	7.56	27.72
<u>Leptosynapta parvipatina</u>	10.10	56.25	0.00	2.94	44.13	10.79	42.16	0.60	0.00	3.76	11.34	34.02
Δ^t/D	+2.39	+0.75	+1.48	+0.89	+0.18	24.13	+0.31	+1.82	+4.56	+1.46		
Veg. lb/tow	11.2	6.1	6.1	4.5	3.7	2.0	3.7	15.8	0.1	9.9		

^{1/} Confidence intervals do not consider stations with 0 catch

Table 29C. Summary of catches, T Log (Catch +1), in Biscayne Bay (July 1970 - May 1971)

Species	N I	N II	NE II	SE I	SE II	SE III	S I	S II	S III	S IV	99% C.I.	
											Low	Upper
<u>Bulla umbilicata</u>	1.08	19.71	9.53	0.30	1.68	1.20	0.00	9.87	2.88	1.69	0.00	10.01
<u>Cerithium eberneum</u>	2.65	0.90	4.74	0.00	7.03	1.80	0.00	36.94	9.27	0.60	0.77	11.55
<u>Cerithium muscarum</u>	5.82	58.60	21.23	8.79	4.72	2.58	4.26	21.57	4.08	1.98	3.08	18.48
<u>Mitra gemmata</u>	0.00	0.90	0.00	0.00	4.53	3.01	0.00	0.30	6.34	3.90	0.00	6.16
<u>Mitrella lunata</u>	8.10	27.78	20.27	14.48	4.21	0.30	6.84	31.63	3.52	0.00	3.85	20.79
<u>Modulus modulus</u>	33.62	62.11	41.51	2.88	15.42	7.68	1.80	41.22	11.42	0.60	13.86	32.34
<u>Prunum apicinum</u>	9.87	27.64	11.42	0.60	1.80	3.36	0.00	6.79	4.62	0.00	0.77	11.55
<u>Rissoina chesneli</u>	3.68	21.65	5.90	0.00	4.65	0.60	0.60	21.95	5.41	3.82	0.77	16.17
<u>Tricolia affinis</u>	52.18	51.85	69.23	5.64	44.08	39.56	2.93	19.11	48.65	27.22	15.40	43.12
<u>Vermicularia spirata</u>	0.60	0.60	0.30	0.00	5.38	3.36	0.30	0.48	17.53	7.57	0.00	6.93
<u>Hippolyte pleuracantha</u>	22.11	20.66	16.36	13.56	0.00	2.98	7.84	3.40	8.26	2.46	0.77	13.09
<u>Thor floridanus</u>	62.87	69.68	78.10	5.09	70.57	41.69	5.88	65.05	94.19	57.30	36.19	68.53
<u>Neopanope packardii</u>	4.91	5.68	6.72	0.60	12.76	4.56	0.00	8.07	13.14	2.46	1.54	10.78
<u>Pagurus bonaiensis</u>	50.59	51.43	67.88	15.22	43.48	33.85	5.39	49.42	53.93	12.17	24.64	49.28
<u>Chondrilla nucula</u>	1.26	0.00	0.00	0.70	14.90	7.81	0.00	20.34	9.24	15.35	6.16	23.10
<u>Leptosynapta parvipatina</u>	4.75	2.28	10.19	1.86	39.84	11.20	0.48	8.83	32.25	13.60	10.01	16.17
Ave. Temp.	24.0	24.0	24.5	28.3	25.4	24.9	28.6	27.8	25.4	24.8		
Δ^t/D	-0.1	-0.1	+0.4	+4.2	+1.3	+0.8	+4.5	+3.7	+1.3	+0.7		
Veg. lb/tow	8.5	7.4	10.5	4.8	4.5	3.4	1.4	4.7	15.0	6.3		

Table 29C. Continued

Species	S V	A	D	E	F	G	H	I	J	K	99% C.I.	
											Low	Upper
<u>Bulla umbilicata</u>	0.00	11.06	0.00	0.60	5.69	0.00	15.41	9.45	3.72	1.75	0.00	10.01
<u>Cerithium eberneum</u>	2.10	3.33	0.90	3.66	3.88	0.00	16.01	0.90	23.56	1.08	0.77	11.55
<u>Cerithium muscarum</u>	0.30	8.37	0.30	1.68	19.32	0.00	25.45	11.93	14.48	4.56	3.08	18.48
<u>Mitra gemmata</u>	2.40	0.30	13.72	9.64	0.00	0.00	0.30	0.00	0.60	0.85	0.00	6.16
<u>Mitrella lunata</u>	0.30	16.52	2.16	1.20	20.00	0.00	52.76	1.08	30.34	4.98	3.85	20.79
<u>Modulus modulus</u>	5.77	64.94	5.17	4.78	33.51	0.00	19.10	36.06	45.23	30.20	13.86	32.34
<u>Prunum apicinum</u>	0.00	8.74	0.30	1.50	4.05	0.00	23.88	1.20	10.38	1.00	0.77	11.55
<u>Rissoina chesneli</u>	1.38	4.99	1.38	0.60	16.38	0.00	63.57	1.50	13.90	3.21	0.77	16.17
<u>Tricolia affinis</u>	18.65	15.09	36.66	34.87	10.97	0.00	57.83	1.80	36.21	8.30	15.40	43.12
<u>Vermicularia spirata</u>	8.35	0.00	2.10	5.08	0.90	0.30	3.18	0.30	4.36	2.46	0.00	6.93
<u>Hippolyte pleuracantha</u>	0.90	11.14	1.50	4.12	4.56	0.00	12.70	5.04	2.88	1.78	0.77	13.09
<u>Thor floridanus</u>	42.89	45.68	37.10	53.52	61.90	0.00	120.63	12.59	93.80	26.71	36.19	68.53
<u>Neopanope packardii</u>	2.90	0.48	6.16	5.96	19.81	0.30	5.56	0.00	15.62	0.90	1.54	10.78
<u>Pagurus bonaiensis</u>	2.28	48.91	10.78	19.75	67.73	1.08	103.13	8.49	63.15	21.24	24.64	49.28
<u>Chondrilla nucula</u>	3.31	12.37	78.60	3.61	66.78	0.00	13.04	0.00	41.89	8.64	6.16	23.10
<u>Leptosynapta parvipatina</u>	8.97	0.48	1.68	17.64	2.76	0.00	16.55	2.94	21.75	1.30	10.01	16.17
Ave. Temp.	24.5	25.9	24.1	24.5	26.4	29.6	26.1	26.6	25.8	25.5		
Δ°/D	+0.4	+1.8	Control	+0.4	+2.3	+5.5	+2.0	+2.5	+1.7	+1.4		
Veg. lb/tow	4.6	11.3	5.8	7.3	5.9	0.4	9.8	2.2	6.9	4.9		

Table 30A. Summary of catches, Σ Log (Catch +1), in Card Sound (July 1970 - May 1971)

Species	0104	0208	0405	0503	0504	0603	0604	0608	0703	1004	99% C.I.	
											Lower	Upper
<u>Bulla umbilicata</u>	6.84	0.00	0.78	12.93	12.18	0.30	10.98	0.30	3.91	0.00	0.00	9.24
<u>Cerithium ebernaum</u>	4.72	0.00	4.44	6.70	5.11	6.69	3.65	0.30	6.14	6.56	0.00	8.47
<u>Cerithium muscarum</u>	3.47	0.00	0.00	2.76	1.56	1.68	0.30	0.30	2.58	0.00	0.00	3.85
<u>Mitra gemmata</u>	5.74	0.30	4.40	50.75	27.41	2.20	44.81	0.30	5.92	2.78	5.39	23.87
<u>Mitrella lunata</u>	1.70	0.00	0.30	1.98	0.60	2.00	0.78	0.00	0.30	0.30	0.00	2.37
<u>Modulus modulus</u>	6.04	0.90	2.71	4.14	5.28	6.28	6.53	0.00	4.08	8.13	0.00	9.24
<u>Prunum apicinum</u>	0.78	0.00	0.00	1.20	0.30	3.15	0.00	0.00	0.90	3.76	0.00	3.44
<u>Rissoina chesneli</u>	0.30	0.00	2.10	14.00	12.53	4.70	5.90	0.00	8.80	10.76	0.77	11.55
<u>Tricolia affinis</u>	37.10	0.30	10.43	88.71	18.67	19.97	22.86	0.90	26.41	18.37	12.32	36.96
<u>Vermicularia spirata</u>	8.81	0.25	25.68	33.38	50.13	6.53	38.87	10.18	12.87	11.76	10.78	29.26
<u>Hippolyte pleuracantha</u>	1.38	0.00	1.98	4.48	4.75	2.98	1.68	0.78	1.80	3.50	0.00	5.39
<u>Thor floridanus</u>	39.70	5.34	64.61	70.95	77.76	28.11	80.66	18.18	26.27	44.15	30.03	60.83
<u>Neopanope packardii</u>	1.98	0.60	6.94	25.21	8.98	14.67	11.40	3.54	14.81	27.99	3.85	19.25
<u>Pagurus bonairensis</u>	17.92	0.90	4.09	38.44	6.22	24.52	4.12	1.68	21.80	19.48	5.39	22.33
<u>Chondrilla nucula</u>	8.94	1.98	50.12	36.92	40.07	3.36	32.83	9.59	13.32	30.35	13.09	31.57
<u>Leptosynapta parvipatina</u>	9.83	0.60	16.90	24.91	26.61	4.98	30.98	2.56	15.23	2.10	5.39	20.79
Ave. Temp.	24.1	24.4	24.6	24.9	24.7	24.9	24.7	24.8	25.2	24.8		
$\Delta^t/0104$	--	+0.3	+0.5	+0.8	+0.6	+0.8	+0.6	+0.7	+1.1	+0.7		
Veg. lb/tow	4.6	0.4	4.6	10.2	7.2	3.5	11.4	0.7	2.9	3.5		

Table 30B. Summary of catches, Σ Log (Catch +1), in Card Sound (July 1970 - December 1971)

Species	0104	0208	0405	0503	0504	0603	0604	0703	99% C. I.	
									Lower	Upper
<u>Bulla umbilicata</u>	8.52	0.00	4.50	23.58	22.22	2.46	33.57	7.82	3.78	21.42
<u>Cerithium eberneum</u>	7.28	0.90	17.60	15.78	8.77	11.68	9.58	12.91	2.52	17.64
<u>Cerithium muscarum</u>	4.03	0.00	0.30	6.59	1.86	2.38	0.30	3.66	0.00	6.30
<u>Mitra gemmata</u>	7.66	0.60	13.87	63.74	52.47	4.18	83.15	8.02	16.38	41.58
<u>Mitrella lunata</u>	1.50	0.00	0.30	1.98	0.60	2.00	0.78	0.30	0.00	2.90
<u>Modulus modulus</u>	6.94	1.50	6.37	7.20	7.08	9.04	11.33	5.64	1.26	11.34
<u>Prunum apicinum</u>	0.78	0.00	0.00	1.20	0.30	4.24	0.00	0.90	0.00	2.97
<u>Rissoina chesneli</u>	0.90	0.48	3.48	25.16	16.40	9.55	9.32	11.93	2.52	17.64
<u>Tricolia affinis</u>	42.14	2.85	13.79	116.05	24.51	30.91	32.29	41.58	21.42	54.18
<u>Vermicularia spirata</u>	11.09	6.73	50.16	49.82	77.77	14.20	54.27	24.46	23.94	49.14
<u>Hippolyte pleuracantha</u>	1.38	0.00	2.88	4.78	5.35	3.28	1.68	1.80	0.00	5.04
<u>Thor floridanus</u>	52.91	10.28	98.93	87.20	104.51	36.90	113.66	33.18	47.88	85.68
<u>Neopanope packardii</u>	2.28	2.15	7.84	32.59	9.28	30.00	13.08	18.23	6.30	21.42
<u>Pagurus bonairensis</u>	19.12	0.90	4.99	42.81	7.72	38.23	5.02	23.96	7.56	27.72
<u>Chondrilla nucula</u>	13.90	2.28	69.25	49.29	53.96	5.34	48.31	15.78	18.90	44.10
<u>Leptosynapta parvipatina</u>	16.50	5.28	43.75	53.47	56.02	7.99	74.17	42.82	32.76	49.14
Ave. Temp.	25.5	25.6	25.8	26.0	26.0	26.0	25.8	26.2		
$\Delta^t/0104$	--	+0.1	+0.3	+0.5	+0.5	+0.5	+0.3	+0.7		
Veg. lb/tow	3	0.5	4	8	5	3	9	2		

Table 30C. Summary of catches, $\Sigma \text{ Log (Catch +1)}$, in Card Sound (July 1970 - June 1973)

Species	0104	0503	0504	0603	0604	99% C.I.	
						Lower	Upper
<u>Bulla umbilicata</u>	13.36	31.07	41.76	8.44	98.62	25.20	50.40
<u>Cerithium eberneum</u>	29.48	36.16	29.26	19.71	24.55	17.64	37.80
<u>Cerithium muscarum</u>	4.63	7.49	3.56	2.68	2.28	0.00	8.57
<u>Mitra gemmata</u>	26.52	77.80	89.30	36.91	158.86	22.68	133.56
<u>Mitrella lunata</u>	2.40	1.98	0.60	2.78	1.08	0.00	4.71
<u>Modulus modulus</u>	17.48	10.08	10.26	19.74	23.31	7.56	22.68
<u>Prunum apicinum</u>	1.15	1.50	0.30	4.54	0.00	0.00	4.51
<u>Rissoina chesneli</u>	3.18	36.86	20.42	16.29	18.86	10.08	30.24
<u>Tricolia affinis</u>	133.39	190.29	86.72	134.52	188.85	113.40	178.92
<u>Vermicularia spirata</u>	82.00	85.55	145.74	62.04	132.25	75.60	110.88
<u>Hippolyte pleuracantha</u>	9.12	6.76	10.57	7.79	12.81	5.04	15.12
<u>Thor floridanus</u>	102.20	102.98	175.06	83.58	126.45	110.88	166.32
<u>Neopanope packardii</u>	21.04	59.61	30.96	46.42	45.23	27.72	68.04
<u>Pagurus bonaiensis</u>	30.83	64.12	12.82	52.78	16.62	22.68	47.88
<u>Chondrilla nucula</u>	109.1	73.26	148.73	50.18	113.35	80.64	115.92
<u>Leptosynapta parvipatina</u>	29.70	75.05	104.61	26.30	154.35	60.48	95.76
Ave. Temp.	25.4	25.9	25.7	26.3	25.7		
$\Delta^t/0104$	--	+0.5	+0.3	+0.9	+0.3		
Veg. lb/tow	3.4	5.7	4.1	3.9	8.9		

Thor floridanus, Pagurus bonairensis and Leptosynapta parvipatina (small sea cucumber).

Stations N II and N V were located off the mouths of Florida City Canal and Moody Canal, respectively. During the rainy season (August and September), salinity at these stations was lowered and at station N V the red algae, Digenia simplex, was killed leaving bare sand for several months. The area was later recolonized by Laurencia. At station N II the dominant vegetation was Diplanthera wrightii (Cuban shoal weed), which is a faster colonizer and more tolerant species of sea grass than the usual grass Thalassia testudinum (turtle grass).

The relatively stenohaline forms such as the sea cucumber Leptosynapta, chicken liver sponge, Chondrilla, checkered pheasant, Tricolia affinis and the gastropod, Vermicularia spirata, which is generally found partially imbedded in sponges were scarce or absent at these stations.

Other animals which were closely associated with Laurencia were also significantly lower in the catches. This was especially noted for the caridean shrimp, Thor floridanus. Catches of the paper mussel shell, Amygdalum papyria, the lunate dove shell, Mitrella lunata and the xanthid crab, Neopanope packardii, were above average at N V, but the bulk of the catch was made during the summer when salinities were relatively normal and the station was covered with the red algae, Digenia simplex.

Stations NE IV, NE V, SE IV, SE V, S IV and S V were mid-Bay or offshore stations, which had relatively stable salinity, only natural temperature fluctuations and little red algae. Their location off the nearshore sediment wedge, which produced the greatest amount of benthic macroalgae, probably led to the low catches of most animals.

Due to the differences in the offshore station populations and the desire to obtain better resolution of the effect of the thermal additions, stations N IV, N V, NE IV, NE V, SE IV, SE V, S IV and S V were discontinued after December 1968 and stations A - H were added. At the same time an improved field sorting technique which retained more of the smaller organisms was initiated. Thus, catches for the two periods are not equivalent and should be treated separately.

Stations SE II and S II elevated 2.25°C above the ambient control station temperature, produced above average catches of Cerithium muscarum (fly-speckled cerith), Modulus modiolus (Atlantic modiolus), Vermicularia spirata (worm shell gastropod) and Thor floridanus (caridean shrimp).

In the analysis of data collected between January 1969-June 1970, it was even more obvious that Tricolia, Vermicularia, Chondrilla and Leptosynapta were mid-Bay or offshore forms, as was the ivory cerith, Cerithium eberneum.

Among the typical inshore species there is a significant decrease in abundance of all species analyzed at station G, which has an average temperature deviation of 4.5°C above the ambient measured at station D on Pelican Bank. Stations S I elevated 3.5° above the ambient also showed lowered catches of all species. Station SE I elevated 3.5° had reduced catches of all species except the ceriths, Cerithium eberneum, C. muscarum and the

chicken liver sponge, Chondrilla nucula. All of the C. eberneum were taken in October 1969 when the temperature was 28.5°C. All of the Chondrilla were taken during the winter and spring of 1969 when the temperature was low. C. muscarum occurred throughout the year and was apparently not killed or forced to emigrate. The presence of this cerith probably reflects the 3 lbs. per tow of vegetation taken at SE I. The algae seem to be essential to the cerith for food or shelter.

Catches of the molluscs of the sediment shelf: Bulla umbilicata, Cerithium muscarum, Mitrella lunata, Modulus modulus and Prunum apicinum were low at the stations located more than 1250 m from shore (NE III, C, D, E). The crustaceans Hippolyte, Thor, Neopanope and Pagurus, although abundant at station NE II, were scarce at stations C, D and E. Station NE II produced more than 9 lbs. of algae per tow, while C, D and E in Thalassia beds produced considerably less. Thus, these crustacea appear to depend on red algae for food and shelter.

At stations S II, F and H which averaged 2.39°, 1.82° and 1.46°C, respectively above the ambient temperature measured at station D, the catches were significantly high. Station SE II, elevated 0.74°C had above average catches of Cerithium eberneum, Neopanope packardii, Thor floridanus, Pagurus bonairensis, Chondrilla nucula and Leptosynapta parvipatina. Catches of Cerithium muscarum, Mitrella lunata, Prunum apicinum, Vermicularia spirata and Hippolyte pleuracantha were significantly low.

From July 1970-May 1971, the desire for closer resolution of temperature plus an interesting phenomenon of dense Thalassia and Diplanthera beds in a minor effluent canal, Little River, pointed out by Florida Power and Light caused us to add stations I, J and K and to discontinue N III, NE I and NE III. In addition, because of plans to discharge into Card Sound, stations S IV and S V between the Sound and the Bay were revived and stations B and C were discontinued.

Vermicularia, Chondrilla, Leptosynapta and the new addition Mitra were essentially mid-Bay or eastern bay species. The previously mid-Bay dominants: Tricolia, Cerithium eberneum and Chondrilla, were still most common in mid-Bay, but relative abundance of Cerithium eberneum was high at station B and Tricolia catches were high at most inshore stations not affected by temperature. This may reflect drought conditions and hypersalinity of inshore stations during the 1970-71 winter and spring.

Station G which averaged 5.5°C above ambient during this period produced low catches of all the inshore species. Of the indicator species, only one Neopanope, one Vermicularia and several Pagurus were taken. Stations S I and SE I averaging 4.5 and 4.2°C above ambient produced low catches of all species except C. muscarum, Mitrella lunata and Hippolyte pleuracantha; of these only C. muscarum appeared in summer when temperatures were high. Both ceriths were shown to have high modal temperatures but the catches drop off rapidly when temperature exceeds 33°C. August and September temperatures were in excess of 33°C and C. muscarum was still present in average numbers at stations S I and SE I. The five year study indicates Cerithium muscarum is extremely tolerant and occurs in inshore areas with abundant red algae unless prolonged temperature elevations above 33°C occur.

At station S II elevated 3.7°C above ambient (D) catches of all species except Leptosynapta parvipatina were average or above average. Leptosynapta was scarce at most of the sediment shelf stations and is probably salinity limited. Stations F, H and I were elevated 2.3, 2.0 and 2.5°C above ambient (D). At station H all of the indicator species catches were average or above average. At station F catches of Tricolia and Leptosynapta, typically mid-Bay species, were low while the other indicator species were present in average or above average numbers. At station I the temperature averaged +2.5 but the extreme temperatures were greater than other stations except C. Here, the crustaceans Thor, Neopanope and Pagurus and the gastropods Mitrella and Tricolia were caught in low numbers. The catches of the mid-Bay species, Chondrilla and Leptosynapta were also low. One gastropod, Modulus modulus, was caught in greater than average numbers.

Stations SE II, S III, A, J and K, were heated 1.3, 1.3, 1.8, 1.7 and 1.4°C above ambient (D), respectively. Catches of Hippolyte were low at station SE II, Mitrella were low at S III, Tricolia, Neopanope and Leptosynapta were low at A, Tricolia, Thor, Neopanope, Pagurus and Leptosynapta were low at K. Tricolia and Leptosynapta are mid-Bay species and generally low at inshore controls. Other species were caught in average or above average numbers.

In Card Sound ten stations were sampled for the period July 1970-May 1971. During this period, no heated discharge was entering the Sound and this is considered base data. Station 0603 was located at the mouth of the Model Land Company Canal and was influenced by fresh water discharge, however, bottom salinities during this period were hypersaline. The salinity controlled species: Mitra, Vermicularia, Chondrilla and Leptosynapta were collected in low numbers. Thor was also relatively scarce. Both eastern bay stations 0208 and 0608 produced reduced numbers of the indicator species. This is related to the low catches of vegetation. At the insular station 0104, used as a temperature control, catches of Rissoina, Vermicularia and Neopanope were low and those of Tricolia were high. At station 1004 located on the Card Sound edge of Card Bank near the Intracoastal Waterway and dominated by sea grasses, catches of Mitra gemmata, and Leptosynapta were low while catches of Neopanope and Prunum were high.

From June 1971-December 1971, stations 0608 and 1004 were not sampled. A comparison of catches of the 16 dominant species from July 1970-December 1971 at the remaining 8 stations indicates station differences (Table 30). Broad Creek inlet station, 0208, produced low numbers of indicator animals. The Arsenicker Key station, 0104, produced low catches of Mitra, Rissoina, Vermicularia, Neopanope, Chondrilla and Leptosynapta. The Model Land Canal effluent station, 0603, produced low catches of Bulla, Mitra, Vermicularia, Thor, Chondrilla and Leptosynapta and high catches of Neopanope and Pagurus. The catches of most of the species are correlated with vegetation and catches are usually highest at 0604 and 0503. Mitra, Vermicularia and Hippolyte were more abundant at 0504, located 1/2 mile off shore and with more sponges. Cerithium aberneum and Chondrilla were more frequently caught at 0405, a mid-Bay sponge station. Thus, the scarcity of Bulla and Thor at 0603 probably reflects the Model Land Canals contribution while the low catches of other species reflects their preference for more offshore stations.

Station 0603 was relocated to the proposed site of Florida Power and

Light Company's discharge in December 1971 and the proposed canal was cut into Card Sound in January 1972 and began discharging in February 1972. It was then closed in February 1973 before unit 3 went on line in November 1973. During the first 18 month period, prior to the canal being opened, the shoreline stations 0503, 0603 and 0703 averaged 26.1°C. During the second 18 month period, including one year when the canal was used, the temperature at 0603 averaged 26.6°C or the Δt was about 0.5°C. Actual observations of 2-3°C above ambient were recorded but only sporadically. None of the other stations showed significant temperature anomalies.

If our findings based on Biscayne Bay data and the predictive models are correct we should see little change in catches at 0603. For the period July 1970-June 1973 catches of Bulla, Vermicularia, Thor, Chondrilla and Leptosynapta were low. All of these species produced low catches in the first 18 months prior to the opening of the effluent canal. Mitra which was not abundant during the first 18 months was caught in average numbers during the canal operation. Pagurus retained its high catch rate and Prunum catches were high. The catch rate of Neopanope dropped but total catch remained within the 99% confidence interval for the five stations sampled (Table 30). Catch rates for the second 18 months at the remaining stations were relatively consistent with those of the first 18 months.

Although Thorhaug (1974) showed some decrease in production of grass and algae, the animal populations taken by trawl, by sponge studies (Smith, 1973) and by trap studies (Hixon, 1975) indicate no significant detrimental effects resulting from the one years' discharge. The bottom Δt during the year (February 1972-February 1973) was less than 3°C. Greater diversity of trawled animals, increased growth and diversity of sponge populations (Smith, 1973) and increased total catches indicate that the effluent-created currents, in an area previously exhibiting poor circulation (Lee and Rooth, 1971), may indeed have been beneficial to the associated fauna.

In all of the analysis of variance tests the interaction among months and stations was significant except for Modulus modiolus from Card Sound in the period July 1970-May 1971 and Prunum apicinum from Card Sound in the period July 1970-December 1971 and July 1970-June 1973. Also, significance was shown for all species tested, except Mitrella lunata from Card Sound in the period July 1970-December 1971; Serichium maccarium, Mitrella lunata, Prunum apicinum and Hippolyte pleuracantha from Card Sound in the period July 1970-June 1973. The catches were significantly different among stations. The catches were significantly different among months (Table 31, 32, 33 and 34) for all species tested, except Tricolia affinis and Chondrilla nucula, from Biscayne Bay in the period July-December 1968; Vermicularia spirata from Biscayne Bay in the period July 1970-May 1971; Prunum apicinum from Card Sound in the period July 1970-December 1971.

In order to try to understand the interaction, graphs of the catch ($\log(\text{catch} + 1)$) indicated by + and temperature (°C) represented by dots versus time at selected stations from Biscayne Bay and Card Sound were plotted.

From the analysis of variance and 99% confidence intervals of total catch by month, it was found that Bulla umbilicata was taken in above average numbers in July 1969; August 1970 and September 1970, and was

Table 31. Summary of analysis of variance among months and among stations in Biscayne Bay -- July 1970 - May 1971

Species	Source	df	ms	F	F _{1/}
<u>Bulla umbilicata</u>	Month	10	0.63		19.23**
	Station	19	0.43		13.23**
	Month X station	190	0.13	7.77**	
	Error	1320	0.02		
	Error + interaction	1510	0.03		
	Total	1539			
<u>Cerithium eberneum</u>	Month	10	0.11		2.85**
	Station	19	1.15		30.78**
	Month X station	190	0.10	3.89**	
	Error	1320	0.03		
	Error + interaction	1510	0.04		
	Total	1539			
<u>Cerithium muscarum</u>	Month	10	1.04		14.95**
	Station	19	2.44		34.96**
	Month X station	190	0.27	6.44**	
	Error	1320	0.04		
	Error + interaction	1510	0.07		
	Total	1539			
<u>Mitra gemmata</u>	Month	10	0.04		2.78**
	Station	19	0.18		12.25**
	Month X station	190	0.03	2.26**	
	Error	1320	0.01		
	Error + interaction	1510	0.01		
	Total	1539			
<u>Mitrella lunata</u>	Month	10	1.28		14.89**
	Station	19	2.67		30.98**
	Month X station	190	0.35	7.56**	
	Error	1320	0.05		
	Error + interaction	1510	0.09		
	Total	1539			
<u>Modulus modulus</u>	Month	10	2.16		21.32**
	Station	19	5.59		55.28**
	Month X station	190	0.36	5.61**	
	Error	1320	0.06		
	Error + interaction	1510	0.10		
	Total	1539			

1/ Tested against pooled error and interaction

** Significant at 99%

Table 31. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Prunum apicinum</u>	Month	10	0.34		9.34**
	Station	19	0.80		21.97**
	Month X station	190	0.11	4.25**	
	Error	1320	0.03		
	Error + interaction	1510	0.04		
	Total	1539			
<u>Rissoina chesneli</u>	Month	10	0.33		4.88**
	Station	19	2.79		40.96**
	Month X station	190	0.20	4.20**	
	Error	1320	0.05		
	Error + interaction	1510	0.07		
	Total	1539			
<u>Tricolia affinis</u>	Month	10	7.34		32.22**
	Station	19	5.70		25.02**
	Month X station	190	0.80	5.50**	
	Error	1320	0.15		
	Error + interaction	1510	0.23		
	Total	1539			
<u>Vermicularia spirata</u>	Month	10	0.03		1.58ns
	Station	19	0.23		14.46**
	Month X station	190	0.03	2.21**	
	Error	1320	0.01		
	Error + interaction	1510	0.02		
	Total	1539			
<u>Hippolyte pleuracantha</u>	Month	10	0.30		6.90**
	Station	19	0.60		13.74**
	Month X station	190	0.16	5.72**	
	Error	1320	0.03		
	Error + interaction	1510	0.04		
	Total	1539			
<u>Thor floridanus</u>	Month	10	3.71		12.13**
	Station	19	13.44		43.89**
	Month X station	190	0.93	4.29**	
	Error	1320	0.22		
	Error + interaction	1510	0.31		
	Total	1539			

^{1/} Tested against pooled error and interaction

** Significant at 9%

ns not significant

Table 31. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Neopanope packardii</u>	Month	10	0.28		10.37**
	Station	19	0.41		15.13**
	Month X station	190	0.05	2.33**	
	Error	1320	0.02		
	Error + interaction	1510	0.03		
	Total	1539			
<u>Pagurus bonaiensis</u>	Month	10	5.22		27.95**
	Station	19	10.12		54.24**
	Month X station	190	0.71	6.38**	
	Error	1320	0.11		
	Error + interaction	1510	0.19		
	Total	1539			
<u>Chondrilla nucula</u>	Month	10	0.44		5.39**
	Station	19	6.42		78.82**
	Month X station	190	0.14	1.85**	
	Error	1320	0.07		
	Error + interaction	1510	0.08		
	Total	1539			
<u>Leptosynapta parvipatina</u>	Month	10	0.97		21.10**
	Station	19	1.68		36.69**
	Month X station	190	0.15	4.59**	
	Error	1320	0.03		
	Error + interaction	1510	0.05		
	Total	1539			

^{1/} Tested against pooled error and interaction

** Significant at 99%

Table 32. Summary of analysis of variance among months and among stations in Card Sound -- July 1970 - May 1971

Species	Source	df	ms	F	F ^{1/}
<u>Bulla umbilicata</u>	Month	10	0.11		3.66**
	Station	9	0.46		15.33**
	Month X station	90	0.08	4.00**	
	Error	660	0.02		
	Error + interaction	750	0.03		
	Total	769			
<u>Cerithium eberneum</u>	Month	10	0.10		4.00**
	Station	9	0.07		2.65**
	Month X station	90	0.06	2.90**	
	Error	660	0.02		
	Error + interaction	750	0.03		
	Total	769			
<u>Cerithium muscarum</u>	Month	10	0.03		4.14**
	Station	9	0.02		3.14**
	Month X station	90	0.02	3.00**	
	Error	660	0.01		
	Error + interaction	750	0.01		
	Total	769			
<u>Mitra gemmata</u>	Month	10	0.51		5.10**
	Station	9	4.83		48.30**
	Month X station	90	0.32	4.57**	
	Error	660	0.07		
	Error + interaction	750	0.10		
	Total	769			
<u>Mitrella lunata</u>	Month	10	0.02		4.00**
	Station	9	0.01		2.00*
	Month X station	90	0.01	2.00**	
	Error	660	0.004		
	Error + interaction	750	0.004		
	Total	769			
<u>Modulus modulus</u>	Month	10	0.07		2.82**
	Station	9	0.09		3.54**
	Month X station	90	0.02	0.70ns	
	Error	660	0.02		
	Error + interaction	750	0.02		
	Total	769			

^{1/} Tested against pooled error and interaction

* Significant at 95%

** Significant at 99%

ns not significant

Table 32. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Neopanope packardii</u>	Month	10	0.60		8.86**
	Station	9	1.13		16.67**
	Month X station	90	0.17	3.06**	
	Error	660	0.05		
	Error + interaction	750	0.07		
	Total	769			
<u>Pagurus bonaiensis</u>	Month	10	1.19		12.82**
	Station	9	2.01		21.63**
	Month X station	90	0.32	5.06**	
	Error	660	0.06		
	Error + interaction	750	0.09		
	Total	769			
<u>Chondrilla nucula</u>	Month	10	0.77		7.56**
	Station	9	3.85		37.77**
	Month X station	90	0.21	2.36**	
	Error	660	0.09		
	Error + interaction	750	0.10		
	Total	769			
<u>Leptosynapta parvipatina</u>	Month	10	0.57		8.58**
	Station	9	1.62		24.36**
	Month X station	90	0.27	9.91**	
	Error	660	0.03		
	Error + interaction	750	0.07		
	Total	769			

^{1/} Tested against pooled error and interaction

** Significant at 99%

Table 32. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Prunum apicinum</u>	Month	10	0.01		1.42ns
	Station	9	0.02		3.42**
	Month X station	90	0.01	1.41*	
	Error	660	0.01		
	Error + interaction	750	0.01		
	Total	769			
<u>Rissoina chesneli</u>	Month	10	0.11		2.90**
	Station	9	0.37		9.69**
	Month X station	90	0.08	2.22**	
	Error	660	0.03		
	Error + interaction	750	0.04		
	Total	769			
<u>Tricolia affinis</u>	Month	10	1.35		6.99**
	Station	9	8.25		42.70**
	Month X station	90	0.61	4.50**	
	Error	660	0.14		
	Error + interaction	750	0.19		
	Total	769			
<u>Vermicularia spirata</u>	Month	10	0.80		7.23**
	Station	9	3.04		27.38**
	Month X station	90	0.34	4.22**	
	Error	660	0.08		
	Error + interaction	750	0.11		
	Total	769			
<u>Hippolyte pleuracantha</u>	Month	10	0.06		5.13**
	Station	9	0.03		2.84**
	Month X station	90	0.02	1.60**	
	Error	660	0.01		
	Error + interaction	750	0.01		
	Total	769			
<u>Thor floridanus</u>	Month	10	4.72		16.46**
	Station	9	9.17		36.96**
	Month X station	90	0.95	4.86**	
	Error	660	0.20		
	Error + interaction	750	0.29		
	Total	769			

^{1/} Tested against pooled error and interaction

* Significant at 95%

** Significant at 99%

ns not significant

Table 33. Summary of analysis of variance among months and among stations in Card Sound -- July 1970 - December 1971

Species	Source	df	ms	F	F ^{1/}
<u>Bulla umbilicata</u>	Month	17	0.40		6.96**
	Station	7	1.16		20.26**
	Month X station	119	0.18	5.15**	
	Error	864	0.03		
	Error + interaction	983	0.06		
	Total	1007			
<u>Cerithium eberneum</u>	Month	17	0.38		10.36**
	Station	7	0.22		5.96**
	Month X station	119	0.10	3.83**	
	Error	864	0.03		
	Error + interaction	983	0.04		
	Total	1007			
<u>Cerithium muscarum</u>	Month	17	0.03		4.13**
	Station	7	0.04		5.25**
	Month X station	119	0.02	4.00**	
	Error	864	0.01		
	Error + interaction	983	0.01		
	Total	1007			
<u>Mitra gemmata</u>	Month	17	0.83		6.83**
	Station	7	8.20		67.36**
	Month X station	119	0.50	7.27**	
	Error	864	0.08		
	Error + interaction	983	0.12		
	Total	1007			
<u>Mitrella lunata</u>	Month	17	0.013		4.19**
	Station	7	0.005		1.58ns
	Month X station	119	0.006	2.26**	
	Error	864	0.003		
	Error + interaction	983	0.003		
	Total	1007			
<u>Modulus modulus</u>	Month	17	0.05		2.87**
	Station	7	0.06		3.31**
	Month X station	119	0.03	1.61**	
	Error	864	0.02		
	Error + interaction	983	0.02		
	Total	1007			

^{1/} Tested against pooled error and interaction

** Significant at 99%

ns not significant

Table 33. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Prunum apicinum</u>	Month	17	0.004		1.23ns
	Station	7	0.017		5.45**
	Month X station	119	0.003	1.03ns	
	Error	864	0.003		
	Error + interaction	983	0.003		
	Total	1007			
<u>Rissoina chesneli</u>	Month	17	0.13		3.20**
	Station	7	0.56		13.55**
	Month X station	119	0.07	1.98**	
	Error	864	0.04		
	Error + interaction	983	0.04		
	Total	1007			
<u>Tricolia affinis</u>	Month	17	1.40		7.16**
	Station	7	9.31		47.50**
	Month X station	119	0.64	4.72**	
	Error	864	0.14		
	Error + interaction	983	0.20		
	Total	1007			
<u>Vermicularia spirata</u>	Month	17	1.01		9.19**
	Station	7	5.17		47.04**
	Month X station	119	0.35	4.57**	
	Error	864	0.08		
	Error + interaction	983	0.11		
	Total	1007			
<u>Hippolyte pleuracantha</u>	Month	17	0.05		6.73**
	Station	7	0.03		3.61**
	Month X station	119	0.01	1.41**	
	Error	864	0.01		
	Error + interaction	983	0.01		
	Total	1007			
<u>Thor floridanus</u>	Month	17	4.15		16.00**
	Station	7	11.88		45.79**
	Month X station	119	0.88	5.01**	
	Error	864	0.17		
	Error + interaction	983	0.26		
	Total	1007			

1/ Tested against pooled error and interaction

** Significant at 99%

ns not significant

Table 33. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Neopanope packardii</u>	Month	17	0.37		7.44**
	Station	7	1.08		21.87**
	Month X station	119	0.13	3.43**	
	Error	864	0.04		
	Error + interaction	983	0.05		
	Total	1007			
<u>Pagurus bonairensis</u>	Month	17	1.01		13.92**
	Station	7	2.04		28.18**
	Month X station	119	0.24	5.00**	
	Error	864	0.05		
	Error + interaction	983	0.07		
	Total	1007			
<u>Chondrilla nucula</u>	Month	17	0.79		8.87**
	Station	7	5.24		58.58**
	Month X station	119	0.22	2.99**	
	Error	864	0.07		
	Error + interaction	983	0.09		
	Total	1007			
<u>Leptosynapta parvipatina</u>	Month	17	1.17		12.11**
	Station	7	4.94		51.02**
	Month X station	119	0.39	6.98**	
	Error	864	0.06		
	Error + interaction	983	0.10		
	Total	1007			

^{1/} Tested against pooled error and interaction
 ** Significant at 99%

Table 34. Summary of analysis of variance among months and among stations in Card Sound -- July 1970 - June 1973

Species	Source	df	ms	F	F ^{1/}
<u>Bulla umbilicata</u>	Month	35	.37		5.72**
	Station	4	5.17		79.61**
	Month X station	140	0.22	5.07**	
	Error	1080	0.04		
	Error + interaction	1220	0.07		
	Total	1259			
<u>Cerithium eberneum</u>	Month	35	0.21		4.60**
	Station	4	0.15		3.32*
	Month X station	140	0.13	3.81**	
	Error	1080	0.03		
	Error + interaction	1220	0.05		
	Total	1259			
<u>Cerithium muscarum</u>	Month	35	0.026		3.48**
	Station	4	0.017		2.34ns
	Month X station	140	0.022	3.89**	
	Error	1080	0.006		
	Error + interaction	1220	0.007		
	Total	1259			
<u>Mitra gemmata</u>	Month	35	0.95		9.89**
	Station	4	10.92		113.95**
	Month X station	140	0.64	25.92**	
	Error	1080	0.02		
	Error + interaction	1220	0.10		
	Total	1259			
<u>Mitrella lunata</u>	Month	35	0.011		3.43**
	Station	4	0.003		1.03ns
	Month X station	140	0.006	1.90**	
	Error	1080	0.003		
	Error + interaction	1220	0.003		
	Total	1259			
<u>Modulus modulus</u>	Month	35	0.06		2.38**
	Station	4	0.13		5.38**
	Month X station	140	0.05	2.50**	
	Error	1080	0.02		
	Error + interaction	1220	0.03		
	Total	1259			

^{1/} Tested against pooled error and interaction

* Significant at 95%

** Significant at 99%

ns not significant

Table 34. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Prunum apicinum</u>	Month	35	0.013		4.52**
	Station	4	0.003		1.17ns
	Month X station	140	0.003	1.18ns	
	Error	1080	0.003		
	Error + interaction	1220	0.003		
	Total	1259			
<u>Rissoina chesneli</u>	Month	35	0.09		2.21**
	Station	4	0.57		14.10**
	Month X station	140	0.11	3.51**	
	Error	1080	0.03		
	Error + interaction	1220	0.04		
	Total	1259			
<u>Tricolia affinis</u>	Month	35	3.35		8.32**
	Station	4	7.60		18.89**
	Month X station	140	2.03	10.66**	
	Error	1080	0.19		
	Error + interaction	1220	0.40		
	Total	1259			
<u>Vermicularia spirata</u>	Month	35	0.84		6.45**
	Station	4	5.02		38.61**
	Month X station	140	0.46	5.30**	
	Error	1080	0.09		
	Error + interaction	1220	0.13		
	Total	1259			
<u>Hippolyte pleuracantha</u>	Month	35	0.05		3.45**
	Station	4	0.02		1.59ns
	Month X station	140	0.03	2.31**	
	Error	1080	0.01		
	Error + interaction	1220	0.01		
	Total	1259			
<u>Thor floridanus</u>	Month	35	2.97		10.97**
	Station	4	14.50		53.53**
	Month X station	140	1.05	6.15**	
	Error	1080	0.17		
	Error + interaction	1220	0.27		
	Total	1259			

^{1/} Tested against pooled error and interaction

** Significant at 99%

ns not significant

Table 34. Continued

Species	Source	df	ms	F	F ^{1/}
<u>Neopanope packardii</u>	Month	35	0.35		5.03**
	Station	4	0.89		12.71**
	Month X station	140	0.19	3.61**	
	Error	1080	0.05		
	Error + interaction	1220	0.07		
	Total	1259			
<u>Pagurus bonairensis</u>	Month	35	0.59		8.48**
	Station	4	1.99		28.66**
	Month X station	140	0.25	5.35**	
	Error	1080	0.05		
	Error + interaction	1220	0.07		
	Total	1259			
<u>Chondrilla nucula</u>	Month	35	1.14		9.02**
	Station	4	5.78		45.57**
	Month X station	140	0.51	6.57**	
	Error	1080	0.08		
	Error + interaction	1220	0.13		
	Total	1259			
<u>Leptosynapta parvipatina</u>	Month	35	0.61		5.68**
	Station	4	11.46		139.65**
	Month X station	140	0.45	7.00**	
	Error	1080	0.06		
	Error + interaction	1220	0.11		
	Total	1259			

^{1/} Tested against pooled error and interaction

** Significant at 99%

below average in March, April and May 1971. Generally, catches were lower in winter than in summer. In Biscayne Bay a control station, NE II, showed seasonal peak catches in summer or fall of 1968, 1969 and 1970. At station F, elevated 2°C, a similar pattern exists but winter catches are higher than at the control. At SE I, elevated 3.5°C, the summer peaks are reduced. However, following dilution and closing of Grand Canal, considerable recovery is evident. At station G, elevated 4.5°C, only a few specimens were taken and even after closing Grand Canal recovery is not marked (Fig. 34). In Card Sound catches were less than in Biscayne Bay but summer dominance still appears. In Card Sound catches were high in September and December 1970, August 1972 and low in March and June 1971 and May 1973. At 0603 catches were low before the new Card Sound connection began discharging heated effluent and did not change significantly during operation of the discharge. This, however, was a period of hypersalinity along the inshore stations of Card Sound. At 0604 catches were somewhat higher during the discharge period than before the canal was opened (Fig. 35).

The monthly total catch of Cerithium eberneum was above average in September 1969 and November 1970 and low in September 1970. Little seasonal trend is evident. Examination of a control NE II, indicates generally low catches on the inshore shelf. At station H, elevated about 1°C, catches were higher than at control station NE II and showed a winter dominance. At station S II, elevated 2°C above ambient, catches were generally high. At station SE I, elevated 3.5°C, a high peak occurred in October 1969 and aside from this spike no individuals were taken until dilution began. Some recovery after the closing of Grand Canal was indicated (Fig. 36). At G, elevated 4.5°C, no specimens were taken until Grand Canal was closed. In Card Sound catches were high in December 1970, January, October, November and December 1971, May 1972 and February 1973. Thus, it appears that C. eberneum is a winter-spring dominant. At the Long Arsenicker Key control station, 0104, catches were moderate with some indication of winter to spring dominance. At 0504, moderate catches were taken. At 0603 and 0604, catches were also moderate and no significant effect of the thermal effluent could be detected (Fig. 37).

The fly-speckled cerith, Cerithium muscarum, produced above average catches in Biscayne Bay in August 1968, June, July, August 1969 and August 1970 and lower than average catches in December, June 1970 and April and May 1971. It appears to be a summer dominant. At control station N I peaks occurred in the summer of 1968, 1969 and 1970, but there was a downward trend in catches over the three years. At H, elevated 1°C, the seasonal trends seem to be reversed. At F, elevated 2°C, catches were greatest in the summer of 1969 and thereafter declined similar to the control station. Station SE I, shows a similar trend and after spring 1970 decline there is no recovery except for the sporadic catch of a few individuals (Fig. 38). At G, elevated 4.5°C, only four individuals were taken between January 1969-June 1973. In Card Sound catches were above average in October 1970 and November 1971. So few individuals were taken that no meaningful data can be obtained on differences among control and affected stations.

Catches of the miter, Mitra gemmata, were low at inshore Biscayne Bay stations and only moderately abundant at mid-Bay stations. They appear more common in winter. At a control station, SE III, near West Arsenicker Key, winter dominance was evident. This was also true at control station D

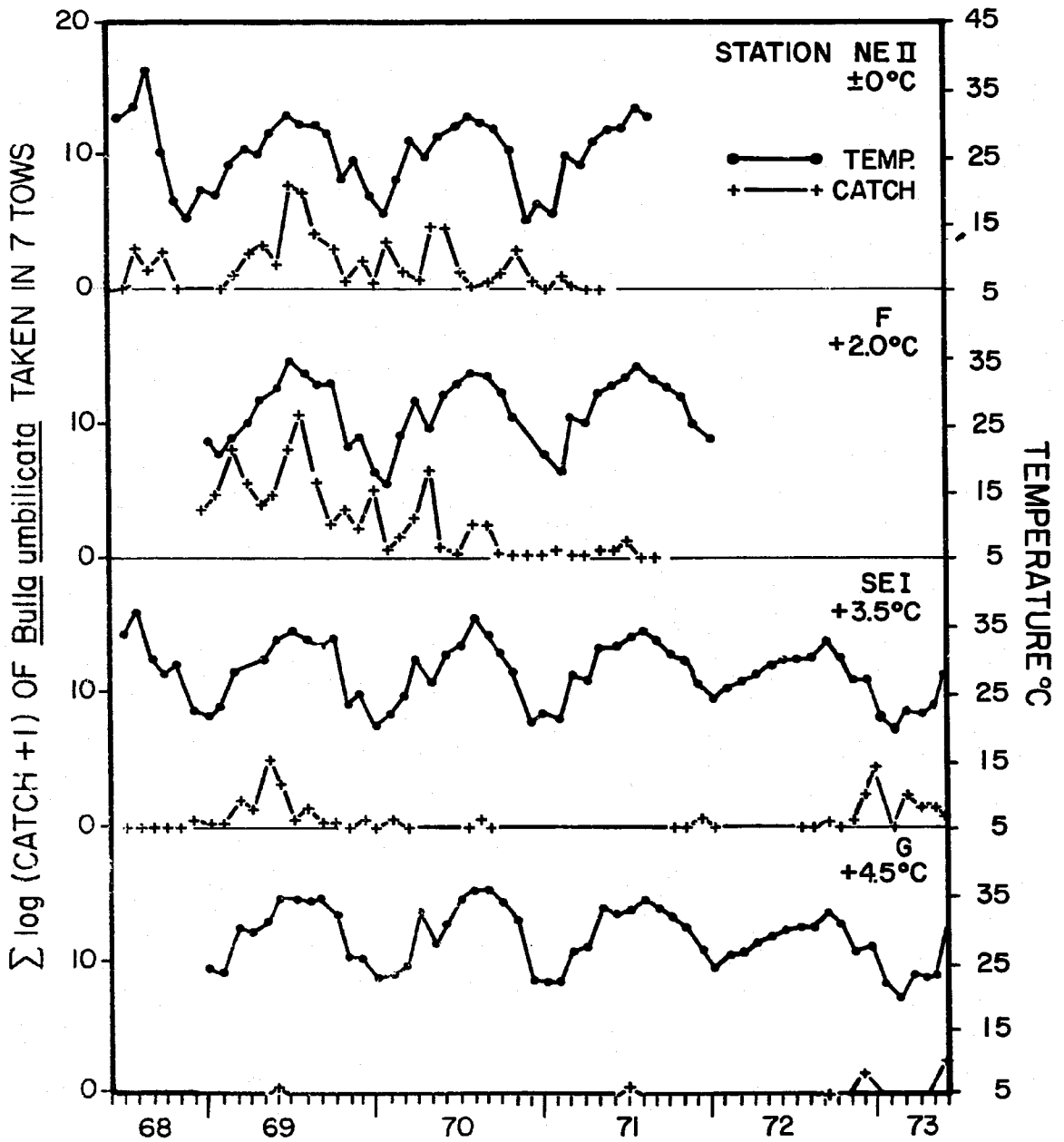


FIGURE 34. Catch, log (catch + 1) of *Bulla umbilicata* taken in seven tows and temperature at stations NE II, F, SE I and G.

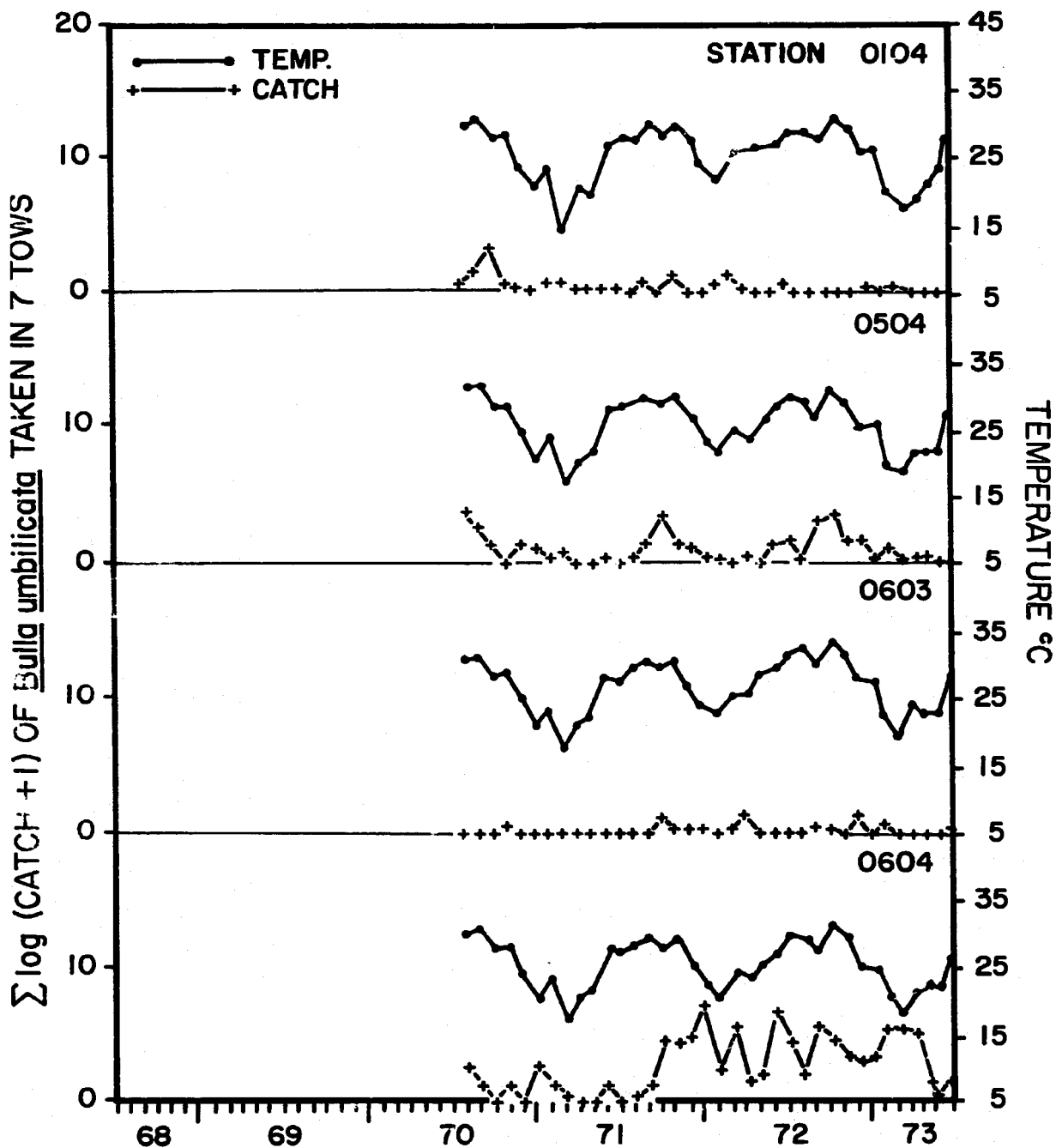


FIGURE 35. Catch, log (catch +1) of *Bulla umbilicata* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

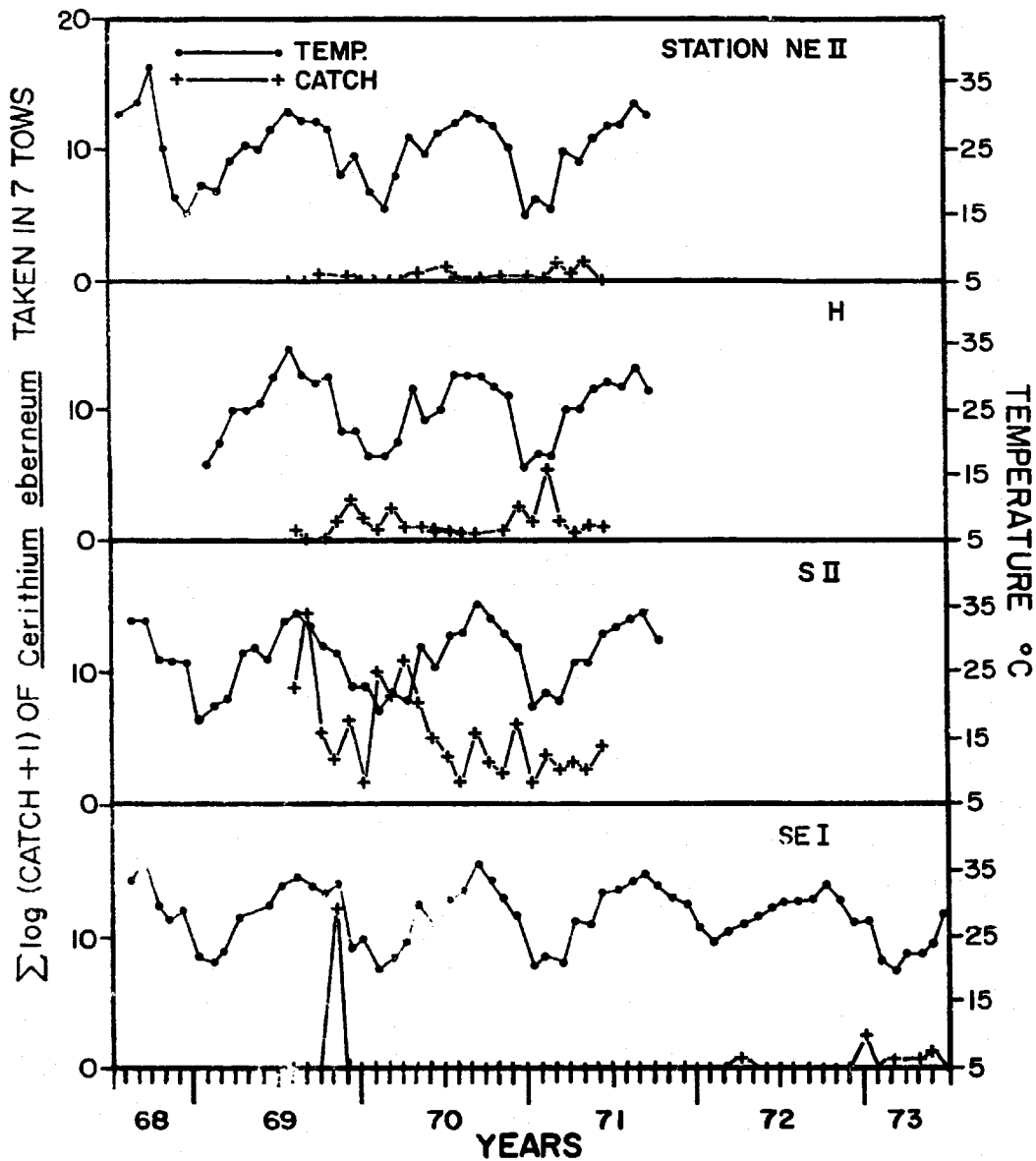


FIGURE 36. Catch, log (catch + 1) of Cerithium eberneum taken in seven tows and temperature at stations NE II, SE I, S II and H.

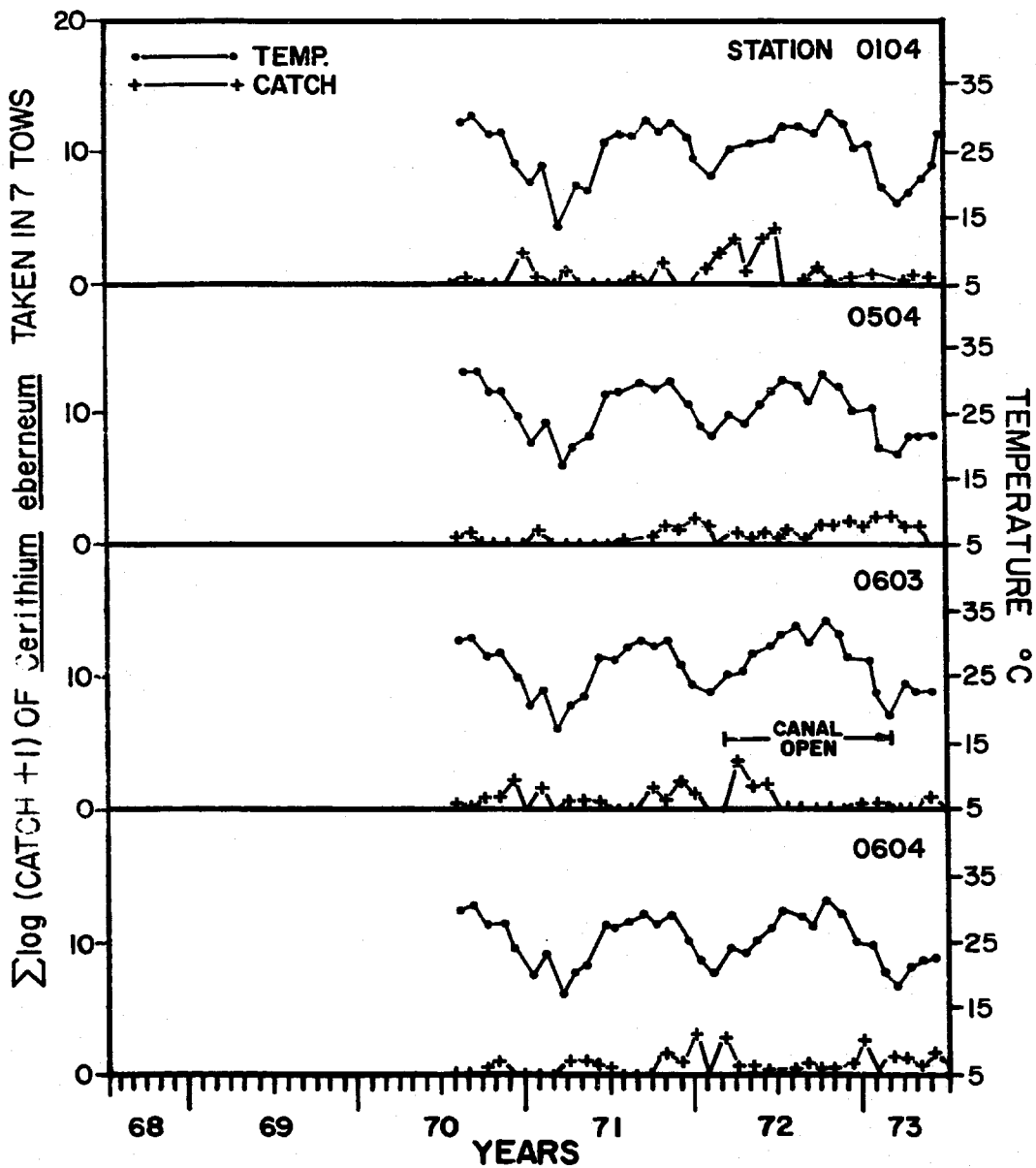


FIGURE 37. Catch, log (catch +1) of Cerithium eberneum taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

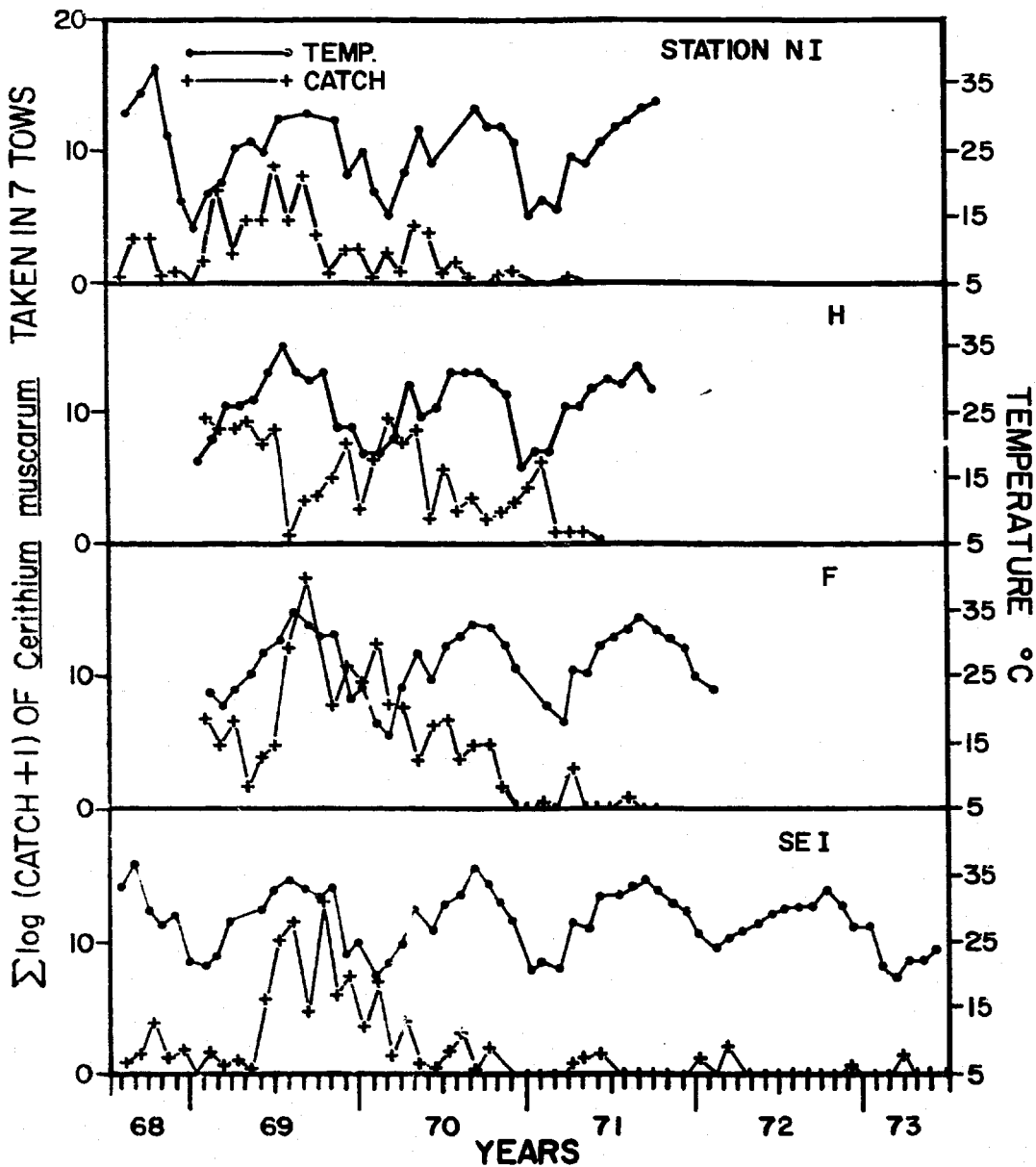


FIGURE 38. Catch, log (catch +1) of Cerithium muscarum taken in seven tows and temperature at stations N I, H, F and SE I.

on Pelican Bank and E in deep water between Pelican Bank and the mainland. At SE II, elevated 1-2°C above ambient, catches were sporadic throughout the years. Catches at heated stations were low but this probably results from the inshore location of these stations (Fig. 39). In Card Sound Mitra catches were above average in July, August, November and December 1970, March, November and December 1971 and below average in June 1971. In the more offshore stations 0504 and 0604 winter peaks are evident. Inshore station 0104 produced a lower catch rate. At 0603 catches were low in the first year when hypersalinity was common at inshore stations, but when the station was moved and salinity returned to just less than 35 ppt in January 1972, the catch increased. During the following summer there was a decline in catch, but this also occurred at control stations (Fig. 40).

Catches of the lunate dove shell, Mitrella lunata, in Biscayne Bay were high in February, March, April and May 1970 and July and August 1971. Catches were below average in August-November 1970. Thus, Mitrella appears to dominate in spring and be scarce in the fall. At control station N I, temperatures only reached 33°C in the summer of 1968 and catches at this time were low. At station S II, elevated 2°C above ambient, temperatures reached 33°C in each summer. Catches were low at these times or dropped sharply in subsequent months. Recovery each winter was noted and the winter peak in 1969-1970 exceeded that of the control stations. At station SE I, elevated 3.5°C above ambient, temperature exceeded 33°C every summer until 1972 when dilution was used to cool the effluent. When temperature exceeded 33°C, catches were low and the period needed for fall or winter recovery became longer in successive years. The winter peaks were generally higher than at control stations. At station G, elevated 4.5°C above ambient, temperatures exceeded 33°C each summer until 1972, when dilution was used. Catches were sporadic and low during the first winter sampling (1969), fell to zero in the summer, showed a minor catch in the spring of 1970 and then remained at zero until after Grand Canal was closed (Fig. 41). Catches were extremely low in Card Sound and no patterns were evident.

Catches of the Atlantic modulus, Modulus modulus, were above average in Biscayne Bay in August 1968, June, July, August and September 1969 and August and November 1970. Catches were low in January, February, March and April 1969 and January 1971. Thus, the species appears to be a summer dominant. At ambient temperature station N I, little seasonal pattern is evident, but higher catches seem to occur in summer. At station H, elevated about 1°C, catches were generally higher in winter and depressed in summer, but the annual yield was similar to controls. At station F, elevated 2°C, peak catches occurred in summer and the annual yield is above control stations. At SE I, elevated 3.5°C, catches were low until dilution and closing of the Grand Canal (Fig. 42). At station G, elevated 4.5°C, no catch was made until after dilution had begun in Grand Canal.

In Card Sound catches were lower than those made in Biscayne Bay. Catches showed no seasonal pattern. Catches were moderately low and sporadic at 0104, 0504, 0603 and 0604 (Fig. 43). No effect of the effluent canal was observed.

Catches of the common Atlantic marginella, Prunum apicinum, were above average in Biscayne Bay in August 1968, July 1969 and August and November 1970. It was below average in May 1970. At control station N II, spring

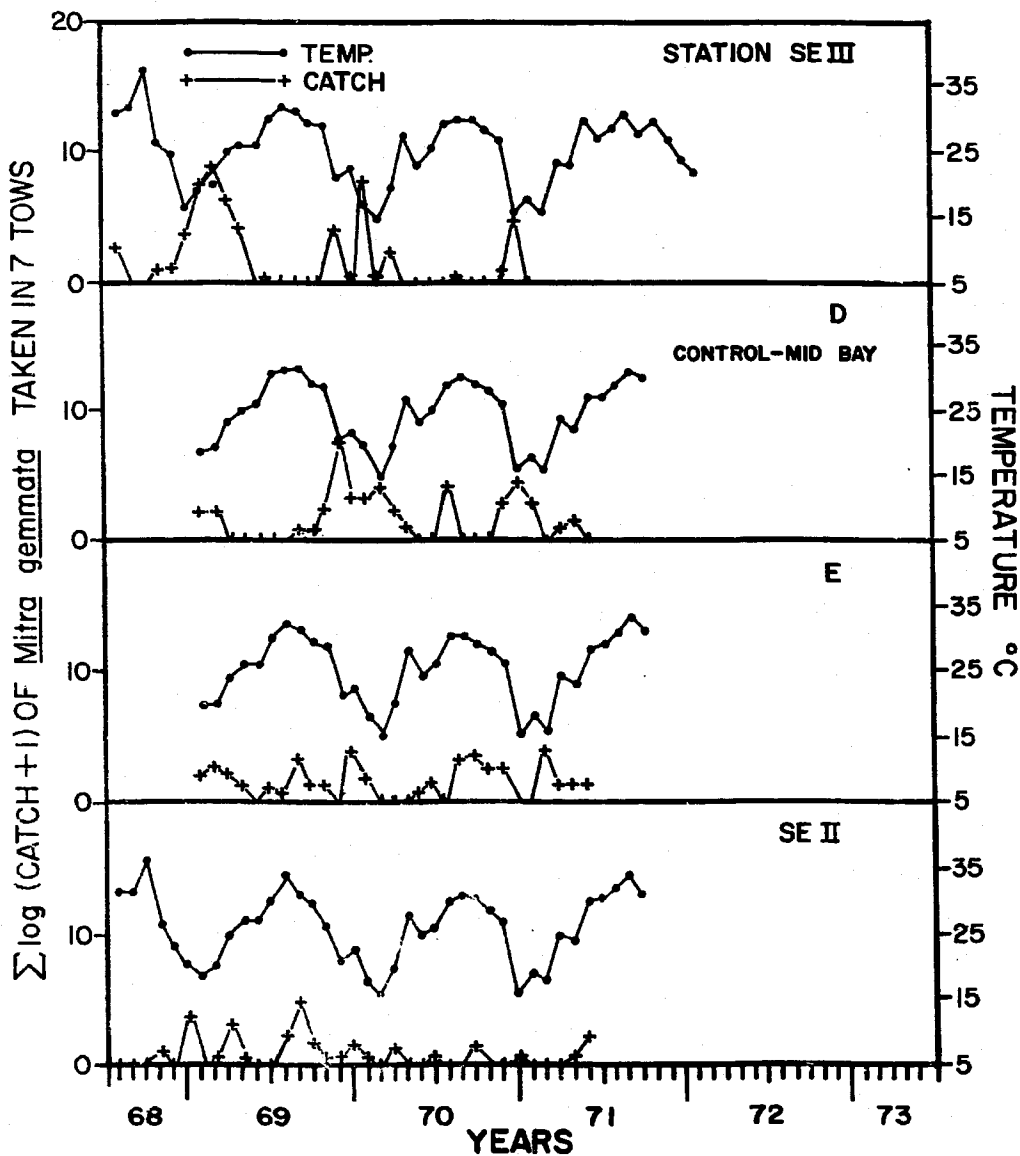


FIGURE 39. Catch, log (catch +1) of *Mitra gemmata* taken in seven tows and temperature at stations SE III, D, E and SE II.

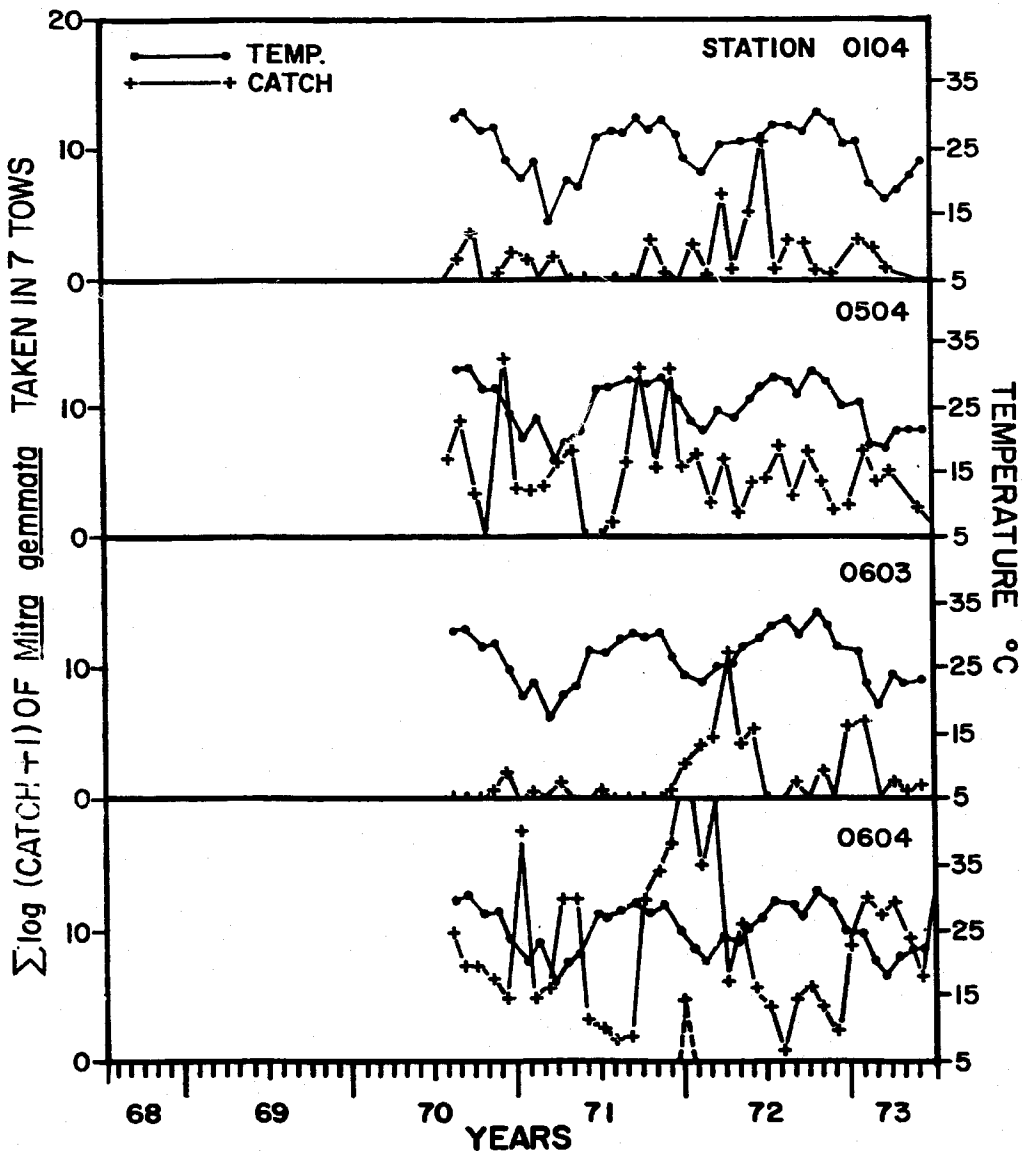


FIGURE 40. Catch, log (catch +1) of Mitra gemmata taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

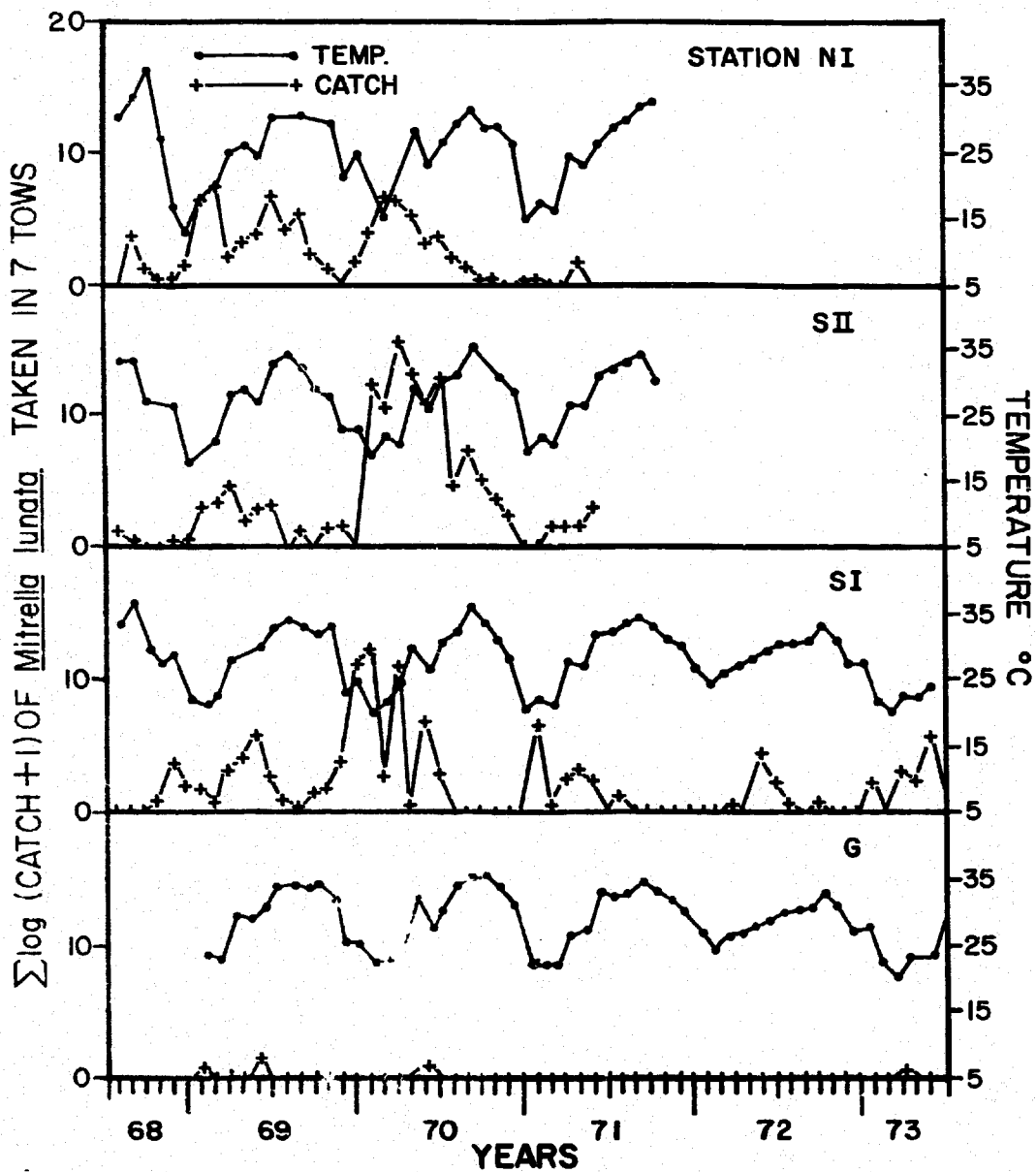


FIGURE 41. Catch, log (catch + 1) of *Mitrella lunata* taken in seven tows and temperature at stations N I, S II, SE I and G.

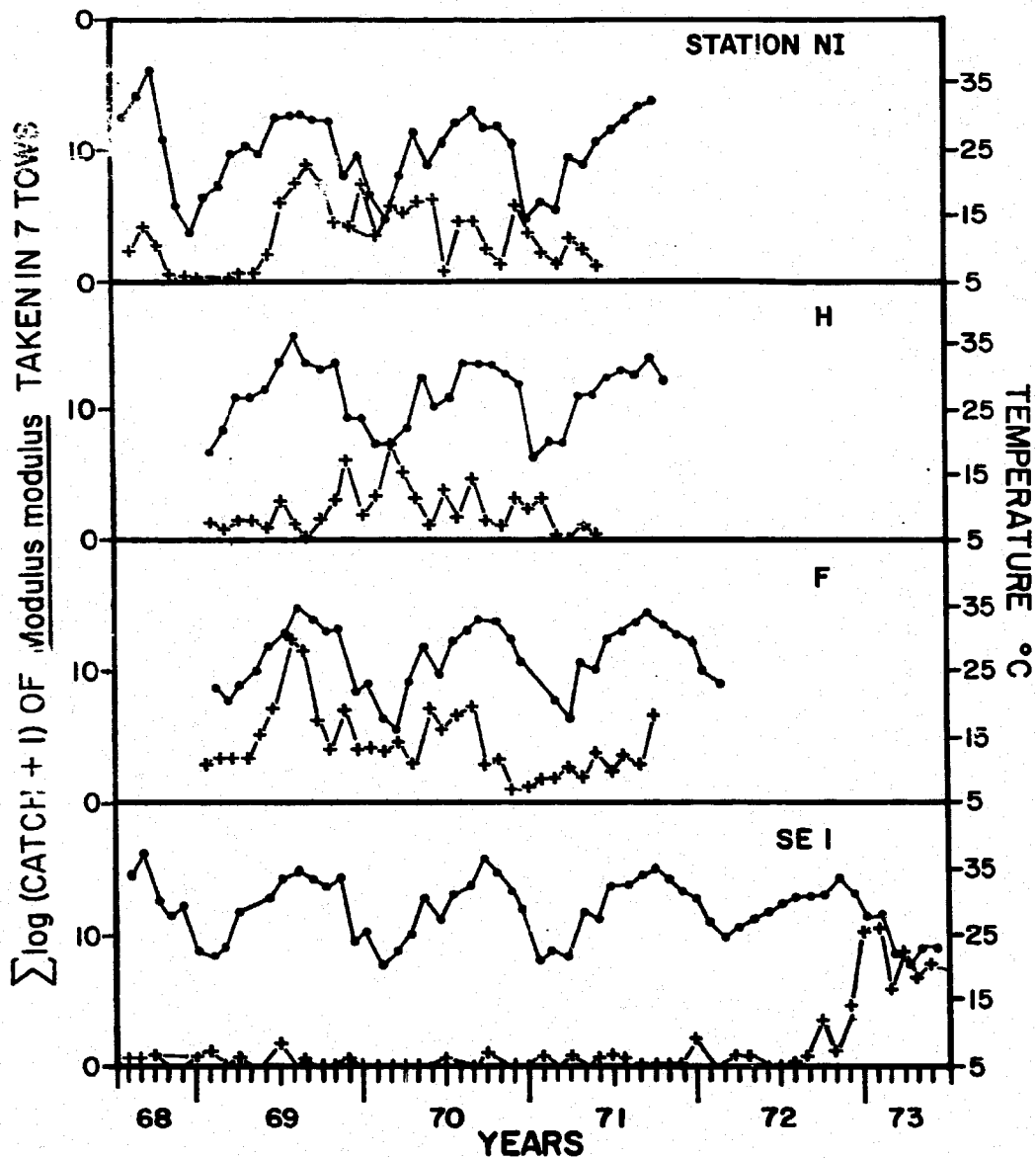


FIGURE 42. Catch, log (catch +1) of Modulus modulus taken in seven tows and temperature at stations N I, H, F and SE I.

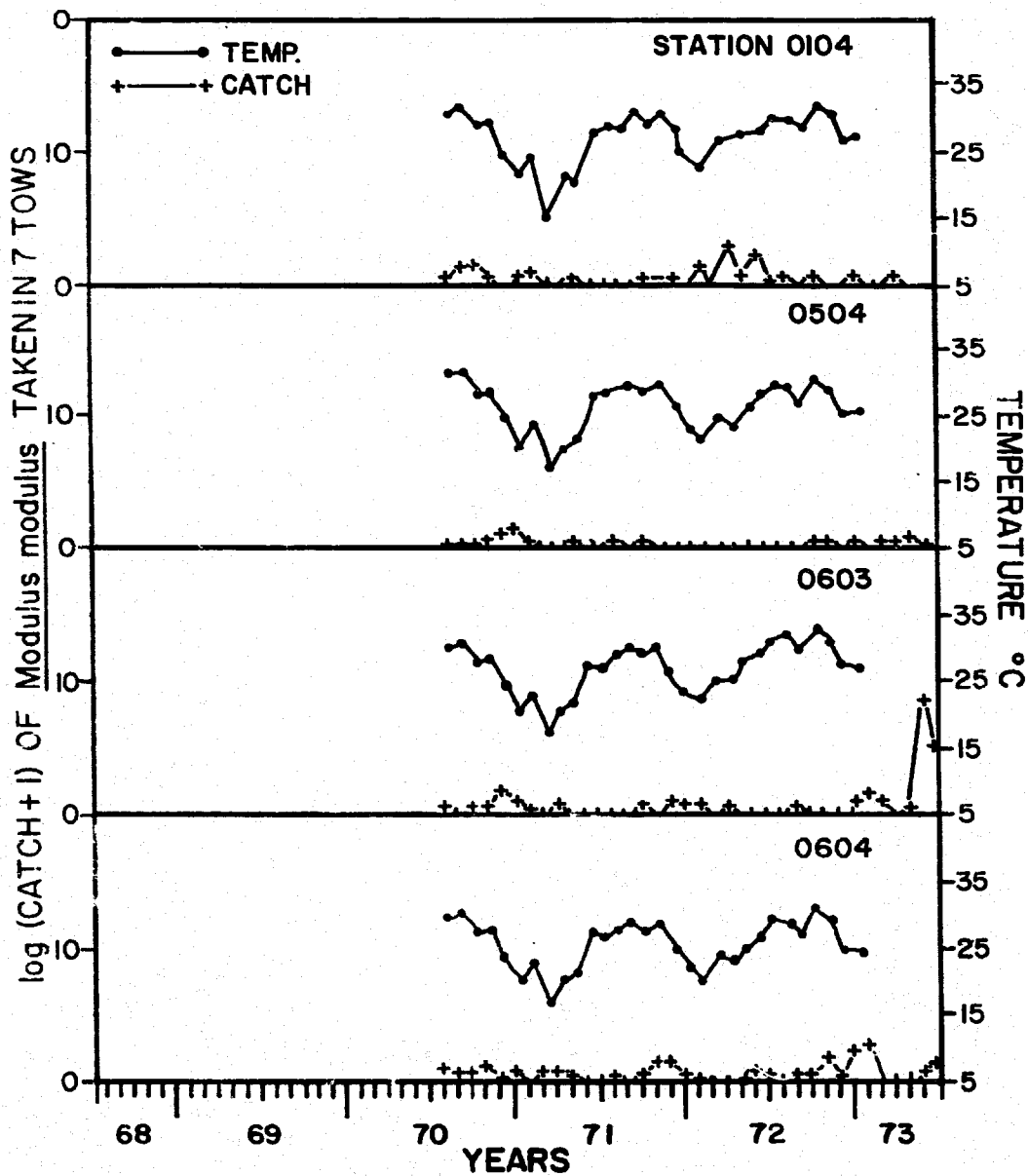


FIGURE 43. Catch, log (catch + 1) of Modulus modulus taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

and summer peaks of abundance are noted. At station H, elevated 1°C above ambient, catches fell sharply in the summer of 1969 after temperatures exceeded 32.5°C. Recovery occurred in the winter of 1969-70 but the catches were lower than at control stations. The summer of 1970 also exhibited depressed catches but the catches were higher than in the previous summer. Recovery in the winter of 1970-71 was good but catches again dropped in the spring of 1971. At station F, elevated about 2°C above ambient, catches were highest in July 1969, when temperatures of 35°C were recorded. In the summer of 1970, catches fell to zero when temperatures again approached 35°C and thereafter catches were low. It is probable that the Atlantic marginella moved into station F during the first summer of study to utilize the large detritus source formed by dead and decaying red algae, Laurencia spp. After this food and shelter source was gone, the mollusc left the area. Albertson (1973) has shown the gastropod to have short term temperature tolerances up to 43°C and it is not likely that the temperature experienced killed the snails. It is more likely that exclusion occurred when the food and shelter supplied by the algae was destroyed. At SE I, elevated 3.5°C, catches were generally low. A peak occurred in June 1969 at a temperature of 33°C. When temperature exceeded 33°C the catches fell and did not recover significantly until dilution and closing Grand Canal was accomplished (Fig. 44). At G, elevated 4.5°C, no Prunum were taken, even in the 5 months after closing Grand Canal. Prunum apicinum was not common in Card Sound and insufficient numbers were taken to warrant discussion of seasonal or spacial trends.

Catches of Chesnel's rissocina, Rissoina chesneli, were analyzed only for the period July 1970-May 1971 in Biscayne Bay. In this period catches were above average in August 1970. Catches at control station NE II generally showed spring peaks. At H, an inshore station elevated 1°C above ambient, spring peaks are also evident but one additional peak occurred in November 1970. No adverse effect of temperature was detected. At station F, elevated 2°C, there are peaks of catch in the spring and fall of 1969 and in the spring of 1970. Thereafter catches were low. As with the previous species, the destruction of algae appears to cause the decline in catches at F. At station SE I, elevated 3.5°C, catches were depressed below controls. None were taken from June 1970-December 1971. Some recovery was noted after dilution began and after Grand Canal was closed (Fig. 45). At G, elevated 4.5°C, catches were made only in January 1969 and September 1969. Only a few individuals were taken.

Rissoina catches in Card Sound were low compared to Biscayne Bay. Figure 46 indicates no effect of thermal additions at 0603 during the period when effluent was discharged.

Catches of the checkered pheasant shell, Tricolia affinis, were above average in Biscayne Bay in July, September and November 1968, May, June and December 1969, November and December 1970 and February 1971. Catches were low in April, May, July, August and September 1970. At control station NE II catches were low in the summer of 1968 and rose in the fall. In the winter of 1968-69 none were taken. In spring, catches increased until in July 1969 catches fell again when temperature exceeded 30°C and salinity was less than 20 ppt. In fall catches recovered. The winter of 1969-70 produced low catches and this low trend continued through the spring and summer of 1970. In the fall and winter, catch rates rose to high levels and then fell again in the spring of 1971. At station F, elevated 2°C above ambient,

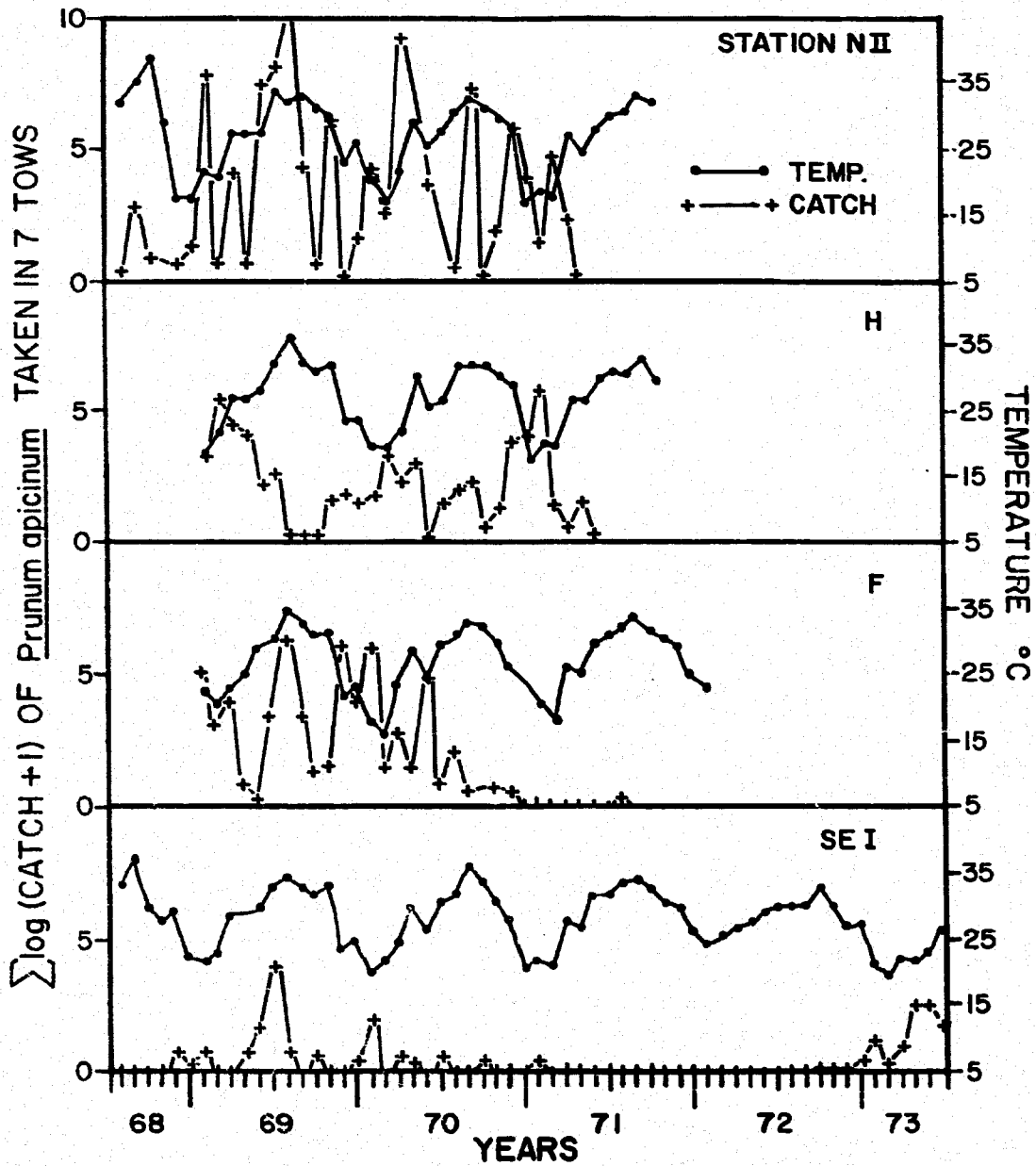


FIGURE 44. Catch, log (catch + 1) of *Prunum apicinum* taken in seven tows and temperature at stations N II, H, F, and SE I.

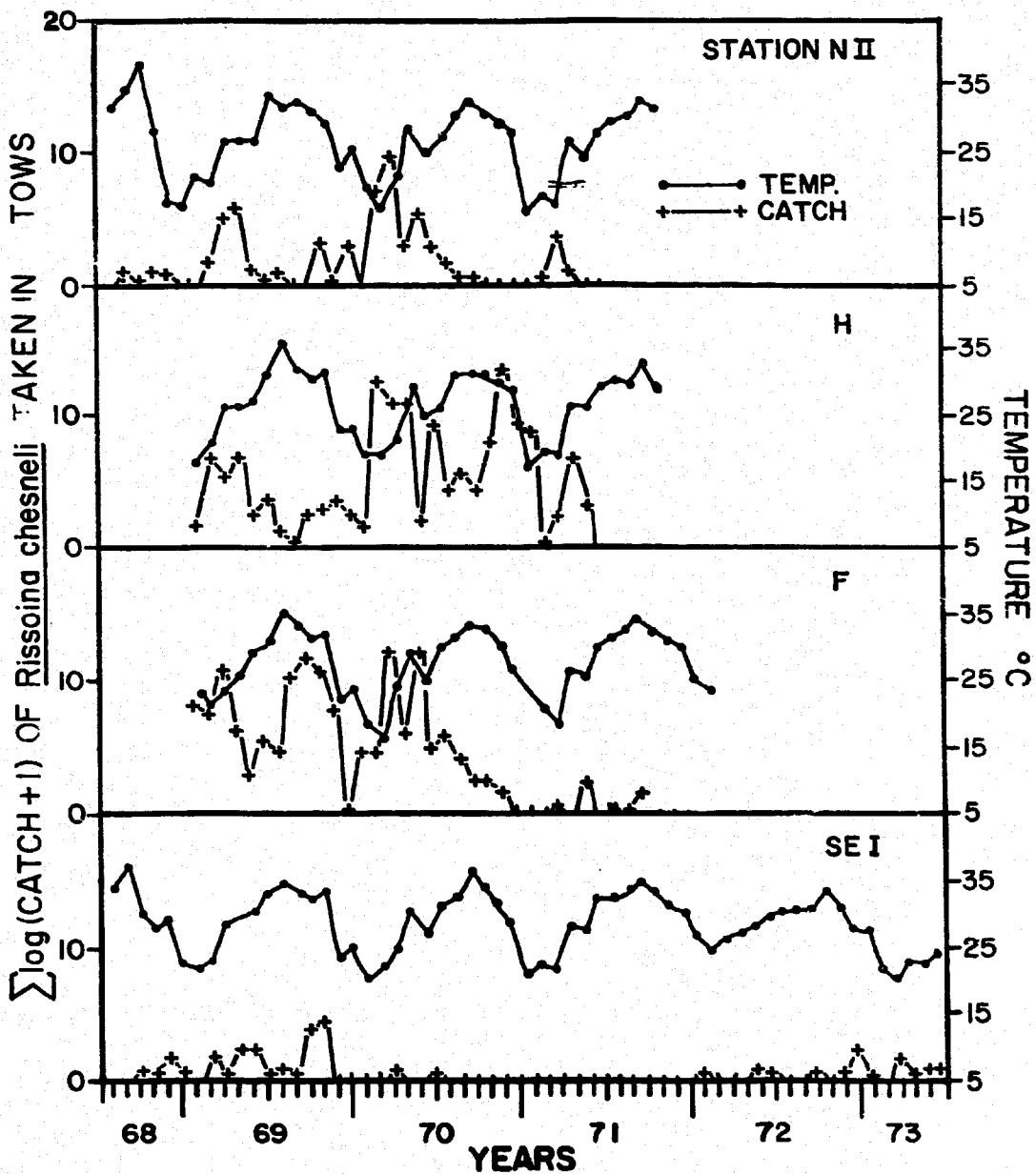


FIGURE 45. Catch, log (catch + 1) of *Rissoina chesneli* taken in seven tows and temperature at stations NE II, H, F and SE I.

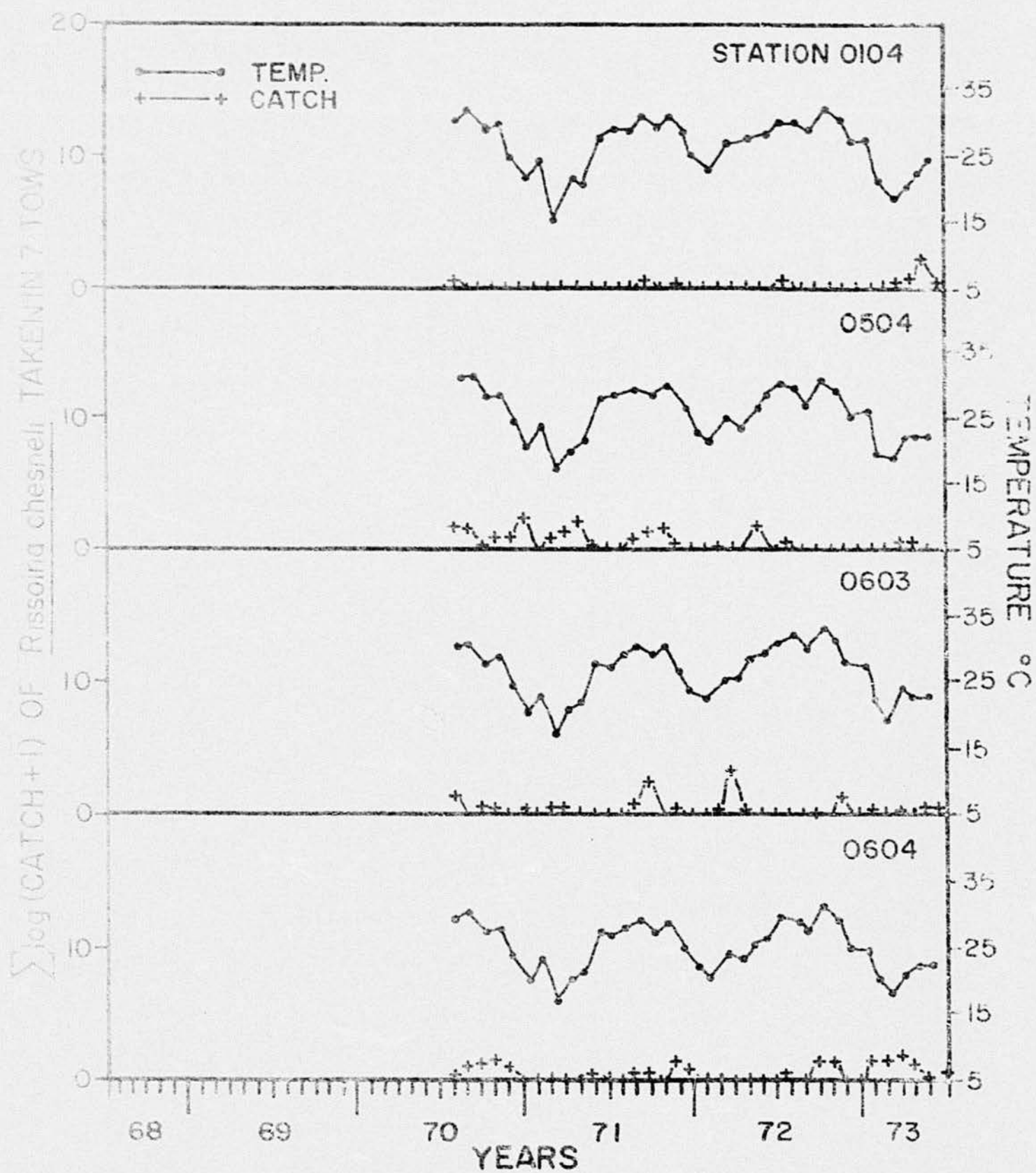


FIGURE 46. Catch, log (catch +1) of *Rissoina chesneli* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

measured at D, catches were generally lower than at inshore control stations. Small peaks occurred in the spring of 1969 and winter of 1970-71. In 1969 when temperatures rose to near 35°C, catches dropped and only slight recovery was noted until this station was abandoned. At station SE I, elevated 3.5°C, catches were low from the onset of the study in July 1968 until the Card Sound Canal was opened in February 1972. After the heated effluent was removed from Biscayne Bay recovery was rapid. A similar pattern in exhibited at station G, elevated 4.5°C during the effluent discharge in Biscayne Bay (Fig. 47).

In Card Sound catches were generally high with highest catches in November and December 1970, December 1971 and during the period January-June 1973. Catches were generally high at 0104, 0504 and 0604. At 0603 catches peaked with the opening of the effluent canal and then during the warmer season dropped markedly. When the Card Sound Canal was closed, recovery was rapid (Fig. 48). Thus, Tricolia appeared to be adversely affected by heat even when temperatures only a few degrees above ambient were experienced.

The worm shell gastropod, Vermicularia spirata, appears to favor off-shore stations and is most frequently found associated with sponges. Where Oligoceras occurred in inshore areas, Vermicularia was common, but where no sponges occurred the snail was scarce. Catches were in excess of the 99% confidence interval in Biscayne Bay in January, February and July 1969 and below average in April and May 1970. Only a few specimens were taken at stations along the (north) inshore transect exemplified by station N III. Similarly inshore station SE I, elevated 3.5°C, produced low and sporadic catches. Station S III, considered a mid-Bay control, produced higher catches than station S II, elevated 2°C above ambient. During the first 18 months the catch rates were similar but then the decline at S II was more pronounced than at S III (Fig. 49). Station G produced no specimens and was less productive than any other inshore station except N V which had low salinity during the 6 months it was sampled.

In Card Sound catches in excess of the 99% confidence interval occurred in August 1970, March and December 1971, May 1972 and June 1973. Catches were low in May-July 1971. Catches were lowest at 0104, which was influenced by Biscayne Bay water and was a shallow station and highest at 0504 and 0604 located 1/2 mile from the mainland shore. At 0603 catches were low when the station was hypersaline, high during the first three months of discharge and then declined in summer. Recovery occurred in the fall and high catches occurred after the closure of the Card Sound Canal. This species, like Tricolia, did show adverse effects from the discharge of heated effluent in Card Sound, but only at station 0603 in the mainstream of the effluent (Fig. 50).

Catches of the caridean shrimp, Hippolyte pleuracantha, were in excess of the 99% confidence interval in December 1968, June 1969, January, February, March and August 1970 and January 1971. Catches were low in April and May 1969 and October 1970. Control stations, exemplified by N I, generally showed high but variable catches. At station F, elevated 3°C above ambient, catches were generally high in winter and extremely low in summer. Catches in the winter and spring of 1970-71 did not recover to the levels of previous years, nor did they approximate control station catches.

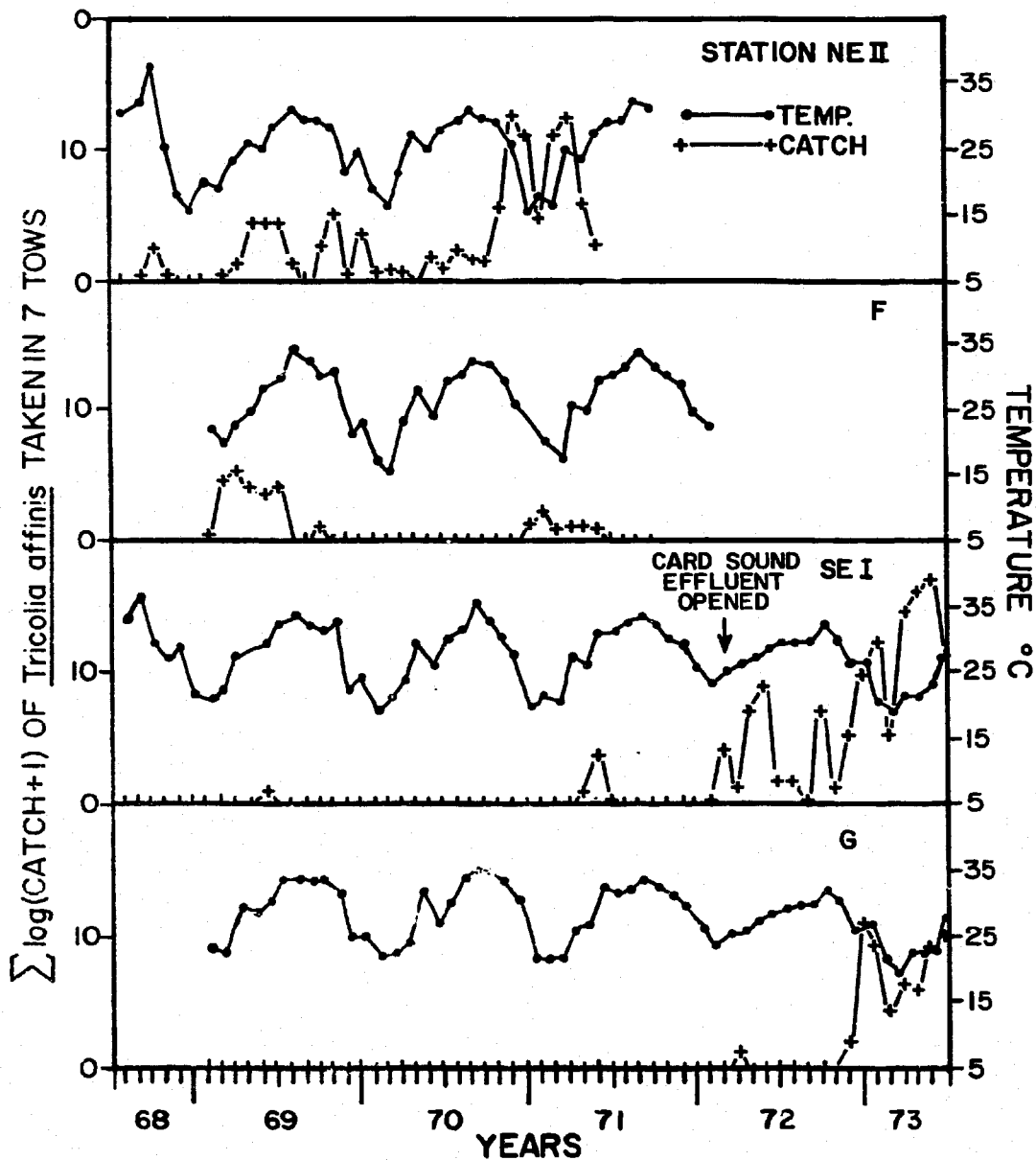


FIGURE 47. Catch, log (catch +1) of *Tricologia affinis* taken in seven tows and temperature at stations NE II, F, SE I and G.

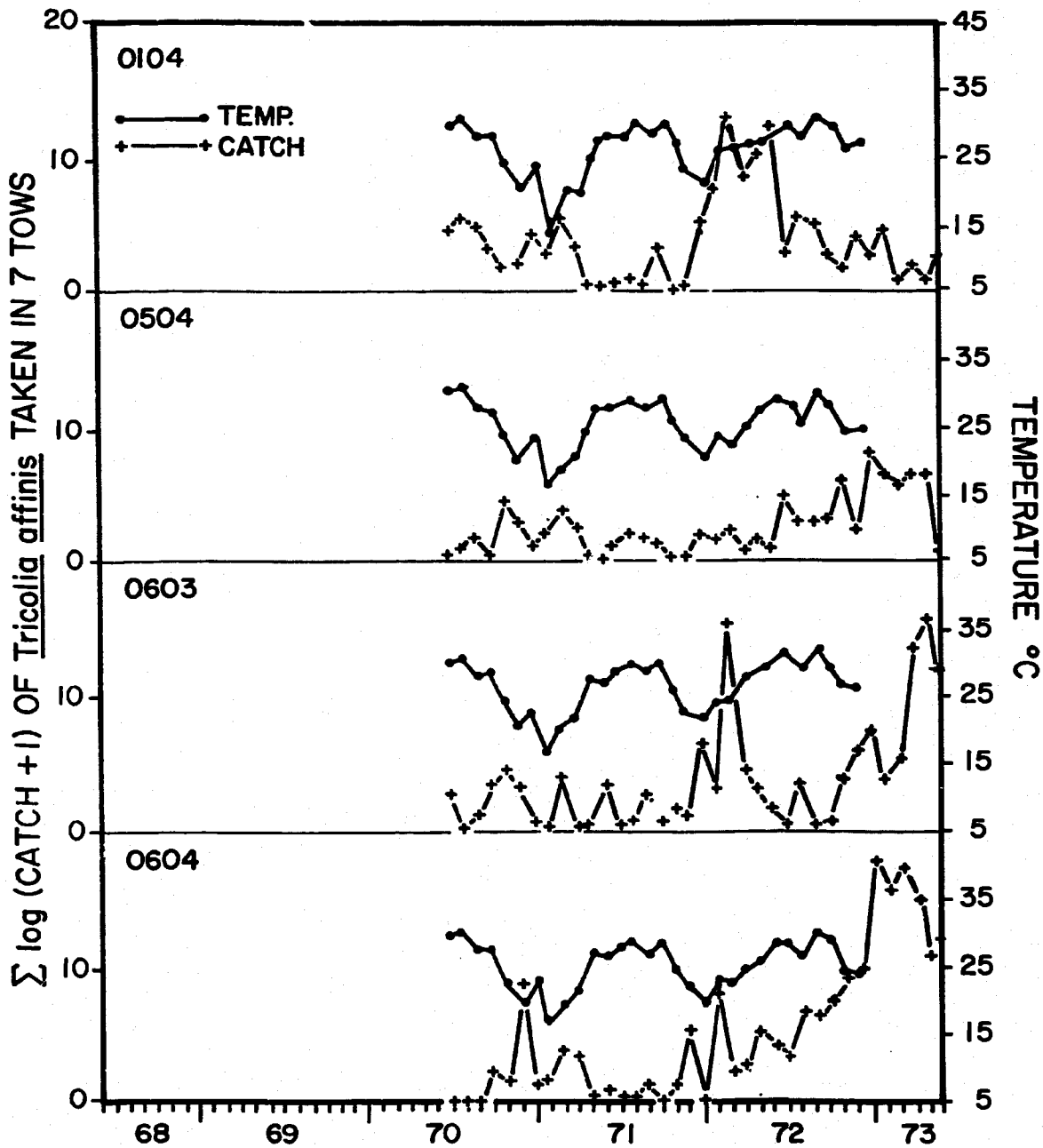


FIGURE 48. Catch, log (catch + 1) of *Tricolia affinis* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

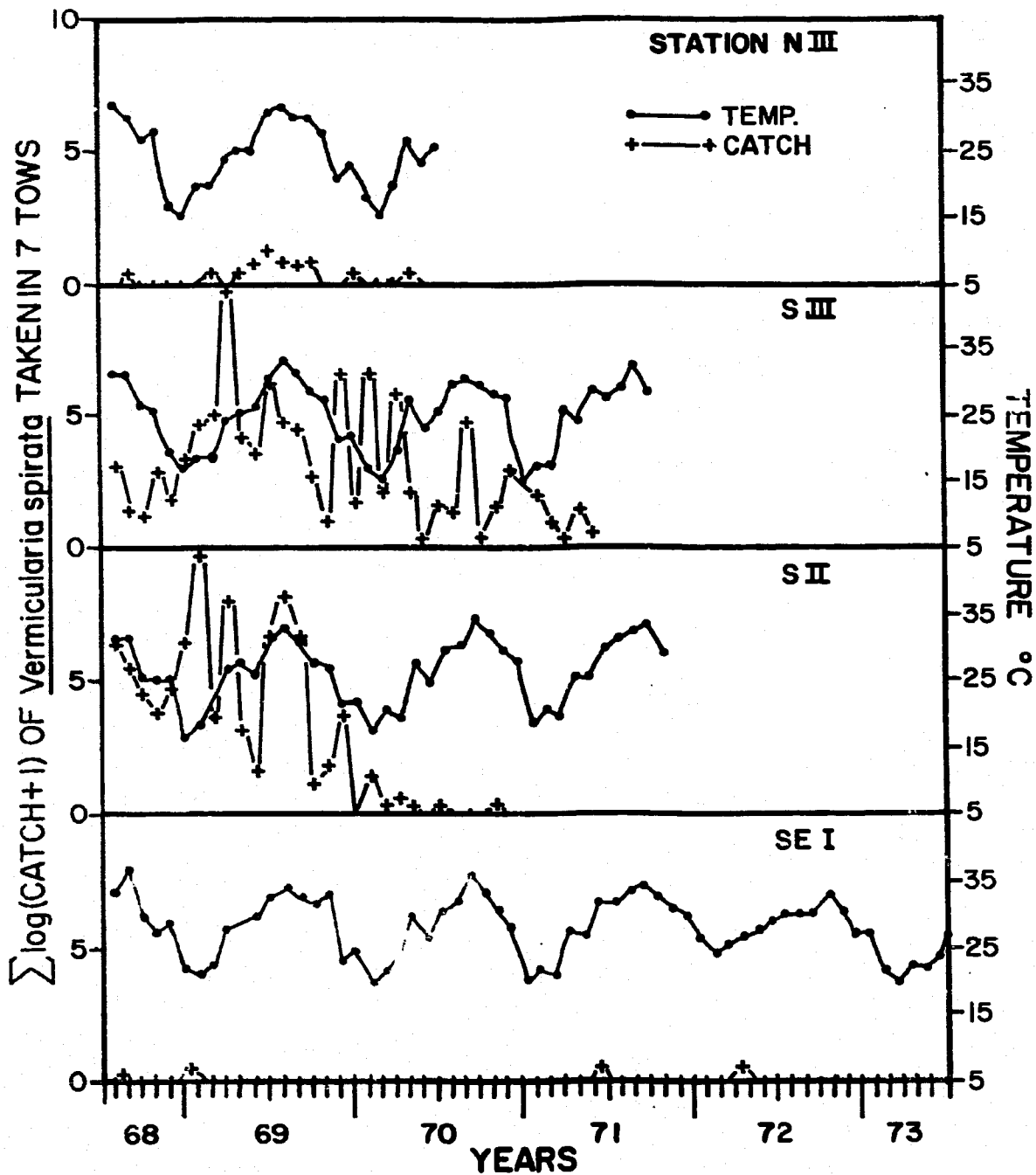


FIGURE 49. Catch, log (catch +1) of *Vermicularia spirata* taken in seven tows and temperature at stations N III, S III, S II and SE I.

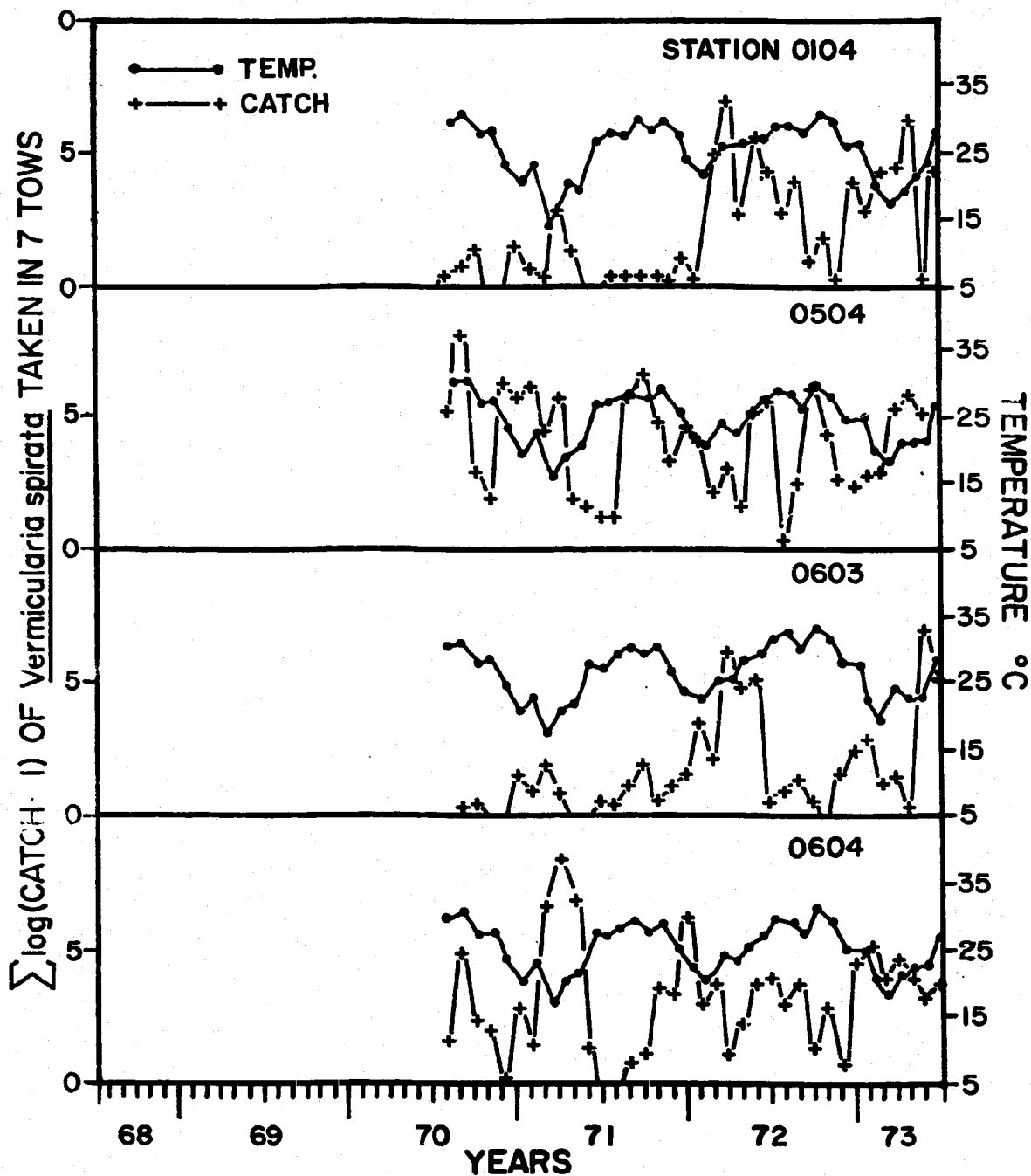


FIGURE 50. Catch, log (catch + 1) of *Vermicularia spirata* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

This may indicate that the annual stress placed on the environment by the effluent each summer has a progressively more limiting effect on the ability of Hippolyte to recolonize in more favorable temperature regime. The probable reason is the decline in vegetation (Thorhaug, 1974). At SE I, elevated 3.5°C above ambient, winter-spring peaks occurred in 1969, 1970 and 1971. In 1971 there is a fall peak and then low catches in the winter of 1971-72. In the spring of 1972 another peak occurred. The summer catches were low but apparently dilution improved the stress sufficiently to permit Hippolyte to remain. The winter of 1972-1973 produced catches comparable to control areas, especially after the closing of Grand Canal in February. At station G, elevated 4.5°C above ambient, catches were zero from January 1969-November 1972; then the dilution and closing of Grand Canal did allow some recovery at station G (Fig. 51).

Catches of Hippolyte were generally low in Card Sound and little can be discerned about temporal distribution from the available data.

The caridean, Thor floridanus, produced catches above the 99% confidence limits in Biscayne Bay in August and September 1968, June 1969, June, August and November 1970. Catches were low in November and December 1968, March, April and May 1969, April 1970 and January 1971. Figure 52 shows that generally, catches at control station NE II follow the temperature cycle and are high in summer and low in winter. At station S II, elevated 2°C, a similar pattern exists but in the summer of 1969 fell to near zero when the temperature approached 35°C. There was also a peak in catch in the winter of 1969-70. Overall catches were similar to the control on an annual basis, even though some shift in seasonality was seen. At SE I, elevated 3.5°C above ambient, catches were lower than at control stations. After dilution began, some recovery was noted and catches rose to levels similar to control stations after Grand Canal was closed. At G, elevated 4.5°C, almost no Thor were taken until dilution was practiced. After the closing of Grand Canal some recovery was noted.

Catches of Thor floridanus in Card Sound were above the 99% confidence limits in August 1970 and January 1971 and were low in February, April, May, June, July and August 1971, April 1972 and June 1972. In Card Sound it appeared that Thor was more common in winter. Perhaps the mild winters in 1971-72 and 1972-73 caused this change from that observed in Biscayne Bay. The greater depth in Card Sound, a temperature sink in winter, may also have been responsible for higher winter catches. There was a sharp rise in catch at 0603 when the Card Sound Canal first opened and this was associated with high catches of Laurencia entrained by the effluent current. During the summer of 1972, catches at 0603 were below 0504 and 0604 but were similar to those at 0104. At 0503, an inshore control station (not shown in Fig. 53), catches also decreased in this period. Thus, it does not appear that the Card Sound Canal adversely affected catches of Thor.

Catches of the mud crab, Neopanope packardii, were above the 99% confidence interval in January and February 1969, March 1970 and August 1970. Catches were low in April and May 1971. At control station NE II, catches were greatest in the summer of 1968 and thereafter peaks occurred in winter. At station F, elevated 2°C above ambient, catches were relatively high in 1969 and 1970 with a winter peak of abundance. In the fall of 1970 catches decreased and continued to decline until the station was discontinued in

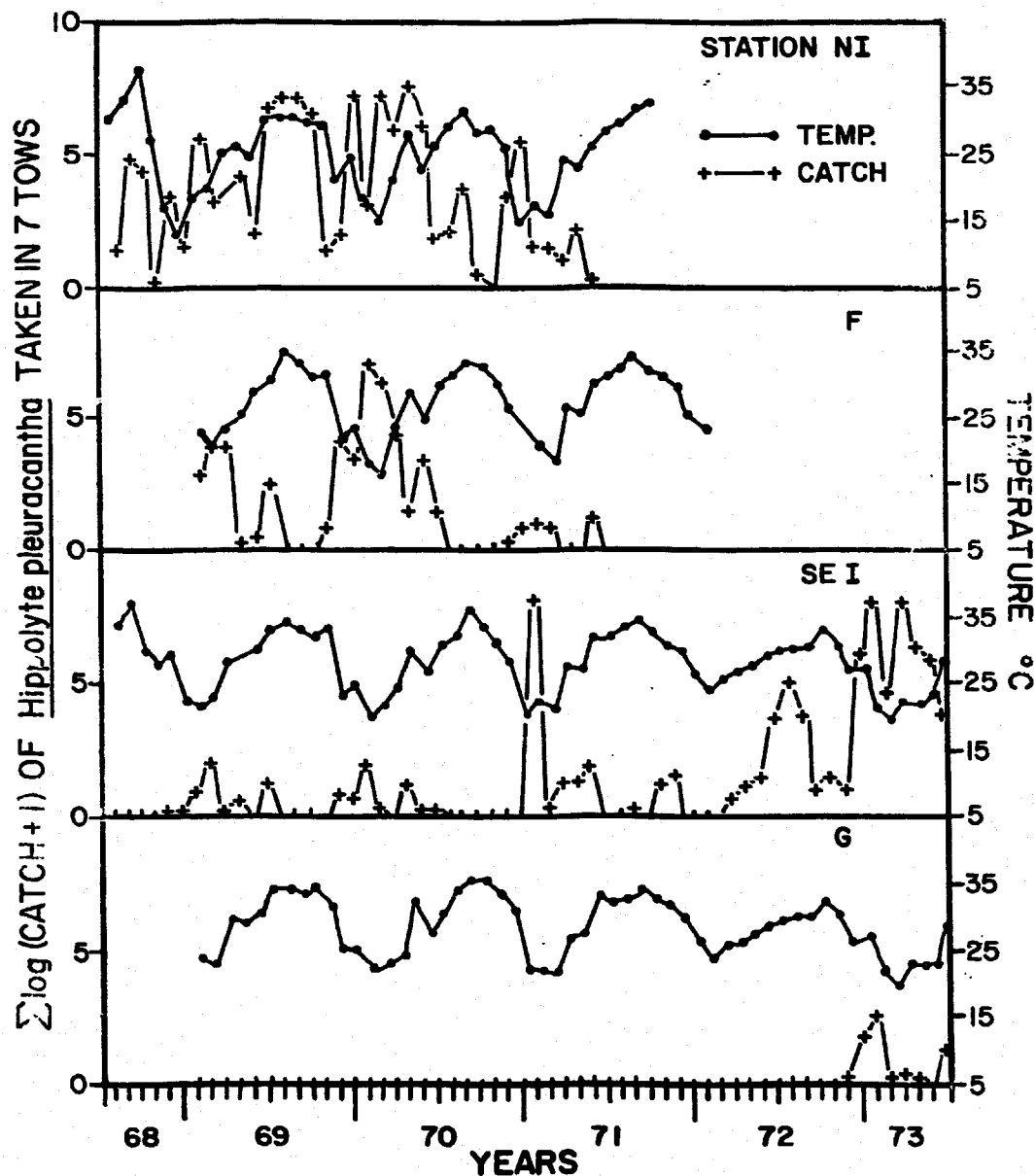


FIGURE 51. Catch, log (catch +1) of *Hippolyte pleuracantha* taken in seven tows and temperature at stations N I, F, SE I and G.

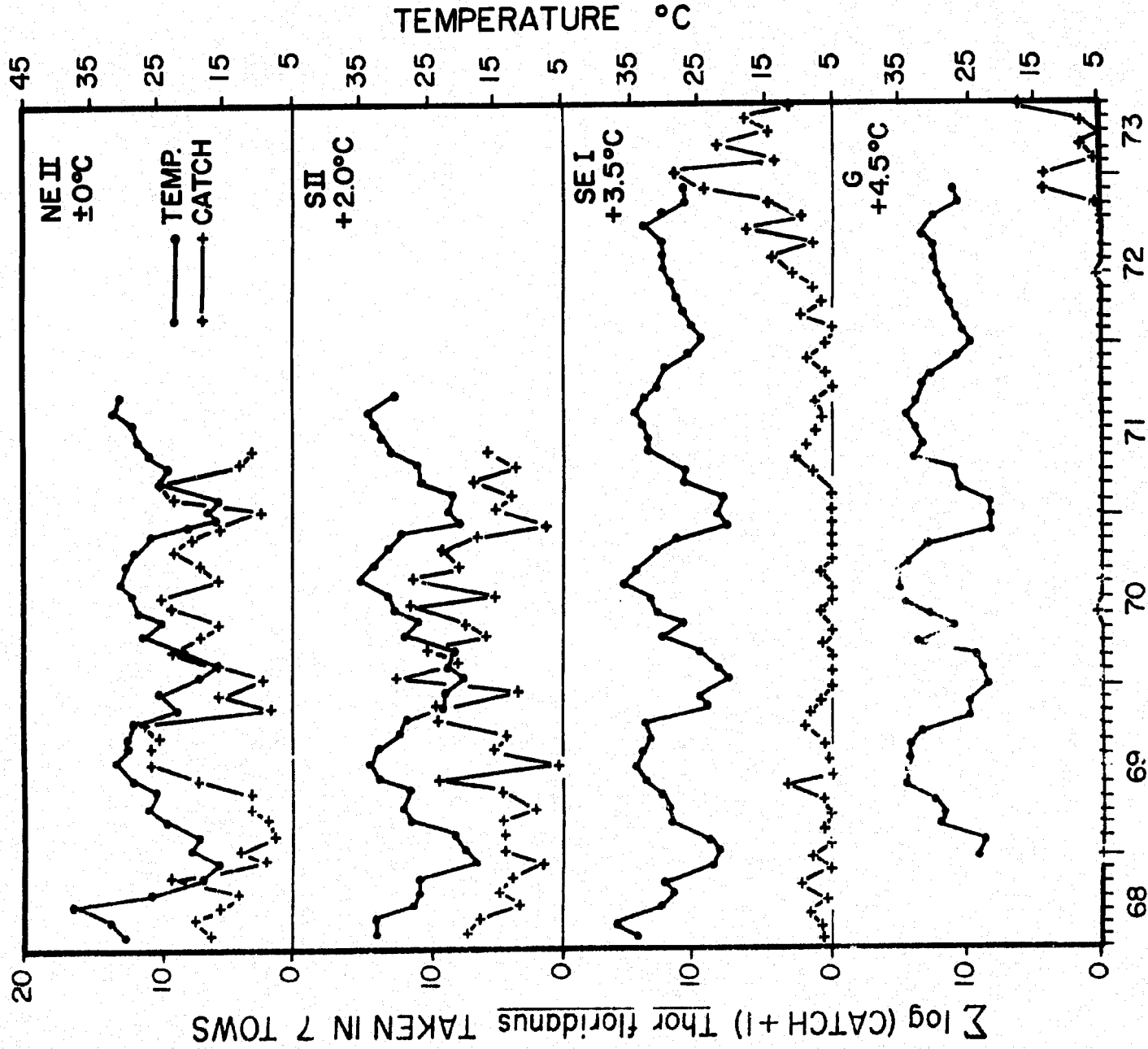


FIGURE 52. Catch, log (catch +1) of *Thor floridanus* taken in seven tows and temperature at stations NE II, S II, SE I and G.

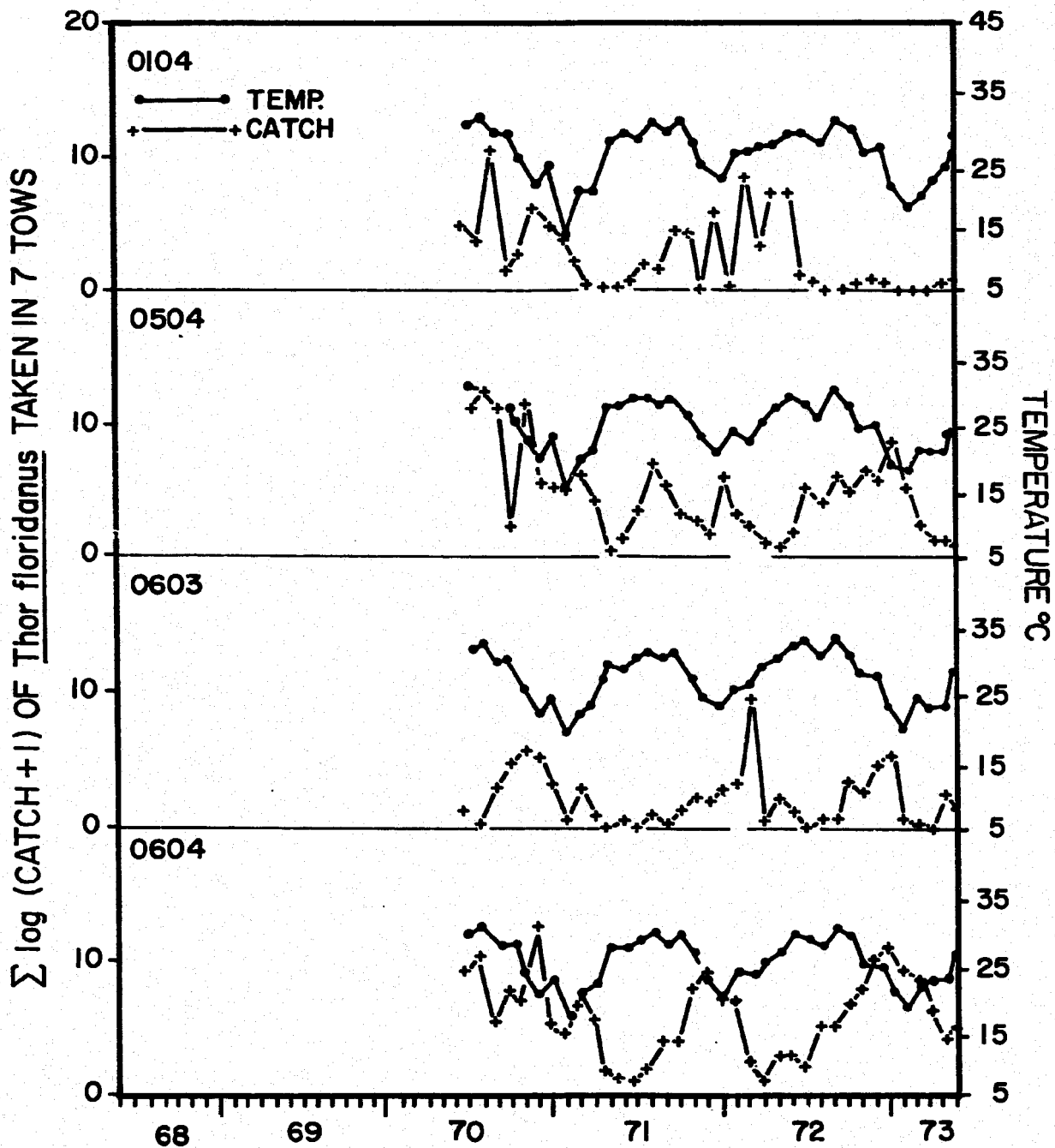


FIGURE 53. Catch, log (catch +1) of *Thor floridanus* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

September 1971. The decline may indicate the loss of Laurencia as a source of food and shelter. At SE I, elevated 3.5°C, catches were moderate in the fall and winter of 1968. Thereafter they decreased and remained low until the end of the study in June 1973. Only slight recovery was noted after dilution and closing of the Grand Canal (Fig. 54). At G, elevated 4.5°C above ambient, only a few specimens were taken during the period of operation of the Grand Canal. After the Canal closed a few individuals were taken indicating slight recovery.

In Card Sound catches were above the 99% confidence interval in July and August 1970, August 1972 and May 1973. Catches were low in April and May 1970. At control station 0104, catches were low for the first half of the study period and somewhat higher in the second half. The same pattern was exhibited at stations 0504 and 0604 except during the summer of 1970 when catches were high. At 0603 catches were moderate until the Card Sound Canal opened. After an initial high peak in March 1972, associated with high catches of Laurencia, Neopanope, catches were low compared to that of adjacent stations during operation of the Canal. A few months after closing the Canal, catches again were similar to adjacent stations (Fig. 55).

Catches of the hermit crab, Pagurus bonairensis, in Biscayne Bay were higher than the 99% confidence limit in August 1968, June 1969, March, July, August and September 1970. Catches were low in October, November and December 1970, February, April and May 1971. At control station N I catches were generally high in spring, summer and fall but low in winter. At stations S II, elevated 2°C above ambient, catches were about equal to control stations except during the winter of 1970 when catches were high. At station SE I, elevated 3.5°C, catches were low in summer and fall. In winter catches began to increase with a peak in spring. Then, as temperatures rose in early summer, catches dropped to near zero. In the summer of 1972 when dilution was used the drop was not as severe as in previous years. Although recovery after closing the Grand Canal in February 1973 was evident, the pattern is similar to seasonal recovery in previous years. At station G, elevated 4.5°C, catches were low and sporadic between January 1969-November 1972. Some apparent increase in catch rate occurred after closing Grand Canal (Fig. 56).

Catch rates in Card Sound were generally low (Fig. 57). In the Sound P. bonairensis meets competition from Paguristes tortugae which is nearly as abundant as Pagurus. Small shells are also frequently inhabited by Pagurapseude, and this competition for shells for juveniles may have provided advantages to the smaller species which were not common in the nearshore areas of Biscayne Bay which has greater salinity fluctuations.

Catches of the chicken liver sponge, Chondrilla nucula, in Biscayne Bay were greater than the 99% confidence interval in January 1969 and September and October 1970. Chondrilla was uncommon at inshore stations. At control station D, fall and winter catches exceeded spring and summer catches. At SE III, another mid-Bay control station, catches were lower. At station F, elevated 2°C, catches were generally high, while at SE II, also elevated 2°C, catches were low (Fig. 58). Chondrilla occurred attached to Thalassia at D and to Laurencia or Digenia at other stations. Salinity fluctuations appeared to control the distribution and the species

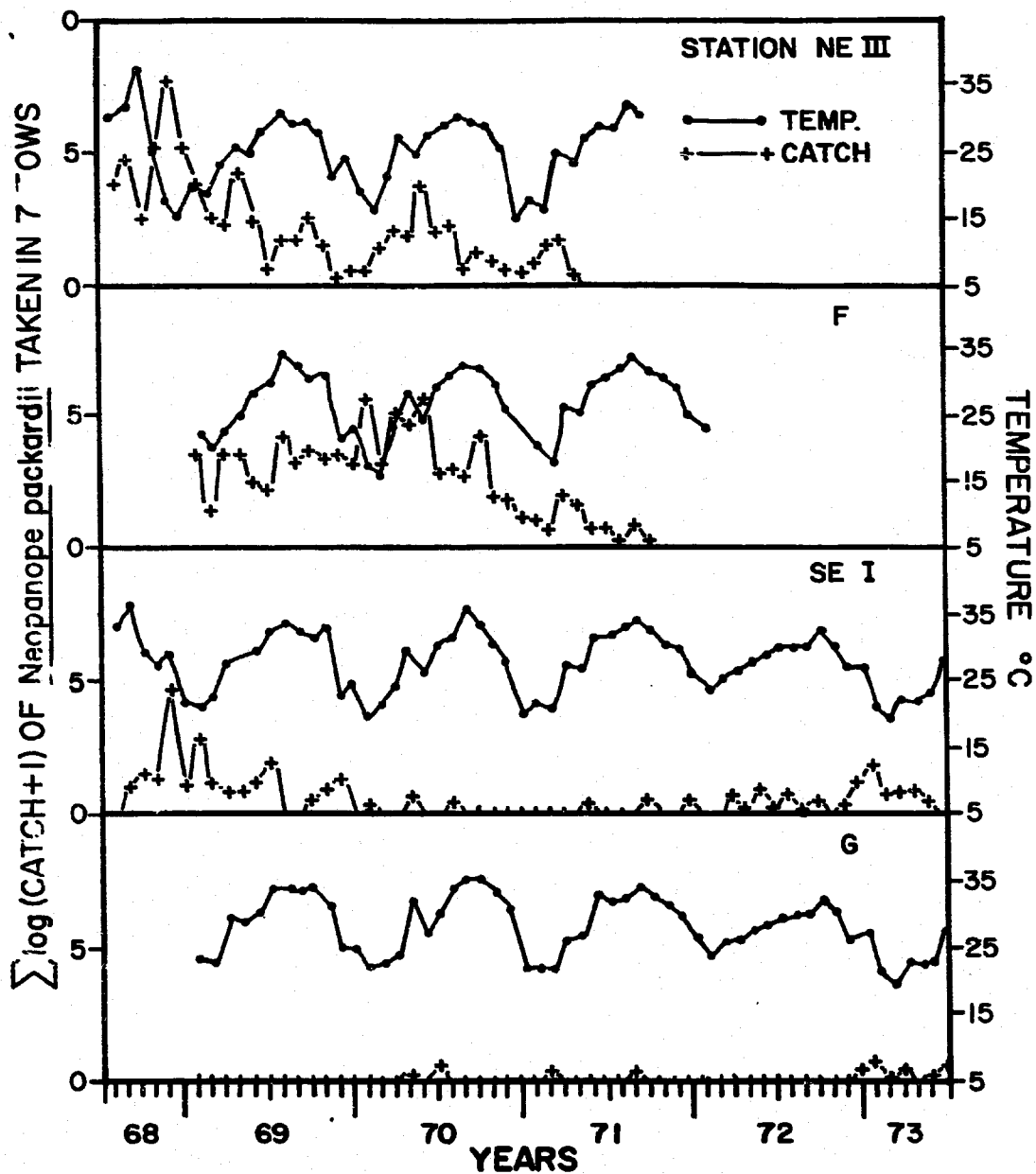


FIGURE 54. Catch, log (catch +1) of Neopanope packardii taken in seven tows and temperature at stations NE II, F, SE I and G.

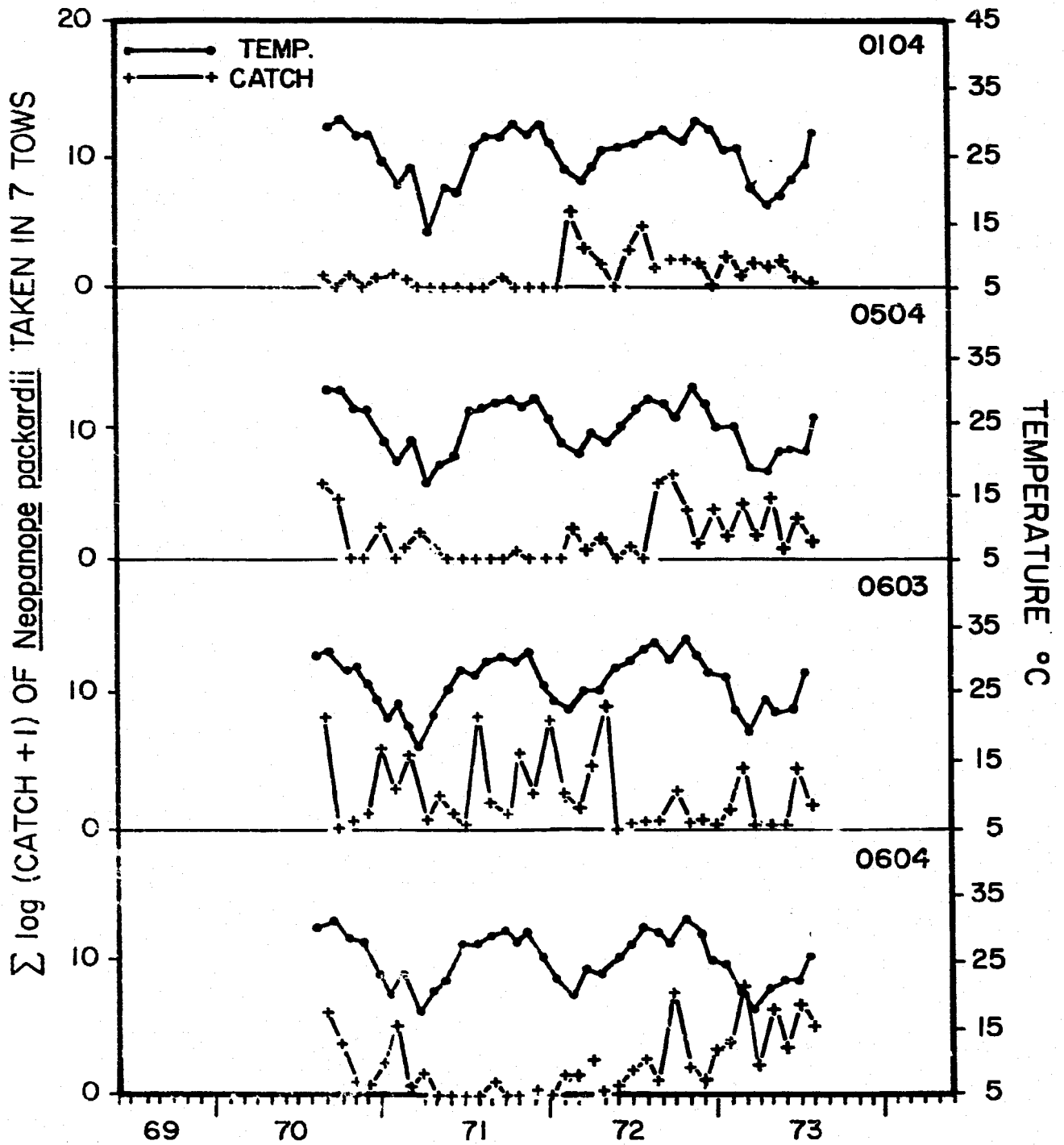


FIGURE 55. Catch $\log(\text{catch} + 1)$ of Neopanope packardii taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

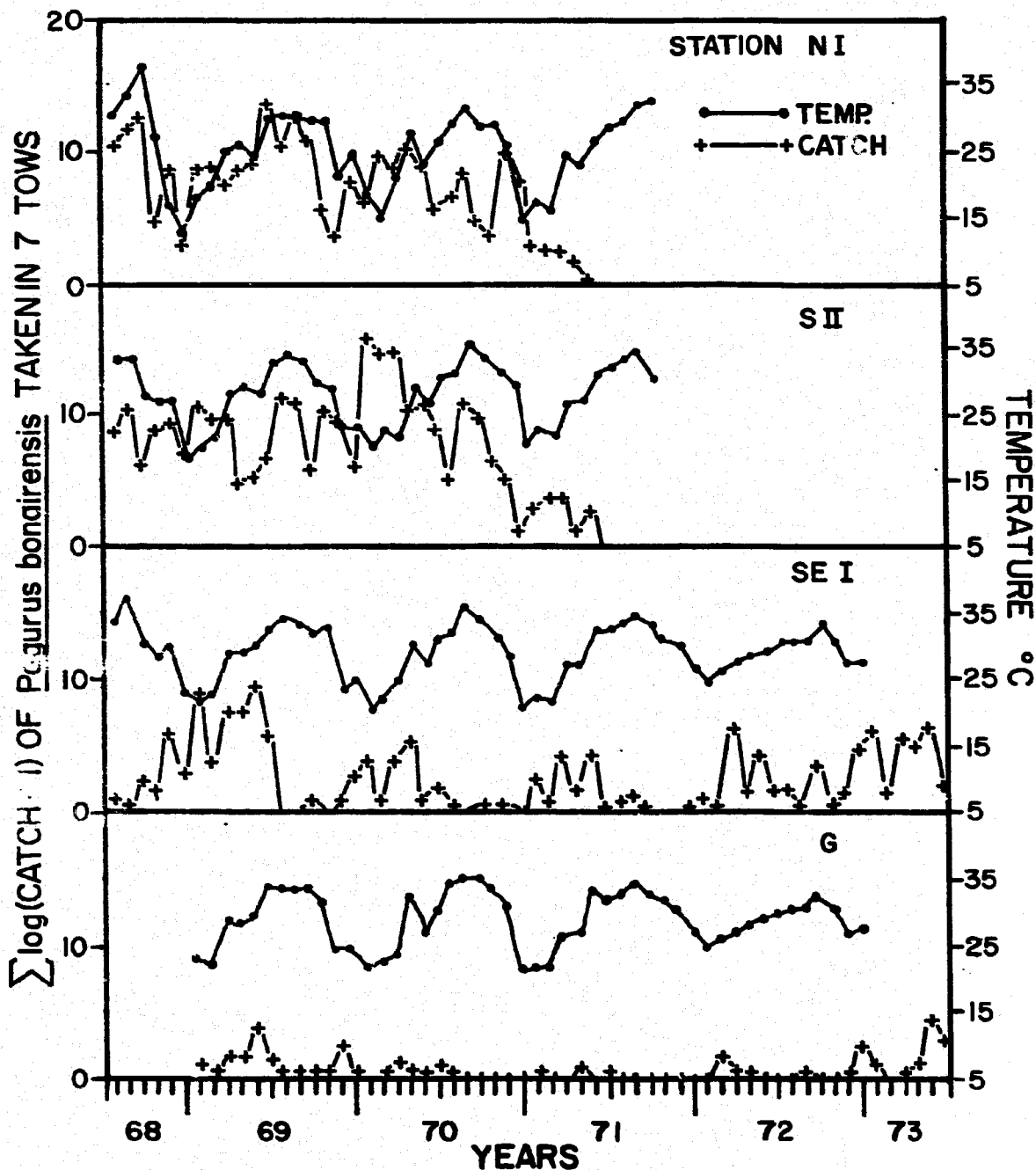


FIGURE 56. Catch, log (catch +1) of *Pagurus bonairensis* taken in seven tows and temperature at stations N I, S II, SE I and G.

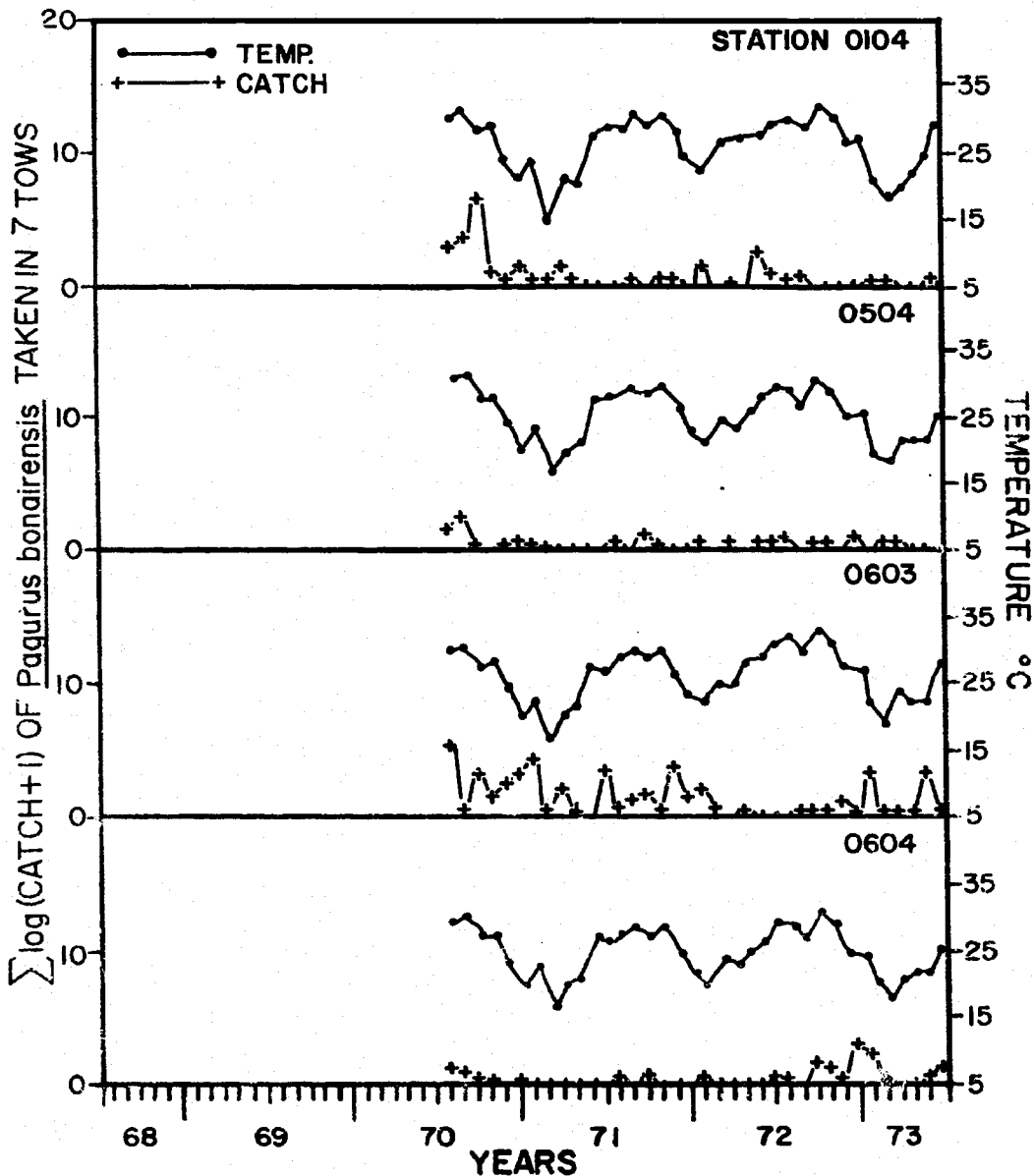


FIGURE 57. Catch, log (catch + 1) of *Pagurus bonairensis* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

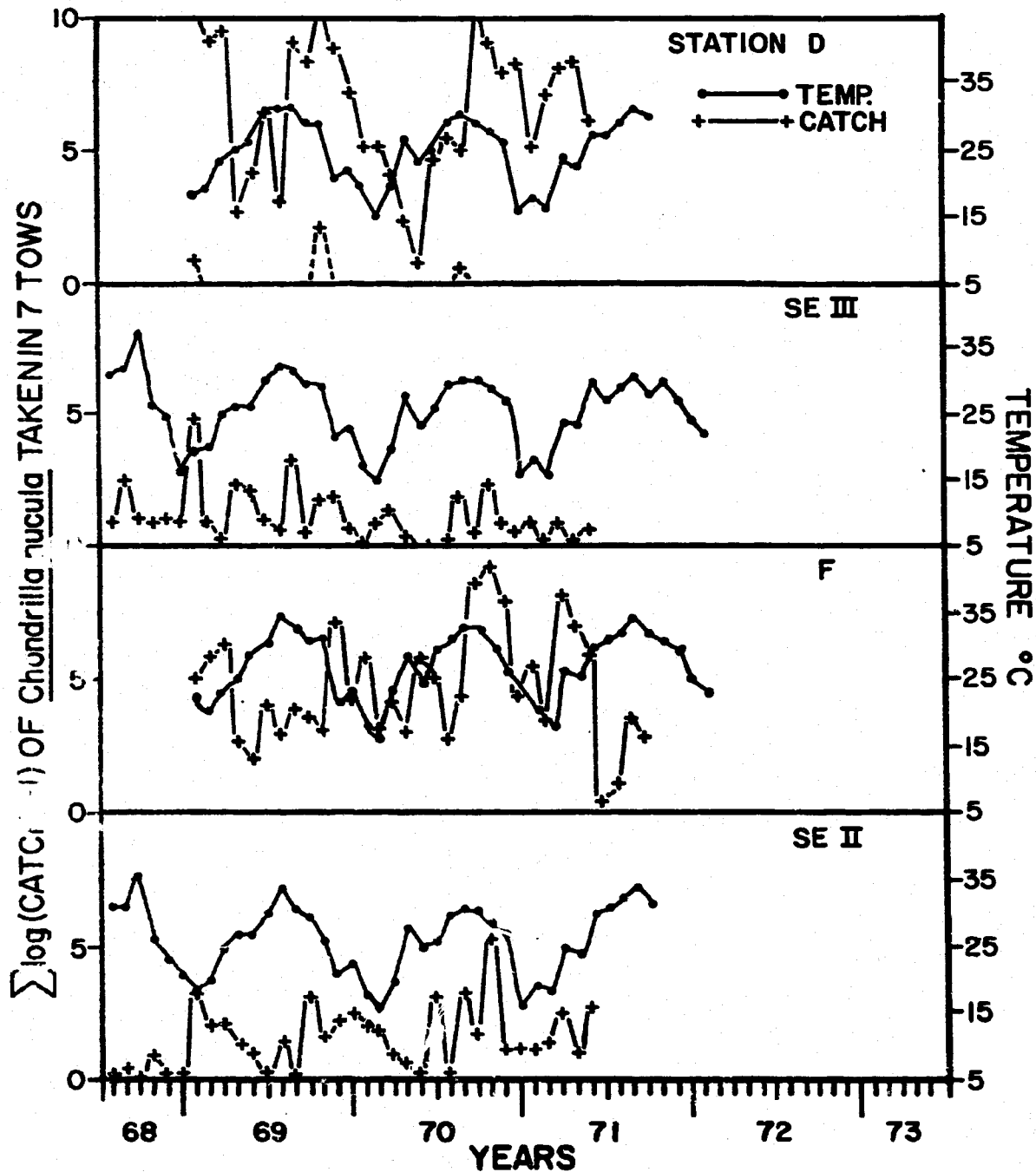


FIGURE 58. Catch, log (catch +1) of *Chondrilla nucula* taken in seven tows and temperature at stations D, SE III, F and SE II.

was uncommon at all inshore stations including those affected by the effluent.

In Card Sound catches of Chondrilla were high in November 1970, December 1972, January, February, March, April and May 1973. Catches were low in May, June and July 1970. Lower salinity appears to limit Chondrilla in the late spring and early summer. At control station 0104, catches were low in the first half of the study but increased especially in the dry fall and winter of 1972-73. Station 0603, at the mouth of the Card Sound Canal, produced low catches when hypersaline conditions were present, but increased during the fall of 1971. Record catches occurred in the first months following opening of the Card Sound Canal, but a drop in catches occurred in summer. Other stations, 0504 and 0604, showed similar decline in catch and the decrease probably results from lowered salinity. All stations showed another increase in the spring of 1973 after the canal was closed (Fig. 59).

The sea cucumber, Leptosynapta parvipatina, like the above species, had its abundance regulated by salinity but Leptosynapta also requires the presence of red algae, Laurencia spp. to be abundant. In Biscayne Bay catches were above the 99% confidence level in September 1968, March and December 1969 and January and February 1970. Catches were low in October 1968 and July and August 1969. At station E, and other control stations, catches were generally high in winter and low in summer. At F, elevated 2°C, catches were low until the dry spring of 1971, then catches increased. At SE 1, elevated 3.5°C above ambient, catches were low until dilution of the effluent began. Then recovery was noted. A similar picture results at station G, elevated 4.5°C (Fig. 60).

In Card Sound catches were high in January, February, November and December 1971, January, February and May 1972. Catches were low in July, September and October 1970, October 1972 and May 1973. At control station 0104, catches were generally low. The same was true at 0603, except for the period immediately following the opening of the Card Sound Canal. Another inshore station, 0503, had higher catches but it was further removed from fresh water inflow and produced more Laurencia. Stations 0504 and 0604 generally produced high catches with low periods occurring in summer rainy months (Fig. 61).

In June 1970, Roessler, Tabb, Rehner and Garcia (1974) summarized the data for Biscayne Bay stations to visually examine the effect of temperature on catches of vegetation and the dominant species. Scatter diagrams of the average of the transformed catch data were compared with the average temperature anomaly for each of the 26 stations. The mean catch value for all stations occurring at each 1°C anomaly interval was calculated and a trend line drawn through these points. For Prunum apicinum, Tricolia affinis and Hippolyte pleurogantha there appears to be a negative relation between temperature anomaly and catches. For all other species and vegetation there appears to be no relation between catches and temperature increases up to 2-3°C above ambient or an optimum at temperature anomalies of +2° to +3°C above ambient occurred. There was a sharp decrease at temperature anomalies in excess of 3°C.

In order to try to identify environmental variables regulating catch

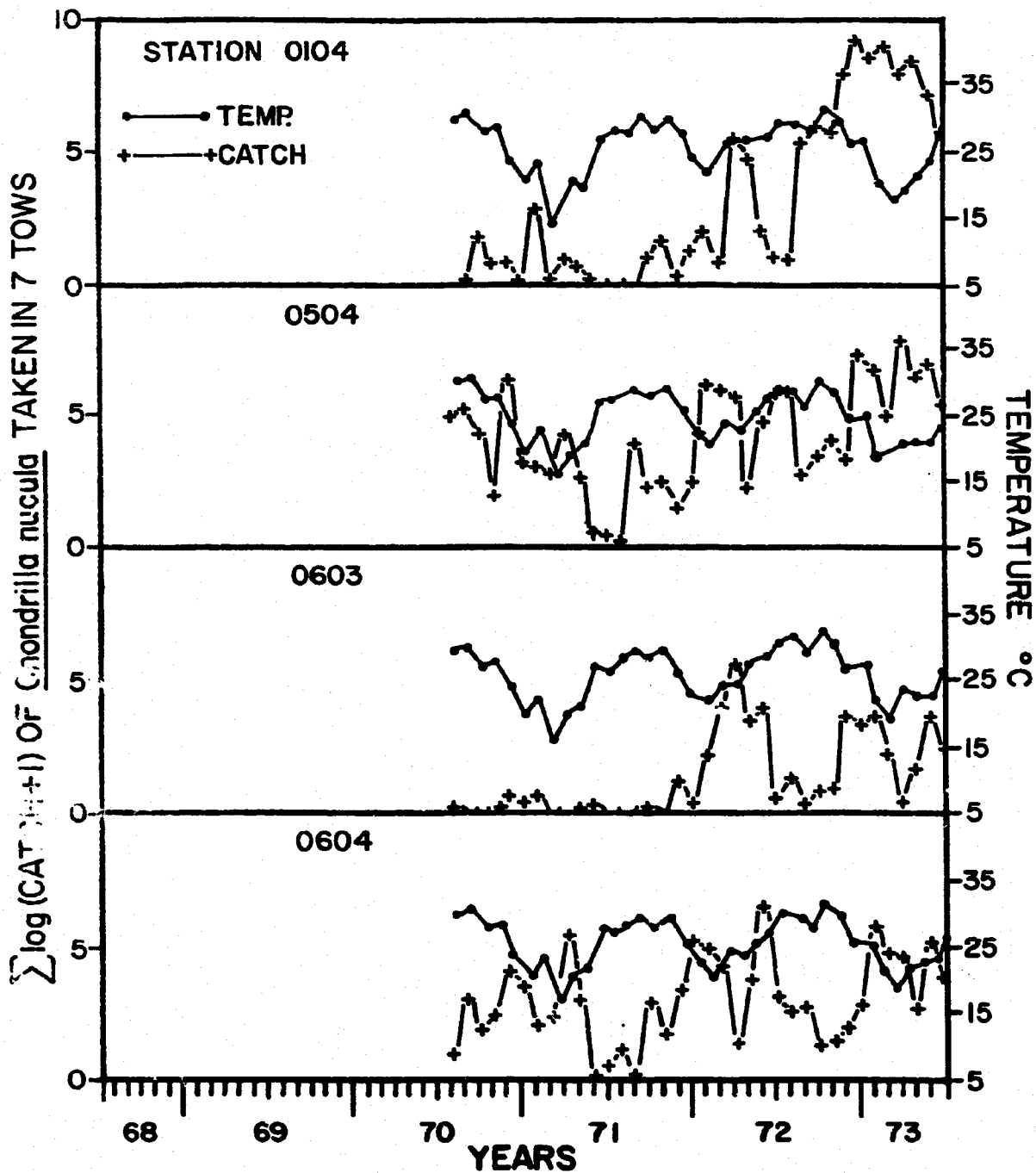


FIGURE 59. Catch, log (catch +1) of *Chondrilla nucula* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

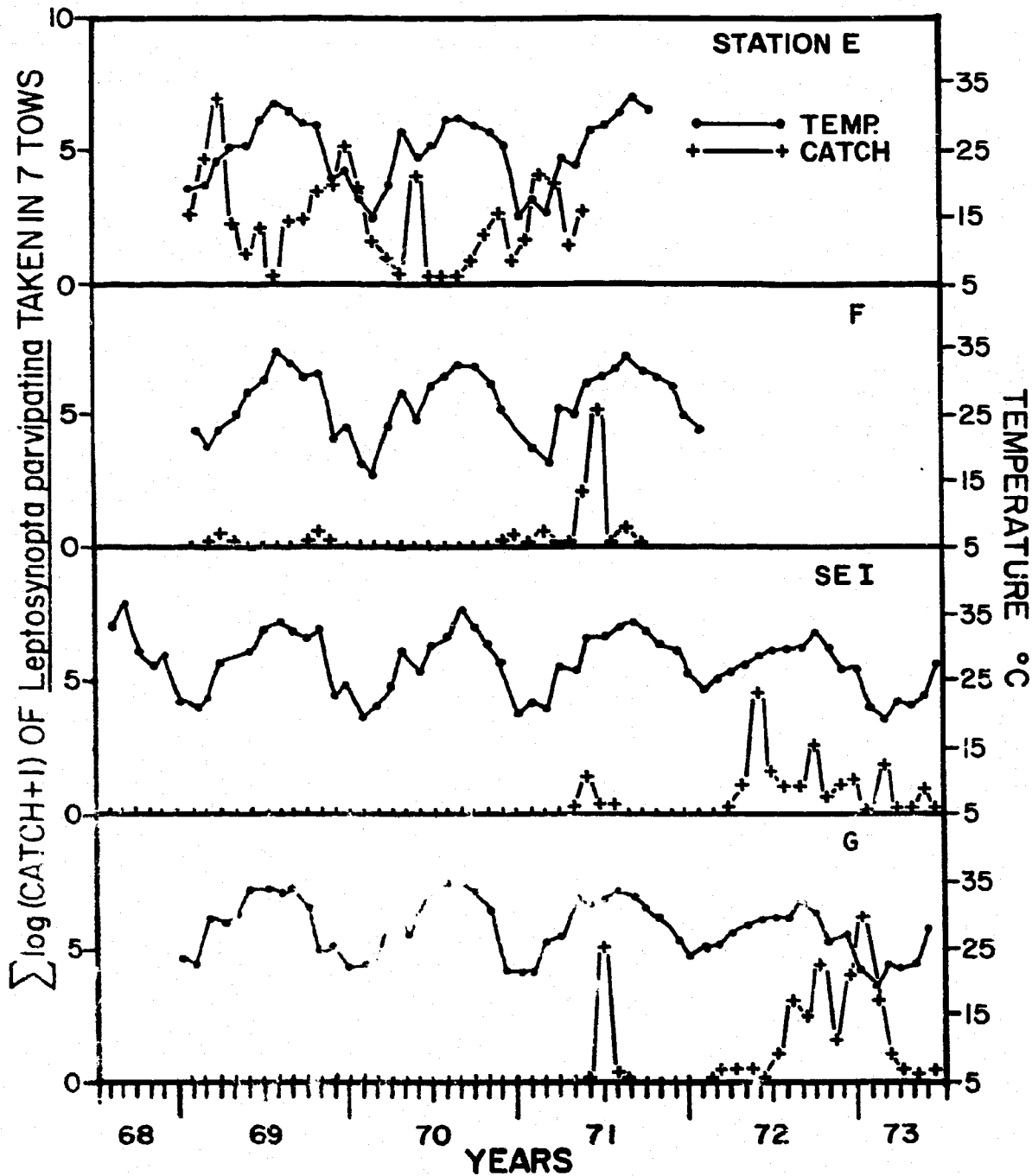


FIGURE 60. Catch, log (catch + 1) of *Leptosynapta parvipatina* taken in seven tows and temperature at stations E, F, SE I and G.

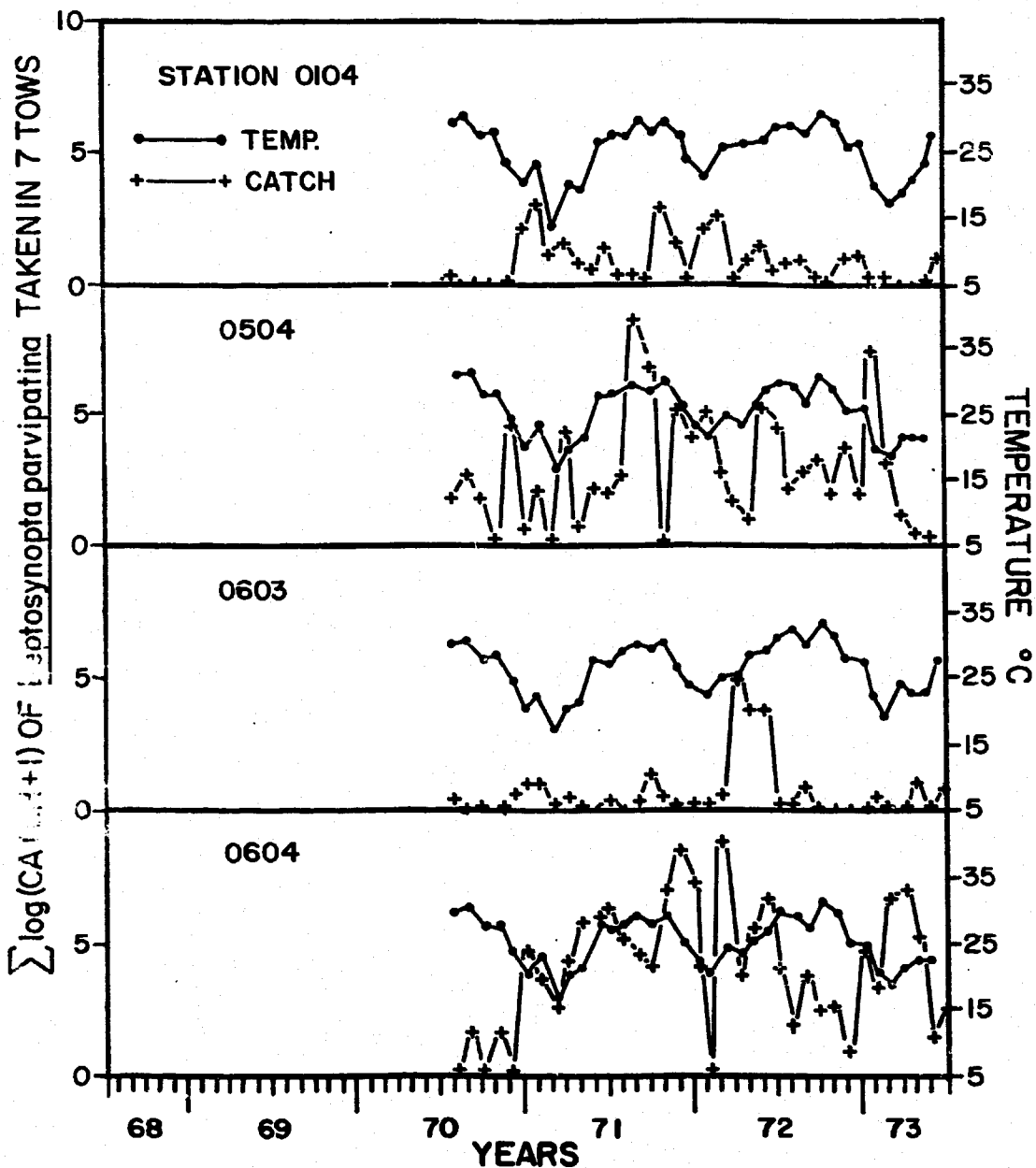


FIGURE 61. Catch, log (catch +1) of *Leptosynapta parvipatina* taken in seven tows and temperature at stations 0104, 0504, 0603 and 0604.

of the dominant animals and to determine the relative effect of the observed temperature range, we conducted stepwise multivariate regression techniques using dominant species in Biscayne Bay, Card Sound and the two areas combined. In addition to the environmental variables, vegetation weight, salinity and temperature, we used the absolute value of the difference between the observed salinity and temperature and their means. This was intended to linearize the peaked distribution seen in the above figures. However, as indicated by the high correlations between salinity and salinity deviation and temperature and temperature deviation, little was gained by adding these variables. Aside from the above mentioned correlations, the independent variables were relatively independent (Tables 35, 36 and 37).

Examining the simple correlation coefficients of the 14 species indicates two communities exist. Bulla, Cerithium muscarum, Prunum, Mitrella, Modulus, Hippolyte, Neopanope and Pagurus appear in one group with a negative relation to salinity and Cerithium eberneum, Vermicularia, Thor, Leptosynapta, Tricolia and Chondrilla appear in a second group with a positive relation to salinity. Vegetation generally is the most significant variable and shows the greatest variability.

In Card Sound, where temperature and salinity ranges were less than in Biscayne Bay catches of all species were most closely related to vegetation and in all cases the relation was positive. The inclusion of all 5 independent variables reduced the importance of vegetation on catches of Prunum where only salinity and salinity deviation were significant at $\alpha = .05$. For Bulla, Mitrella, Vermicularia and Pagurus the second variable selected was temperature. However, when the other independent variables were added, the effect of temperature was not significant. When all variables were included only vegetation was significant for Bulla, Mitrella and Vermicularia. Vegetation and salinity were significant to catches of the hermit crab, Pagurus. For all other species, salinity or salinity deviation was the second variable (Table 38). After inclusion of the 5 variables, salinity was significant for Modulus, Prunum, Thor and Neopanope.

The multiple regression explained from 3% of the variation in catch for Cerithium muscarum and Prunum apicinum to 62% for Thor floridanus.

In Biscayne Bay where temperature and salinity variations were larger than in Card Sound, the catches of 11 of the 14 species were best predicted by vegetation. Chondrilla was best predicted by salinity. Tricolia and Leptosynapta were best predicted by temperature and temperature deviation (Table 39). Inclusion of all 5 variables indicated that vegetation is the most significant variable for species other than Vermicularia, Tricolia and Leptosynapta. Of these, only Tricolia has a negative correlation with temperature. The other two are regulated by salinity. The multiple correlations generally explained 25 to 50% of the variability of catches for the inshore sediment community species Bulla, Cerithium muscarum, Prunum, Mitrella, Modulus, Hippolyte, Neopanope and Pagurus and was less efficient for mid-Bay species such as Vermicularia, Tricolia, Chondrilla and Leptosynapta. Thor floridanus appears to be a mid-Bay species, but will become abundant in inshore areas if salinity is relatively high. The multiple regression explains 20% of the variation in catches. Variations in catches of the cerith, C. eberneum, were not well explained by the regression (9%), even though this species appears commonly inshore.

Table 35. Simple correlation matrices (upper right excluding diagonal) and variance-covariance (lower left including diagonal) of abundant animal catch, Log (catch +1) per tow, vegetation (lbs), temperature ($^{\circ}$ C), salinity (ppt) absolute value of temperature minus mean temperature, and absolute value of salinity minus mean salinity in Biscayne Bay -- July 1968 - June 1973

	Veg.	Temp.	Sal.	Temp.- \bar{c}	Sal.- \bar{s}
Veg.	42.015*	-.016*	-.181*	-.017*	-.165*
Temp.	-.542*	28.751*	.109*	.998*	.086*
Sal.	-8.206*	4.114*	49.113*	.112*	.967*
Temp.- \bar{c}	-.059*	2.909*	.428*	.295*	.087*
Sal.- \bar{s}	-.794*	.342*	5.032*	.035*	.551*

Species	Catch	Veg.	Temp.	Sal.	Temp.- \bar{t}	Sal.- \bar{s}
<u><i>Bulla umbilicata</i></u>						
Catch (r)	1.000	.488	.114	-.225	.117	-.189
Catch (V-COV)	.087	.933	.181	-.464	.019	-.041
<u><i>Cerithium eberneum</i></u>						
Catch (r)	1.000	.286	.049	-.013	.051	-.002
Catch (V-COV)	.043	.387	.054	-.018	.006	<-.001
<u><i>Cerithium muscarum</i></u>						
Catch (r)	1.000	.640	.030	-.242	.030	-.201
Catch (V-COV)	.171	1.716	.067	-.703	.007	-.062
<u><i>Nereis lumata</i></u>						
Catch (r)	1.000	.587	-.093	-.112	-.088	-.090
Catch (V-COV)	.206	1.727	-.226	-.356	-.022	-.030
<u><i>Modulus modolus</i></u>						
Catch (r)	1.000	.555	.048	-.057	.049	-.042
Catch (V-COV)	.138	1.336	0.92	-.147	.010	-.012
<u><i>Prunum apicinum</i></u>						
Catch (r)	1.000	.685	-.017	-.168	-.017	-.137
Catch (V-COV)	.051	1.002	-.021	-.266	-.002	-.023
<u><i>Tricolia affinis</i></u>						
Catch (r)	1.000	.126	-.192	.170	-.191	.161
Catch (V-COV)	.117	.279	-.351	.406	-.035	.041
<u><i>Vermicularia spirata</i></u>						
Catch (r)	1.000	.140	-.016	-.117	-.016	-.083
Catch (V-COV)	.057	.217	-.020	-.195	-.002	-.015

Table 35. Continued

Species	Catch	Veg.	Temp.	Sal.	Temp.- \bar{r}	Sal.- \bar{s}
<u>Hippolyte pleuracantha</u>						
Catch (r)	1.000	<u>.597</u>	-.198	-.201	-.196	-.168
Catch (V-COV)	.089	1.155	-.317	-.421	-.032	-.037
<u>Thor floridanus</u>						
Catch (r)	1.000	<u>.351</u>	-.019	.192	-.022	.172
Catch (V-COV)	.194	1.002	-.044	.592	-.005	.056
<u>Neopanope packardii</u>						
Catch (r)	1.000	<u>.595</u>	-.065	-.310	-.060	-.249
Catch (V-C V)	.355	2.297	-.207	-1.294	-.019	-.110
<u>Pagurus bonairensis</u>						
Catch (r)	1.000	<u>.506</u>	.080	-.015	.081	.009
Catch (V-COV)	.248	1.635	.213	-.051	.022	.003
<u>Chondrilla nucula</u>						
Catch (r)	1.000	.975	-.045	<u>.148</u>	-.042	.142
Catch (V-COV)	.066	.125	-.062	<u>.267</u>	-.006	.027
<u>Leptosynapta parvipatina</u>						
Catch (r)	1.000	-.053	-.128	.053	<u>-.131</u>	.054
Catch (V-COV)	.063	-.086	-.172	.092	<u>-.018</u>	.010

_____ Most significant variable
 * Same for all species
 r correlation vector
 V-COV variance covariance vector

Table 36. Simple correlation matrices (upper right excluding diagonal) and variance-covariance (lower left including diagonal) of abundant animal catch, Log (catch +1) per tow, vegetation (lbs), temperature (°C), salinity (ppt), absolute value of temperature minus mean temperature, and absolute value of salinity minus mean salinity in Card Sound — July 1970 - June 1973

	Veg.	Temp.	Sal.	Temp.- \bar{t}	Sal.- \bar{s}
Veg.	58.135*	-.165*	-.105*	-.157*	-.098*
Temp.	-5.179*	16.848*	-.058*	.999*	-.062*
Sal.	-2.388*	-.718*	8.946*	-.063*	.999*
Temp.- \bar{t}	-.505*	1.727*	-.079*	.763*	-.066*
Sal.- \bar{s}	-.191*	-.065*	.763*	-.007*	.065*

Species	Catch	Veg.	Temp.	Sal.	Temp.- \bar{t}	Sal.- \bar{s}
<u>Bulla umbilicata</u>						
Catch (r)	1.000	.315	.156	-.223	.157	-.219
Catch (V-COV)	.037	.463	.123	-.129	.013	-.011
<u>Cerithium eberneum</u>						
Catch (r)	1.000	.356	-.084	-.162	-.078	-.157
Catch (V-COV)	.036	.513	-.065	-.092	-.006	-.008
<u>Cerithium muscarum</u>						
Catch (r)	1.000	.135	-.035	-.083	-.034	-.079
Catch (V-COV)	.006	.081	-.011	-.019	-.001	-.002
<u>Mitrella lunata</u>						
Catch (r)	1.000	.229	.051	-.065	.050	-.061
Catch (V-COV)	.001	.053	.006	-.006	.001	<-.001
<u>Modulus modulus</u>						
Catch (r)	1.000	.623	-.047	-.150	-.041	-.143
Catch (V-COV)	.013	.536	-.022	-.050	-.002	-.004
<u>Prunum apicinum</u>						
Catch (r)	1.000	-.132	-.019	-.045	-.014	-.040
Catch (V-COV)	.001	-.028	-.002	-.004	<-.001	<-.001
<u>Tricolia affinis</u>						
Catch (r)	1.000	.542	-.130	-.254	-.124	-.251
Catch (V-COV)	.276	2.172	-.281	-.399	-.027	-.034
<u>Vermicularia spirata</u>						
Catch (r)	1.000	.525	-.173	-.115	-.167	-.109
Catch (V-COV)	.119	1.383	-.246	-.119	-.024	-.010

Table 36. Continued

Species	Catch	Veg.	Temp.	Sal.	Temp.- \bar{t}	Sal.- \bar{s}
<u>Hippolyte pleuracantha</u>						
Catch (r)	1.000	<u>.312</u>	.088	-.187	.086	-.185
Catch (V-COV)	.004	.150	.023	-.035	.002	-.003
<u>Thor floridanus</u>						
Catch (r)	1.000	<u>.777</u>	-.143	-.123	-.136	-.113
Catch (V-COV)	.383	3.663	-.364	-.227	-.035	-.018
<u>Neopanope packardii</u>						
Catch (r)	1.000	<u>.468</u>	.000	-.220	.004	-.214
Catch (V-COV)	.039	.704	<.001	-.130	<.001	-.011
<u>Pagurus bonaiensis</u>						
Catch (r)	1.000	<u>.408</u>	.074	-.185	.075	-.178
Catch (V-COV)	.037	.602	.059	-.107	.006	-.009
<u>Chondrilla nucula</u>						
Catch (r)	1.000	<u>.464</u>	-.148	-.189	-.141	-.185
Catch (V-COV)	.154	1.390	-.239	-.223	-.023	-.019
<u>Leptosynapta parvipatina</u>						
Catch (r)	1.000	<u>.294</u>	-.119	.112	-.115	.112
Catch (V-COV)	.109	.741	-.161	.110	-.016	.009

_____ Most significant variable
 * Same for all species
 r correlation vector
 V-COV variance covariance vector

Table 37. Simple correlation matrices (upper right excluding diagonal) and variance-covariance (lower left including diagonal) of abundant animal catch, Log (catch +1) per tow, vegetation (lbs), temperature (°C), salinity (ppt), absolute value of temperature minus mean temperature, and absolute value of salinity minus mean salinity in Biscayne Bay -- July 1968 - June 1973 and Card Sound -- July 1970 - June 1973

	Veg.	Temp.	Sal.	Temp.- \bar{t}	Sal.- \bar{s}
Veg.	47.027*	-.058*	-.140*	-.057*	-.129*
Temp.	-1.989*	25.049*	.057*	.998*	.043*
Sal.	-6.445*	-.198*	45.082*	.064*	.973*
Temp.- \bar{t}	-.198*	2.540*	.217*	.259*	.049*
Sal.- \bar{s}	-.611*	.150*	4.503*	.017*	.475*

Species	Catch	Veg.	Temp.	Sal.	Temp.- \bar{t}	Sal.- \bar{s}
<u><i>Bulla umbilicata</i></u>						
Catch (r)	1.000	.427	.126	-.241	.127	-.210
Catch (V-COV)	.072	.786	.169	-.435	.017	-.039
<u><i>Cerithium eberneum</i></u>						
Catch (r)	1.000	.305	.012	.011	.016	.020
Catch (V-COV)	.041	.426	.012	.015	.002	.003
<u><i>Cerithium muscarum</i></u>						
Catch (r)	1.000	.480	.038	-.343	.034	-.303
Catch (V-COV)	.134	1.205	.070	-.844	.006	-.077
<u><i>Mitrella lunata</i></u>						
Catch (r)	1.000	.440	-.061	-.237	-.061	-.209
Catch (V-COV)	.159	1.204	-.122	-.634	-.012	-.058
<u><i>Modulus modiolus</i></u>						
Catch (r)	1.000	.481	.050	-.185	.047	-.163
Catch (V-COV)	.108	1.086	.082	-.410	.008	-.037
<u><i>Prunum apicinum</i></u>						
Catch (r)	1.000	.522	-.003	-.258	-.006	-.226
Catch (V-COV)	.038	.697	-.003	-.337	-.001	-.030
<u><i>Tricolia affinis</i></u>						
Catch (r)	1.000	.301	-.167	.163	-.162	.160
Catch (V-COV)	.177	.869	-.353	.461	-.035	.047
<u><i>Vermicularia spirata</i></u>						
Catch (r)	1.000	.285	-.078	.070	-.072	.080
Catch (V-COV)	.088	.579	-.116	.139	-.011	.016

Table 37. Continued

Species	Catch	Veg.	Temp.	Sal.	Temp.- \bar{t}	Sal.- \bar{s}
<u>Hippolyte pleuracantha</u>						
Catch (r)	1.000	.469	-.147	-.301	-.148	-.267
Catch (V-COV)	.068	.841	-.192	-.592	-.020	-.048
<u>Thor floridanus</u>						
Catch (r)	1.000	.507	-.069	.226	-.065	.211
Catch (V-COV)	.278	1.831	-.181	.799	-.018	.077
<u>Neopanope packardii</u>						
Catch (r)	1.000	.487	-.037	-.408	-.036	-.352
	.291	1.801	-.099	-1.476	-.010	-.131
<u>Pagurus bonaiensis</u>						
Catch (r)	1.000	.420	.088	-.176	.085	-.143
Catch (V-COV)	.208	1.313	.201	-.539	.020	-.045
<u>Chondrilla nucula</u>						
Catch (r)	1.000	.232	-.088	.203	-.080	.196
Catch (V-COV)	.106	.518	-.143	.444	-.013	.044
<u>Leptosynapta parvipatina</u>						
Catch (r)	1.000	.085	-.129	.192	-.126	.180
Catch (V-COV)	.086	.171	-.190	.379	-.019	.036

_____ Most significant variable
 * Same for all species
 r correlation vector
 V-COV variance covariance vector

Table 38. Summary of stepwise multiple regression between animal catch Log (catch +1) per tow, and vegetation, temperature, salinity, absolute value of temperature minus mean temperature and absolute value of salinity minus mean salinity in Card Sound -- July 1970 - June 1973

	b	R ²	F
<u>Cerithium eberneum</u>	a = -5.70191		
Vegetation	.00780	.1268	36.0629**
Salinity	-.15329	.1426	3.0999ns
Sal.- \bar{s}	1.70461	.1493	2.7908ns
Temperature	-.04855	.1503	1.1036ns
Temp.- \bar{t}	.45933	.1529	1.0426ns
<u>Cerithium muscarum</u>	a = -2.12723		
Vegetation	.00113	.0183	3.9625*
Salinity	-.06660	.0231	2.9955ns
Sal.- \bar{s}	.75904	.0313	2.8336ns
Temp.- \bar{t}	-.00247	.0315	.0598ns
<u>Modulus modulus</u>	a = -3.50785		
Vegetation	.00894	.3884	190.2238**
Salinity	-.10116	.3956	5.4231*
Sal.- \bar{s}	1.15070	.4037	5.1087*
Temp.- \bar{t}	.09499	.4069	.1791ns
Temperature	-.00818	.4072	.1260ns
<u>Prunum apicinum</u>	a = -1.18206		
Vegetation	.00036	.0175	3.1583ns
Salinity	-.02854	.0185	4.4146*
Sal.- \bar{s}	.33178	.0298	4.3443*
Temp.- \bar{t}	.09274	.0299	1.7465ns
Temperature	-.00946	.0348	1.7230ns
<u>Hippolyte pleuracantha</u>	a = .14711		
Vegetation	.00271	.0975	39.3549**
Salinity	-.02222	.1218	.5877ns
Temperature	.03272	.1388	4.5194*
Temp.- \bar{t}	-.29872	.1492	3.9769*
Sal.- \bar{s}	.22269	.1503	.4296ns

* significant at 95%

** significant at 99%

ns not significant

Table 38. Continued

	b	R ²	F
<u>Thor floridanus</u>	a = -22.67604		
Vegetation	.06065	.6030	451.3853**
Salinity	-.65674	.6047	11.7734**
Sal.- \bar{s}	7.59855	.6177	11.4752**
Temperature	-.04967	.6178	.2390ns
Temp.- \bar{t}	.46735	.6180	.2233ns
<u>Neopanope packardii</u>	a = -5.81409		
Vegetation	.01154	.2188	83.2159**
Salinity	-.19808	.2485	5.4556*
Sal.- \bar{s}	2.19188	.2584	4.8637*
Temperature	.01242	.2636	.0761ns
Temp.- \bar{t}	-.08656	.2637	.0390ns
<u>Chondrilla nucula</u>	a = -6.83599		
Vegetation	.02148	.2153	71.3650**
Salinity	-.16257	.2354	.9093ns
Temperature	-.13665	.2424	2.2801ns
Temp.- \bar{t}	1.25443	.2466	2.0281ns
Sal.- \bar{s}	1.68419	.2481	.7106ns
<u>Leptosynapta parvipatina</u>	a = 3.28801		
Vegetation	.01305	.0865	31.5833**
Salinity	.14983	.1070	.9260ns
Temperature	-.05359	.1106	.4204ns
Sal.- \bar{s}	-1.57363	.1128	.7437ns
Temp.- \bar{t}	.47215	.1137	.3445ns
<u>Tricolia affinis</u>	a = 3.28851		
Vegetation	.03518	.2938	121.3309**
Sal.- \bar{s}	-1.08609	.3333	.1873ns
Temperature	-.06998	.3365	.3791ns
Temp.- \bar{t}	.60872	.3371	.3027ns
Salinity	.05717	.3373	.0713ns
<u>Bulla umbilicata</u>	a = -3.59776		
Vegetation	.00816	.0991	39.3071**
Temperature	.04574	.1436	.9745ns
Salinity	-.14803	.1744	2.8755ns
Sal.- \bar{s}	1.60000	.1807	2.4459ns
Temp.- \bar{t}	-.35184	.1822	.6085ns

* significant at 95%

** significant at 99%

ns not significant

Table 38. Continued

	b	R ²	F
<u>Mitrella lunata</u>	a = -.54547		
Vegetation	.00095	.0523	18.3335**
Temperature	.00774	.0604	.9700ns
Temp.- \bar{t}	-.06862	.0629	.8049ns
Salinity	-.02103	.0643	2.0177ns
Sal.- \bar{s}	.24199	.0696	1.9457ns
<u>Vermicularia spirata</u>	a = -7.98227		
Vegetation	.02202	.2761	103.2907**
Temperature	-.06360	.2838	.6801ns
Salinity	-.22168	.2883	2.3280ns
Sal.- \bar{s}	2.51086	.2925	2.1745ns
Temp.- \bar{t}	.54601	.2936	.5291ns
<u>Pagurus bonairensis</u>	a = -6.30925		
Vegetation	.01022	.1664	64.1776**
Temperature	.04372	.1869	.9280ns
Salinity	-.22425	.2043	6.8779**
Sal.- \bar{s}	2.52624	.2197	6.3551*
Temp.- \bar{t}	-.36060	.2212	.6662ns

* significant at 95%

** significant at 99%

ns not significant

 \bar{v} = 6.11 lbs \bar{t} = 25.43°C \bar{s} = 36.00 ppt

N = 345

Table 39. Summary of stepwise multiple regression between animal catch, Log (catch +1) per tow, and vegetation, temperature, salinity, absolute value of temperature minus mean temperature and absolute value of salinity minus mean salinity in Biscayne Bay -- July 1968 - June 1973

	b	R ²	F
<u>Bulla umbilicata</u>	a = -2.08491		
Vegetation	.02086	.2383	214.8964**
Salinity	-.02499	.2575	23.4743**
Temp.- \bar{t}	.69470	.2775	6.0717*
Sal.- \bar{s}	.17743	.2891	13.4398**
Temperature	-.06215	.2936	4.7361*
<u>Cerithium muscarum</u>	a = -1.10157		
Vegetation	.03906	.4101	485.7607**
Salinity	-.03373	.4267	27.5829**
Sal.- \bar{s}	.24864	.4381	17.0233**
Temp.- \bar{t}	.27606	.4422	.6184ns
Temperature	-.02301	.4425	.4186ns
<u>Prunum apicinum</u>	a = -.73822		
Vegetation	.02347	.4694	628.8335**
Salinity	-.01102	.4714	10.5530**
Sal.- \bar{s}	.09238	.4769	8.4263**
Temp.- \bar{t}	.22004	.4769	1.4089ns
Temperature	-.02207	.4779	1.3818ns
<u>Vermicularia spirata</u>	a = -.59649		
Vegetation	.00437	.0195	10.5762**
Salinity	-.01135	.0282	14.2212**
Sal.- \bar{s}	.14685	.0410	10.3428**
Temp.- \bar{t}	.17934	.0411	.4546ns
Temperature	-.01790	.0416	.4412ns
<u>Thor floridanus</u>	a = 2.57220		
Vegetation	.02726	.1234	146.2345**
Salinity	.03651	.1909	19.9701**
Sal.- \bar{s}	-.18867	.1959	6.0587*
Temp.- \bar{t}	-.96551	.1986	4.6757*
Temperature	.09370	.2032	4.2912*

* significant at 95%

** significant at 99%

ns not significant

Table 39. Continued

	b	R ²	F
<u><i>Neopanope packardii</i></u>	a = -5.77996		
Vegetation	.05066	.3536	392.3585**
Salinity	-.07859	.3959	71.8969**
Sal.- \bar{s}	.58930	.4276	45.9176**
Temperature	-.21860	.4279	18.1454**
Temp.- \bar{t}	2.14031	.4413	17.8495**
<u><i>Pagurus bonairensis</i></u>	a = -1.99445		
Vegetation	.03977	.2562	267.0069**
Sal.- \bar{s}	.21259	.2649	6.5975*
Temp.- \bar{t}	.56012	.2716	1.3497ns
Salinity	-.01698	.2749	3.7039ns
Temperature	-.04862	.2759	.9912ns
<u><i>Mitrella lunata</i></u>	a = -3.36134		
Vegetation	.04097	.3445	388.1278**
Temperature	-.14272	.3516	11.6983**
Temp.- \bar{t}	1.34407	.3598	10.6459**
Sal.- \bar{s}	.12724	.3600	3.2376ns
Salinity	-.01318	.3626	3.0604ns
<u><i>Hippolyte pleuracantha</i></u>	a = -1.11152		
Vegetation	.02662	.3561	405.1621**
Temperature	-.06054	.3917	5.2052*
Salinity	-.01533	.3973	10.2271**
Sal.- \bar{s}	.11611	.4020	6.6680**
Temp.- \bar{t}	.50222	.4049	3.6764ns
<u><i>Cerithium eberneum</i></u>	a = -.83207		
Vegetation	.00940	.0820	67.7802**
Temp.- \bar{t}	.27513	.0851	1.4796ns
Sal.- \bar{s}	.04205	.0868	1.1727ns
Temperature	-.02579	.0882	1.2673ns
Salinity	-.00335	.0889	.6540ns
<u><i>Modulus modulus</i></u>	a = -1.04319		
Vegetation	.03220	.3086	333.6605**
Temp.- \bar{t}	.33461	.3120	.9184ns
Sal.- \bar{s}	.06669	.3140	1.2380ns
Temperature	-.03001	.3146	.7199ns
Salinity	-.00485	.3151	.5761ns

* significant at 95%

** significant at 99%

ns not significant

Table 29. Continued

	b	R ²	F
<u>Chondrilla nucula</u>	a = -.63727		
Salinity	.00787	.0219	2.2467ns
Vegetation	.00421	.0325	8.4402**
Temperature	-.03049	.0363	1.1012ns
Temp.- \bar{t}	.27153	.0376	.8960ns
Sal.- \bar{s}	-.01514	.0377	.0945ns
<u>Tricolia affinis</u>	a = .33069		
Temperature	-.01377	.0368	38.2327**
Salinity	.01720	.0736	6.5874*
Vegetation	.00866	.0993	21.7181**
Sal.- \bar{s}	-.06173	.1005	.9623ns
<u>Leptosynapta parvipatina</u>	a = 1.18345		
Temp.- \bar{t}	-.38650	.0170	1.9100ns
Salinity	.00221	.0216	2.8085ns
Vegetation	-.00174	.0236	1.5146ns
Temperature	.03279	.0253	1.3382ns

* significant at 95%

** significant at 99%

ns not significant

 \bar{v} = 6.17 lbs \bar{s} = 29.68 ppt t = 25.93°C

N = 754

Forty-four percent of the variation in catches of the cogener, C. muscarum, is explained by the independent variables in the regression. Perhaps the spotty distribution of C. eberneum can be attributed to the indirect larval development and various survival of planktonic stages, while the more regular distribution of C. muscarum is the result of direct development and lack of planktonic forms (Houbrick, 1973).

By combining Biscayne Bay and Card Sound samples we effectively increased the salinity range and did not change the temperature range from that observed in Biscayne Bay alone. In the combined analysis, vegetation was the best predictor for all species except the holothurian, Leptosynapta. Leptosynapta, like most echinoderms, has poor osmoregulatory ability and the primary variable associated with catch was salinity. Salinity, or the deviation of salinity from the mean (32 ppt), was the second variable chosen for all species except Leptosynapta. For Bulla, Cerithium eberneum, Mitrella, Modulus, Hippolyte, Thor, Neopanope and Pagurus, when all five independent variables were considered, vegetation was most important, followed by salinity. Leptosynapta followed the same pattern. Even though salinity was the best single predictor when all five independent variables are considered, vegetation is most significant followed by salinity (Table 40).

Table 40. Summary of stepwise multiple regression between animal catch, Log (catch +1) per tow, and vegetation, temperature, salinity, absolute value of temperature minus mean temperature and absolute value of salinity minus mean salinity in Biscayne Bay (July 1968 - June 1973) and Card Sound (July 1970 - June 1973).

	b	R ²	F
<u>Bulla umbilicata</u>	a = -1.47171		
Vegetation	.01583	.1823	234.2484**
Salinity	-.02590	.2159	32.4322**
Temp.- \bar{t}	.45590	.2422	3.7404ns
Sal.- \bar{s}	.17934	.2528	16.5461**
Temperature	-.03734	.2545	2.4335ns
<u>Cerithium muscarum</u>	a = .84684		
Vegetation	.02364	.2307	313.0582**
Salinity	-.04288	.3085	53.3219**
Sal.- \bar{s}	.27540	.3227	23.3981**
Temperature	.05359	.3301	3.0064ns
Temp.- \bar{t}	-.46617	.3316	2.3452ns
<u>Mitrella lunata</u>	a = -.80416		
Vegetation	.02389	.1938	234.5727**
Salinity	-.03047	.2251	19.7426**
Sal.- \bar{s}	.19772	.2312	8.8430**
Temperature	-.03374	.2318	.8737ns
Temp.- \bar{t}	.31455	.2323	.7829ns
<u>Modulus modulus</u>	a = .56686		
Vegetation	.02246	.2315	314.5706**
Salinity	-.01891	.2457	11.5437**
Temperature	.03728	.2528	1.6188ns
Sal.- \bar{s}	.12964	.2570	5.7693*
Temp.- \bar{t}	-.31106	.2578	1.1618ns
<u>Prunum apicinum</u>	a = .20820		
Vegetation	.01408	.2727	384.7292**
Salinity	-.01657	.3074	27.5909**
Sal.- \bar{s}	.11136	.3158	13.2515**
Temperature	.01612	.3175	.9422ns
Temp.- \bar{t}	-.14315	.3179	.7660ns

* significant at 95%

** significant at 99%

ns not significant

Table 40. Continued

	b	R ²	F
<u>Tricolia affinis</u>	a = -1.80134		
Vegetation	.01967	.0906	130.6314**
Salinity	.01459	.1335	3.7210ns
Temperature	-.09344	.1593	5.5053*
Temp.- \bar{t}	.78763	.1625	4.0329*
Sal.- \bar{s}	-.01375	.1625	.0352ns
<u>Hippolyte pleuracantha</u>	a = .09171		
Vegetation	.01629	.2195	276.1669**
Salinity	-.02456	.2760	32.5133**
Temp.- \bar{t}	.00394	.2877	.0003ns
Sal.- \bar{s}	.15414	.2965	13.6191*
Temperature	-.00582	.2965	.0660ns
<u>Thor floridanus</u>	a = -.10901		
Vegetation	.04208	.2566	494.1182**
Salinity	.04241	.3465	25.9780**
Temperature	-.01215	.3494	.0769ns
Sal.- \bar{s}	-.18461	.3526	5.2347*
Temp.- \bar{t}	.06038	.3526	.0196ns
<u>Neopanope packardii</u>	a = -2.68139		
Vegetation	.03397	.2371	326.4485**
Salinity	-.09113	.3547	121.5639**
Sal.- \bar{s}	-.62772	.3873	61.3553**
Temp.- \bar{t}	.91231	.3877	4.5336*
Temperature	-.09055	.3902	4.3321*
<u>Pagurus bonairensis</u>	a = .61738		
Vegetation	.02709	.1766	226.8893**
Salinity	-.04049	.1906	26.2364**
Temperature	.06268	.2047	2.2692ns
Sal.- \bar{s}	.32221	.2181	17.6731**
Temp.- \bar{t}	-.50601	.2192	1.5247ns
<u>Chondrilla nucula</u>	a = -2.50503		
Vegetation	.01227	.0537	81.2360**
Salinity	.01345	.1100	5.0502*
Temperature	-.10837	.1175	11.8355**
Temp.- \bar{t}	1.01284	.1263	10.6580**
Sal.- \bar{s}	.02118	.1264	.1332ns

* significant at 95%

** significant at 99%

ns not significant

Table 40. Continued

	b	R ²	F
<u>Cerithium eberneum</u> a = 1.07246			
Vegetation	.00923	.0931	115.0360**
Sal.- \bar{s}	.04616	.0967	1.5830ns
Temp.- \bar{t}	.37700	.0977	3.6932ns
Temperature	-.03704	.1003	3.4575ns
Salinity	-.00319	.1009	.7123ns
<u>Vermicularia spirata</u> a = -2.11676			
Vegetation	.01268	.0814	102.8639**
Sal.- \bar{s}	.08241	.0952	2.3925ns
Temperature	-.00638	.0995	8.9201**
Temp.- \bar{t}	.81406	.1060	8.1673**
Salinity	-.00358	.1063	.4242ns
<u>Leptosynapta parvipatina</u> a = -.23985			
Salinity	.01648	.0370	8.7802**
Temperature	-.02866	.0567	.9586ns
Vegetation	.00460	.0679	13.2078**
Sal.- \bar{s}	-.07178	.0696	1.7716ns
Temp.- \bar{t}	.20307	.0700	.4960ns

* significant at 95%

** significant at 99%

ns not significant

 \bar{v} = 6.15 lbs \bar{t} = 25.77°C \bar{s} = 31.67 ppt

N = 1099

CONCLUSIONS AND SUMMARY

1. Average temperature elevations above 4°C caused almost barren conditions where few animals and almost no macrophytes occurred. The area at Turkey Point which was elevated above 4°C with two 400,000 KWe fossil units and 1,270 cfs flow was approximately 75 acres. After the Grand Canal was closed slight recovery was observed.

2. Average temperature elevations between 3 and 4°C above ambient summer water temperature caused serious depletion of the biota in summer. Although recovery was noted in winter, the summer loss was not offset by winter gains. At Turkey Point, the area between the +3 and +4°C isotherms was about 100 acres. After the Grand Canal closed, recovery, indicated by diversity, total numbers of organisms and inshore sediment wedge indicator species, was nearly complete after 1 year.

3. Average temperature elevations between 2 and 3°C caused damage to the biota in summer; but this decrease was offset by increased relative abundance in winter. This area, about 125 acres, at Turkey Point, recovered after dilution was implemented to reduce the temperature of the effluent.

4. A total area of about 300 acres showed a decline in abundance of animals that was statistically measurable for at least part of the year. In approximately 125 acres, the increased winter catches compensated for low summer catches. Approximately 250 acres recovered to relative abundance levels and diversity levels comparable to control stations after closing Grand Canal. The inner barrier zone of about 50 acres showed incomplete recovery and will probably require a long period to recover due to sediment changes and the death of root and rhizomes of sea grasses.

5. In Card Sound, outfall temperatures generally did not exceed +1°C and only rarely exceeded 33°C. Only a few indicator species showed lowered catches in summer. In general no significant damage was recorded in Card Sound.

6. Calculated optimal temperatures for diversity of species and maximum numbers of individuals were between 21-27°C.

7. The 50% upper exclusion temperature for fishes, mollusks, crustaceans, polychaete families, porifera, coelenterates, echinoderms was between 27.6 (fishes) and 31.2 (sponges). The 75% exclusion temperatures were between 30.6 and 35.0°C.

8. Areas such as stations I and H, which received periodic or intermittent heat, were not as severely damaged as those receiving constant exposure.

9. Animal abundance was greatest in areas where red algae (Laurencia spp., Acanthophora sp. and Digenia simplex) were abundant; less in Thalassia without red algae, and least where few macrophytes occurred on sand, mud or peat bottoms.

10. Multiple regressions indicated the presence of algae was the dominant variable controlling abundance of indicator animals, followed by salinity.

11. Point sources of fresh water from "flood control" canals, such as at Florida City Canal (Station N II) and Moody Canal (Station N V), can cause severe stress to animals but recovery is generally rapid.

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