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**The Effects of Thermal Effluent  
on Some of the Macrofauna of a  
Subtropical Estuary**

**Richard S. Nugent Jr.**

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The Effects of Thermal Effluent on Some  
of the Macrofauna of a Subtropical Estuary

Richard Nugent, Jr.

Research Sponsored by Florida Power and Light Company

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## PREFACE

The Sea Grant Colleges Program was created in 1966 to stimulate research, instruction, and extension of knowledge of marine resources of the United States. The responsibility for administration of the program rests with the Department of Commerce.

The Sea Grant Program of the University of Miami was established in 1969. This activity at the University should be useful in much the same way as the land-grant program, which in 100 years has brought the United States to its current superior position in agricultural production. The successful accomplishment of the three objectives in the Sea Grant concept - to promote excellence in education and training, research, and advisory services - will make its contribution by relating sea science to economics and other practical matters.

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## INTRODUCTION

The demand for electric power in the United States has doubled about once every ten years since 1900 and indications are that the rate of increase will be even greater in the coming decades (U. S. Senate, 1963). The increasing demand for electricity has lead to a potentially serious threat to aquatic and estuarine environments -- that of thermal additions.

The generation of electric power by steam involves the production of large quantities of heat. About 5500 BTU of thermal energy are produced for every kilowatt hour of electricity generated by a conventional power plant (Bregman, 1969). Nuclear powered plants, being less efficient, produce about 10,000 BTU per kilowatt hour. Large volumes of water are used as a transfer medium to remove the heat from the condensers and dissipate it into the environment. The cooling water is drawn from a large source such as a river or an estuary, passed through the condenser-cooling system of the plant and returned to the receiving waters with its thermal load.

Most units in use today raise the temperature of the cooling water between 5° and 13°C (9-23°F). The pumping rate varies widely according to the plant design but it is estimated that 50 trillion gallons of water passed through power stations in 1968 (Krenkel and Parker, 1969).

The problems associated with the release of these large volumes of heated water are compounded by recent trends within the

power industry. Larger plants, including more nuclear powered generators, are being built, and groups of these units are being located at a single site. Bregman (1969) points out that the average size of all steam generating stations retired from 1961 to 1965 was 22 megawatts, while the average size of the 217 new fossil-fuel plants under construction for operation in 1971 is 295 megawatts. The movement toward nuclear power will mean even larger capacities -- the average size of the nuclear plants under construction or planned for operation in 1973 is 624 megawatts (Bregman, 1969). In 1968, five percent of the thermally generated electricity was produced by nuclear power, by 1985 thirty-five percent of the production will be of nuclear origin (Kolflat, 1968). This trend is significant because this type of plant will produce about fifty percent more waste heat than a conventional unit of the same capacity. For reasons of safety, steam temperatures and pressures are less in nuclear plants and consequently energy conversion is less efficient.

The cooling water requirements of the power industry will be in the order of 100 trillion gallons per year by 1980 (Krenkel and Parker, 1969) -- a volume of water equal to one fifth of the total freshwater runoff of the 48 conterminous United States. To meet these water needs, more plants will be built near estuaries and coastal areas where limitless supplies of water are available. Picton (1960) projects that by 1980, thirty-two percent of all steam electric stations will be located adjacent to estuaries or on open sea coasts.

The United States thus faces a potential problem in environmental alteration of enormous proportions, particularly in estuarine

and littoral marine waters. The proper management of the large volumes of heated effluent is essential to the protection of the living populations of these areas. However, our knowledge of temperature effects on the plants and animals is incomplete.

The literature dealing with the influences of temperature on marine, estuarine and aquatic organisms is large. One bibliography on the effects of heat on aquatic life (Raney and Menzel, 1969) lists 1870 separate references. Some aspects of temperature effects on organisms will be briefly discussed below and some of the more pertinent references cited.

As Mihursky (1967) points out, the information obtained thus far has shown temperature to be a lethal, directive and controlling factor in the aquatic environment.

Temperature at certain high and low levels (varying with the species) can cause mortality directly. The ultimate source of death in such cases is believed to be failure of the central nervous system (Orr, 1955; Brett, 1956; Fisher, 1958; Roots and Prosser, 1962). Indications are that, at least in the case of fish, inactivation of certain metabolic enzymes is involved (Brett, 1956; Pegel and Remorov, 1961; Timet, 1963; Baslow and Nigrelli, 1964). The exact manner in which heat acts to interrupt the normal biochemical pathways is not well understood. Some (Weiss, 1961) believe that there is a direct inactivation of an enzyme involved, while others (Somero, 1969) feel that the enzyme-substrate affinities are altered. The research of Pegel and Remorov (1961) indicates that it is the high levels of lactic acid, induced by the heat stress, that destroys the activity of the enzyme.

The most that can be said at the present time is that the experimental evidence points to a complex mechanism, or series of mechanisms, that act on the enzyme level to disrupt the functions of the central nervous system.

Since temperature is so intimately involved in all the life processes of aquatic poikilotherms, artificially heated water may have other effects far more harmful to a species than the death of individual animals. Activities such as reproduction, feeding and growth, as well as factors such as the ability to resist disease and other stress conditions, and the ability to cope with competition and predation are all temperature influenced to some degree. As Brett (1956) points out, the inability of a population to maintain any one of these functions or activities under conditions of even slight thermal stress may be as decisive to continued survival of a species as more extreme temperatures are to immediate life. These sublethal and long-term effects are, perhaps, more important than thermal death points.

Most estuarine and marine poikilotherms have reproductive cycles in which periods of nutrient storage and maturation of gametes alternate with restricted periods of natural spawning. These patterns display a constant relationship to the seasons. The environmental factor that appears to be most important in synchronizing the reproductive periodicity with season is temperature (Orton, 1940 and Gunter, 1957). Other factors such as photoperiod, which work alone or in combination with temperature, appear to be of lesser importance.

It is well known that in addition to the necessity of having a specific temperature to initiate spawning, many organisms require that environmental temperatures be at certain levels for definite lengths of time in order that gametogenesis may be completed (Kinne, 1963; Hedgepeth and Gonor, 1969). Sastry (1963, 1966 and 1968) showed this to be true for the bay scallop, Aequipecten irradians and others, (Pfitzenmeyer, 1965; Ropes and Stickney, 1965) illustrated similar requirements for the soft shelled clam Mya arenaria. Loosanoff (1969) was able to separate the American oyster (Crassostrea virginica) along the Atlantic coast into distinct races on the basis of the different temperature regimes they required for completion of gametogenesis and spawning.

Similar variable requirements have been found for various species of marine and estuarine fishes. Experimentally it has been shown by Burger (1939) and Matthews (1939) that spermatogenesis in Fundulus heteroclitus, the mummichog, is directly correlated with increasing water temperature. In the female killifish of a different species (F. confluentus), Harrington (1959) found that high temperatures induced the later phases of ovarian maturation but retarded the earlier ones, while lower temperatures had the opposite effect. Herring in the North Sea have been reported to spawn in response to specific water temperatures (Fabricus, 1950; Brandhorst, 1959). Similar temperature dependence has been reported for the spawning of the striped bass, Morone saxatilis (Farley, 1968).

After the eggs have been cast and fertilized, the rates at which the embryos develop are temperature dependent. The cleavage stages of most marine invertebrates require narrower temperature

ranges than do the larval stages (Kinne, 1963). It has also long been recognized that the developmental rate of fish eggs is influenced by temperature (Dannevig, 1894). There is a large body of literature reporting more rapid development of fish embryos with increasing temperature. Some of the work has been done on herring (Clupea harengus) by Williamson (1909) and Blaxter (1956); on haddock (Melanogrammus aeglefinus) by Williamson (1909); on cod (Gadus morhua) by Dannevig (1894); on pilchard (Sardinops caerulea) by Ahlstrom (1943) and Lasker (1963, 1964); on the jack mackerel (Trachurus symmetricus) by Farris (1961) and on the English sole (Parophrys vetulus) by Alderdice and Forrester (1968).

The temperature requirements of larval stages, although less precise than those for embryonic development, are stricter than those for juveniles. The larvae of five different species of estuarine crabs were shown by Costlow and Bookhout (1962) to develop properly only within a narrow range of temperatures and salinities. Cook and Murphy (1969) found that the developmental and survival rates of the larvae of the brown shrimp, Penaeus aztecus, were dependent upon temperature. At a given salinity and temperature that produced the fastest development did not necessarily give the greatest survival. Similar results were reported for larvae of the Dungeness crab, Cancer magister, by Reed (1969). The survival and growth of European oyster larvae (Ostrea edulis) were also shown to be closely associated with temperature (Davis and Calabrese, 1969).

De Sylva (1969) states that the eggs and larvae of marine fishes are extremely exacting in their temperature requirements while



the subjuveniles and juveniles appear to be eurythermal. As in invertebrates, both the survival and growth of larvae are related to temperature (Marak and Colton, 1961; Herman et al., 1965). Studies by fishery scientists into the causes of natural fluctuations in the abundance of commercial species have yielded information indicating that success of year classes is dependent upon temperature, at least in the cases of some species (Ketchen, 1952; Herman, 1953; Colton, 1959; Hela and Laevastu, 1962). The dependence can be direct by causing actual larval mortality or indirect by limiting the supply of food organisms.

There have been many investigations into the effects of temperature on the metabolism of aquatic poikilotherms. Some of the better general reviews and discussions of the problem are given by Kinne (1963, 1964) and Naylor (1965). Work on temperature and fish physiology has been summarized or reviewed by a number of authors (Brett, 1956, 1960; Johnson, 1957; de Sylva, 1969).

Heat affects metabolism through its action on biochemical reaction rates. Metabolic rates increase with rising temperature within the tolerance range of the particular animal and may drop sharply at some point near the upper lethal limit (Kinne, 1963). This action appears to be due to effects on enzyme systems. Precht (1961) working with eels (Anguilla anguilla) found a temperature-related increase in activity of certain enzymes. So did Dean (1969), working with rainbow trout.

Since functions and activities of organisms such as respiration are the result of the integration of many metabolic systems,

various investigators have used these parameters to measure temperature effects on metabolism. Respiration rates of fishes increase with rising temperature up to a certain level. The increased oxygen demand of the accelerated metabolism accounts for the rate change (Fry, 1957). This has been shown for a number of species: the killifishes, Fundulus heteroclitus (Sizer, 1935) and F. diaphanus (Kropp, 1947); the eel, Anguilla (Precht, 1961); the pinfish, Lagodon rhomboides (Wohlschiag et al., 1968); the plaice, Pleuronectes platessa (Edwards et al., 1969); and the toadfish, Opsanus tau (Haschemeyer, 1969). In most of these studies it was shown that animals acclimated to higher temperatures could better withstand thermal stress as measured by oxygen consumption. In some cases, the fish reacted to higher temperatures by lowering their metabolic rates (Brett, 1956). A similar method of accommodation is exhibited by some marine invertebrates (Nichol, 1967).

A final consideration is that of temperature as a directive factor influencing daily and seasonal behavior. This aspect has been best documented in fishes. The ability to perceive very narrow ranges of water temperature has been reported in several species. Breder (1951) observed the dwarf herring (Jenkinsia lamprotaenia) discriminating between temperatures of 30°C and 29.5°C, under natural conditions. Laboratory studies utilizing conditioned response techniques have shown that a wide variety of fish species can perceive temperature increases as small as 0.03 to 0.10°C (Bull, 1937).

When placed in a thermal gradient, fish seek out and remain in water of a particular temperature (Doudoroff, 1938; Dendy, 1945; Sullivan and Fisher, 1953; Alabaster and Downing, 1966). The preferred temperature has been shown to correspond closely to the temperature of optimum activity in several species (Fry and Hart, 1948; Fisher and Elson, 1950). This is significant in that, under natural conditions, the ability of a fish to survive in the presence of competition and predation is directly related to his ability to be active (Brett, 1956).

As was mentioned above, the seasonal reproductive cycles in fishes are closely linked to changes in water temperature. Likewise the initiation and direction of migrations have been shown to be a response to thermal stimuli. Foerster (1937) related the seaward migration of young sockeye salmon (Oncorhynchus nerka) to changes in water temperature. The seasonal movements of both the Atlantic mackerel (Scomber scombrus) and the winter flounder (Pseudopleuronectes americanus) are believed to be temperature related (Sette, 1940; McCracken, 1963)

It can be seen that temperature is an environmental factor of great significance. However, in most of these investigations temperature effects were isolated and studied separately from those of other parameters. In the natural environment an organism is subjected to a wide variety of constantly changing physical and biological conditions. In any study of the effects of heated discharge, temperature cannot be treated as an isolated factor. As several authors (Mihursky and Kennedy, 1967; Trembley, 1968; Allen, 1969) have emphasized, temperature

interacts with other physical and chemical parameters, including pollutants, to produce effects more complex and varied than those resulting from any of the factors acting alone. This complex aspect of temperature and other effects is particularly difficult to assess.

#### The Problem

Little is known about the ecological consequences of imposing artificial temperature regimes on estuarine environments. We have some insight into the key operative mechanisms of natural ecosystems, but the gaps in our knowledge of the subject prevent making projections on the effects of increased temperature on the plant and animal communities in any given area. This is particularly true in tropical and subtropical regions where the problem of heated effluents is compounded because organisms may already be living within a few degrees of their thermal death points (Mayer, 1914; Cairns, 1956).

A case in point is the Turkey Point power plant. The Florida Power and Light Company is constructing an electric generating facility on the mainland shore of Biscayne Bay, a subtropical estuary, south of Miami, Florida (Figure 1). The complex has two conventional units in operation and two nuclear units in advanced stages of construction. The two oil-burning plants together require 1270 cubic feet per second of bay water for cooling purposes. The temperature of the water is raised between 5° and 6°C (9-11°F) during a single pass through the condensers. The effluent is discharged into a system of canals and tidal streams that carry it back into the bay. Ecologists cannot yet predict what effects the discharge will have. However, it is feared by many that these volumes of heated water will

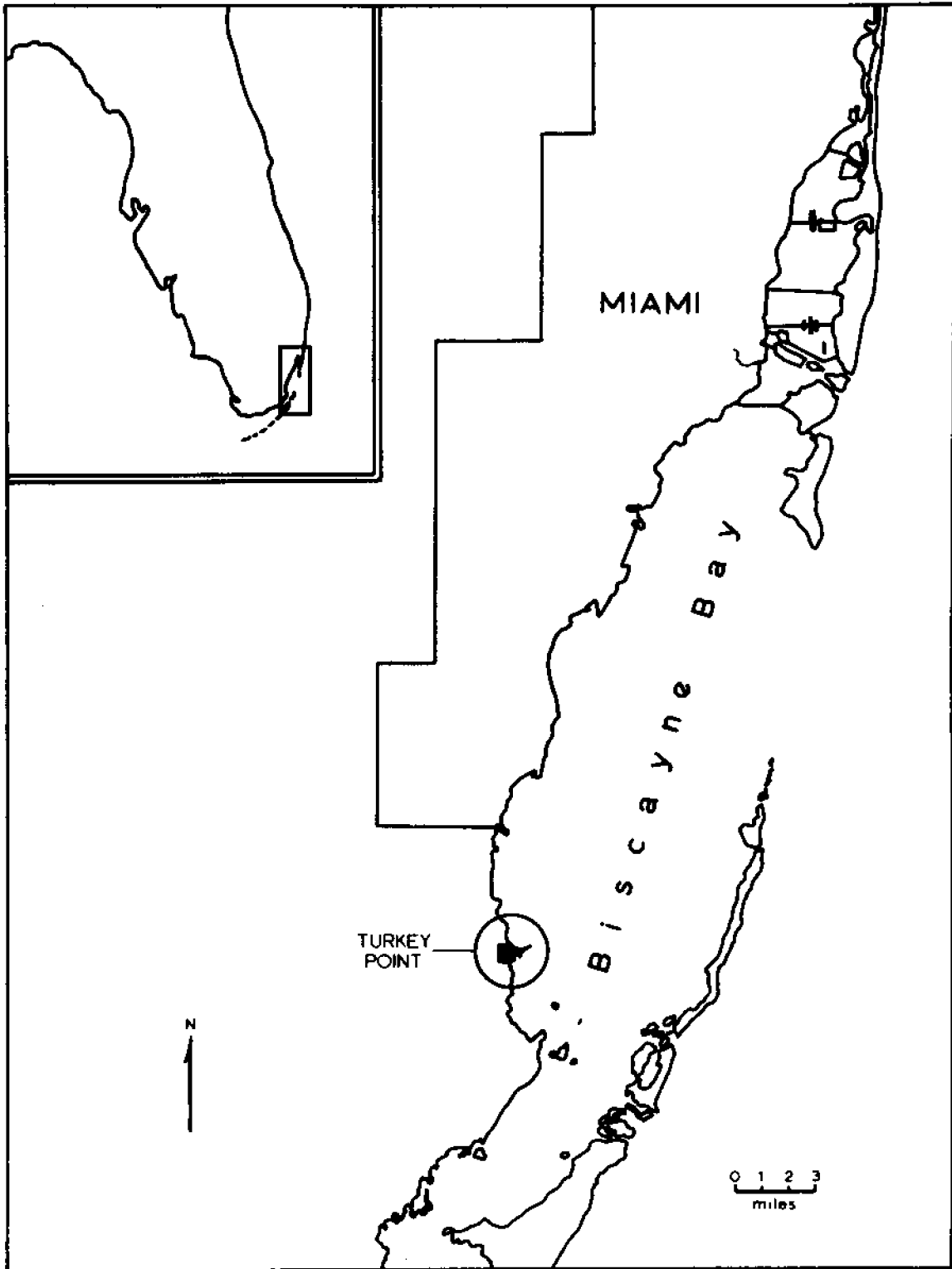


Figure 1. Map showing the location of Turkey Point.

exert severe environmental stress on the biota of the area, particularly during summer months, and do severe damage to the organisms in the bay.

The threat of damage takes on added significance because southern Biscayne Bay still represents a unique and relatively unspoiled natural habitat. The water in this area is so free from pollutants that it was judged to be the chemical equivalent of ocean water by the Florida State Board of Health (1962). The federal government intended that the unique and pristine character of the region be preserved for the benefit of all when it established the Biscayne National Monument, which includes a large portion of South Biscayne Bay.

It is also feared that the deleterious effects of the increased temperature regime could reach beyond the area receiving the effluent. Scientists have only recently become aware of the vital role that estuaries play in the productivity cycles of the oceans (E. P. Odum, 1961; Shelske and Odum, 1962; Heald, 1969; W. E. Odum, 1970). Not only are environments such as estuaries and their adjacent salt marshes and mangrove swamps the habitat for complex communities of animals, they also serve as feeding areas for a wide variety of other animals, including birds, and play a vital role as nursery areas for a diversity of marine animals. McHugh (1966) states that nearly two-thirds of the total catch of fish and shellfish from waters off the east coast of the United States is made up of estuarine dependent species. It has also been estimated (Tabb, 1965; Sykes, 1967) that more than 75 percent of the economically important marine species of the southeastern United States are

intimately tied at some stage of development to estuaries. Gamefishes such as tarpon, snook and seatrout, and commercial species such as mullet and shrimp spend at least some of their early life stages in the open bays and in the drainage channels of the marshes. These animals are able to utilize this habitat as a source of food and shelter because they have a greater tolerance to the constantly changing environmental conditions within the estuary than do most of their predators (Gunter, 1967). They are able to complete the most vulnerable of their life stages in an area comparatively free from predation. If these areas are significantly altered or destroyed the effects would be far-reaching. The disruption of life cycles would decrease recruitment and eventually result in decreased populations. This could have economic consequences throughout south Florida since much of the local economy is based on fishing and related activities.

Several investigations have been undertaken to assess the effects of the heated effluents from the Turkey Point plant on the biological communities in the bay. The largest of these, sponsored jointly by the Atomic Energy Commission and the Federal Water Quality Administration, is a five-year study concerned with the areas immediately offshore from the plant. The present study, sponsored by Florida Power and Light Company, has been concerned with the animal populations in the waterways of the mangrove region through which the heated water flows.

### The Objectives of the Investigation

The objective of the present research was to determine the effects of the effluent on the macrofauna, particularly the fishes, of the mangrove habitat. The investigation involved qualitative and, as far as possible, quantitative observations on the kinds, distribution and abundance of the animals. Gill nets, traps and hoop nets were used to sample the fish and larger invertebrates, and slate panels were employed to study some of the fouling organisms. Various hydrological parameters were monitored routinely at various stations throughout the study area.

### Description of the Area

The Turkey Point power plant is located on a low-lying coastal mangrove area approximately 25 miles south of Miami on the western shore of south Biscayne Bay (Figure 1). In this area, Biscayne Bay is about eight miles wide and is bounded on the east by Sands, Elliott and Old Rhodes Keys. Water depths at mean low tide grade very gradually from a few inches at the vegetation line to six feet about 1200 yards offshore. Maximum depths of 10-12 feet occur at midbay.

The tides in the area are mixed semidiurnal, characterized by two daily tides of unequal amplitude. Mean tide range is about 1.6 feet. Due to the shallow nature of the bay, both the tidal period and tidal height are strongly influenced by the direction and velocity of the wind.



The salinity of the bay follows a definite seasonal pattern (Figure 2), closely associated with rainfall and consequent runoff from the mainland. Lowest salinities are normally reached in early summer and late fall during two peak rainy periods. At these times lows of 12 to 15 ppt are not uncommon along the mainland shore. Runoff from rain squalls can temporarily lower salinities in inshore areas to close to zero. During the dry months salinities can range as high as 45 ppt.

There are three major ecological zones in this region of the bay (Figure 3): the mangrove community that fringes the edge of the bay, the shallow seagrass beds that extend outward from the mangroves in a band that runs parallel to the shore, and a relatively barren region beyond the grass beds.

The mangrove forest in the area of the power plant extends from the bay edge inland for distances of from 2,000 to 3,500 yards. The sediment is a fine grained mud consisting of calcium carbonate mixed with organic debris, overlying a four-foot layer of mangrove peat which itself lies on the calcareous rock substrate. Numerous tidal streams penetrate the mangrove area.

The dominant vegetation is the red mangrove (Rhizophora mangle). It occurs predominately as low bushes two to four feet high, except in isolated tree hammocks and along the edges of the streams where heights of 10 to 15 feet are achieved. Scattered among the red mangroves are a few isolated buttonwood (Conocarpus erectus), white mangrove (Laguncularia racemosa), and black mangrove (Avicennia nitida) trees.

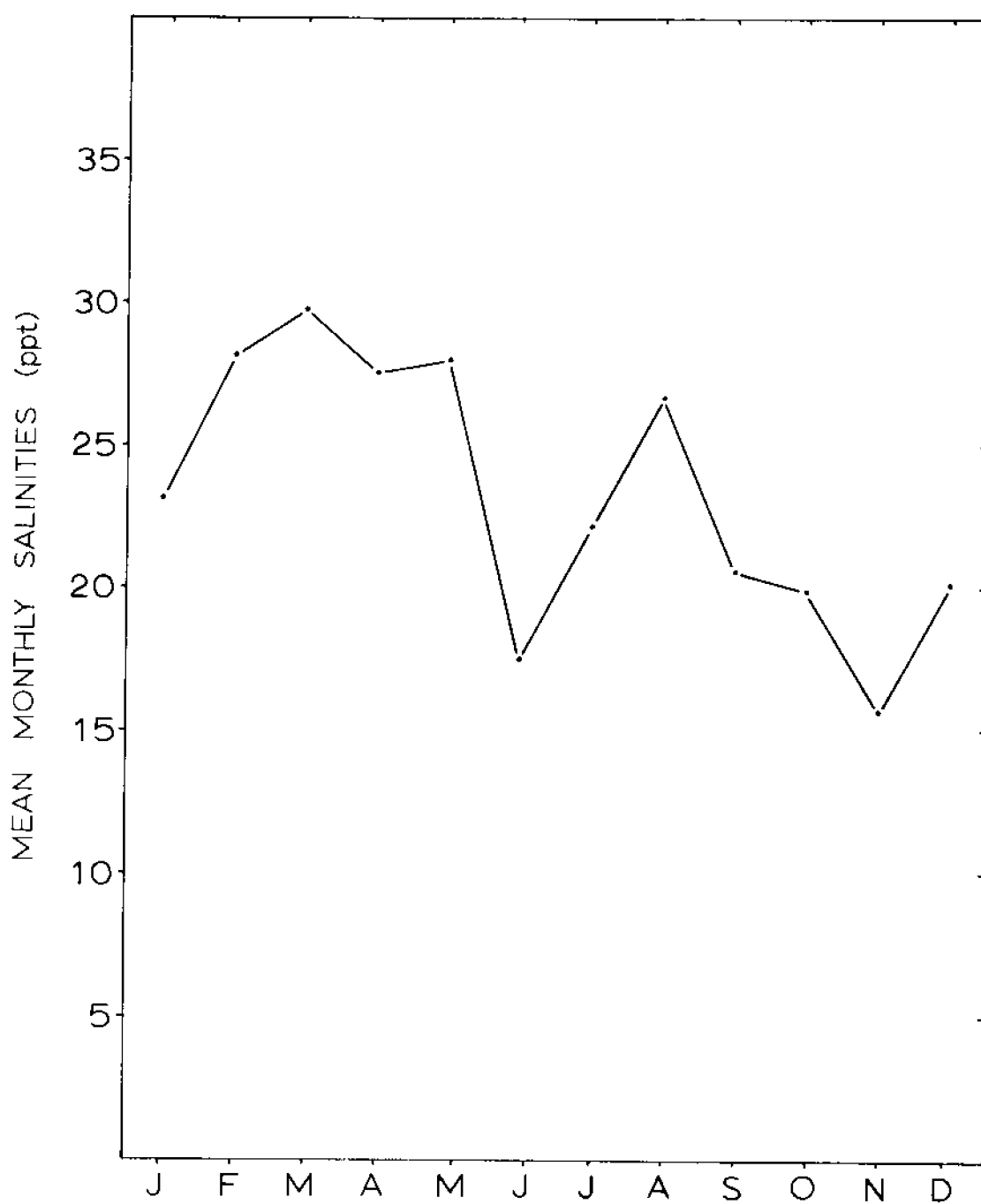


Figure 2. Normal monthly average salinity values for inshore areas around Turkey Point.

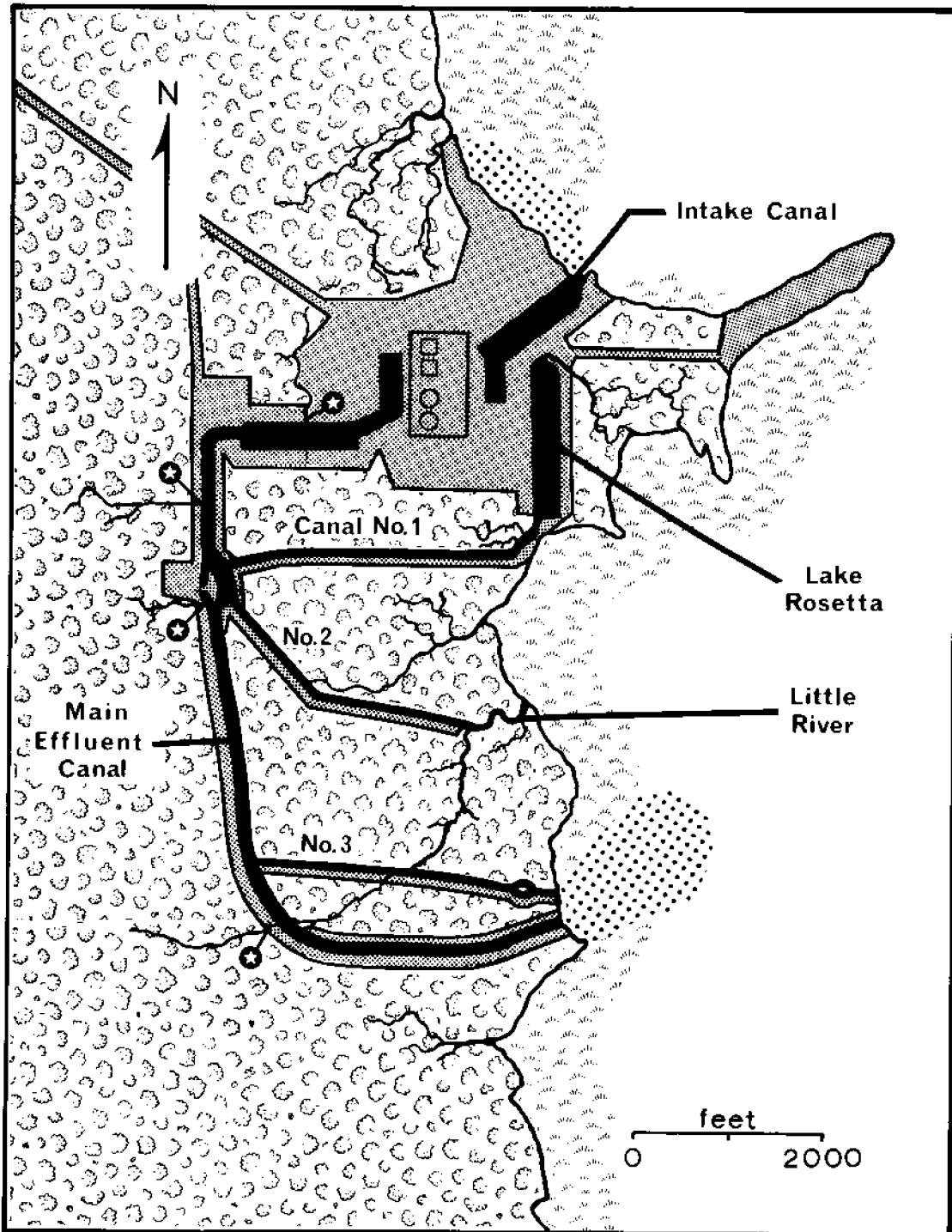
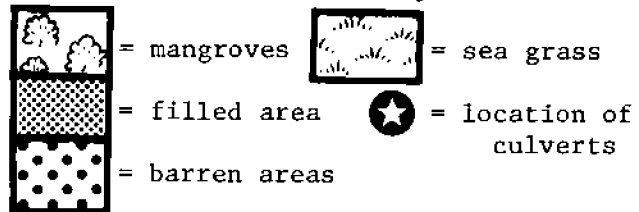


Figure 3. Map showing the major ecological zones and man-made features at Turkey Point.



The sea grass beds extend from the mainland shore outward in a band that varies from several hundred to several thousand feet in width. This zone is characterized by a thick layer of highly organic, fine grained carbonate mud sediment (calcilutite) that overlies the calcareous bedrock. The thick sediment supports dense growths of rooted vegetation, principally turtle grass (Thalassia testudinatum) and isolated patches of Cuban shoal grass (Diplanthera wrightii). This type of habitat also reaches into the tidal streams.

The third zone, which extends outward from the sea grass beds and includes most of the bay bottom, occurs where there is little or no sediment over the underlying rock. It is characterized by numerous patches of sponges, alcyonarians and corals. Vegetation is limited to various species of brown and red algae that appear seasonally, and to dense growths of turtle grass that occur in random pockets of sediment scattered throughout the area.

Superimposed over these natural zones are relatively barren areas associated with the construction and operation of the power plant (Figure 3). A large barren area, about 60 acres in extent, begins at the mouth of the main effluent canal and extends to the east and north. This is the region over which flows most of the plant effluent. A second smaller area (25 acres) is immediately northwest of the intake canal. It is composed of soft mud and silt washed down from temporary spoil banks put up during the initial phases of construction. A large portion of this area is exposed at low tide. In both regions the only macroscopic vegetation is a few isolated individuals of various species of algae.

Figure 4 is a map of the area showing the layout of the power plant and the cooling canal system, indicating the direction of flow of the cooling water.

During the investigation, two conventional steam units were in operation and two nuclear powered units were under construction. The fossil-fuel plants each have a generating capacity of 432,000 kilowatts. The volume of cooling water required by each is 635 cubic feet per second. Essentially, this flow of water is constant but its temperature varies directly with the amount of electricity the plant is producing. Figure 5 shows the curves of water temperatures at the intake and outfall during a typical 24-hour period. The temperature of the effluent closely follows the curve of power consumption. The average daily temperature rise across the condensers is  $5^{\circ}$  to  $6^{\circ}\text{C}$  ( $9\text{--}11^{\circ}\text{F}$ ) with a range from about  $3^{\circ}\text{C}$  ( $5^{\circ}\text{F}$ ) in the early morning to about  $8^{\circ}\text{C}$  ( $14^{\circ}\text{F}$ ) in the evening.

The cooling water for both power plants is drawn from the bay through intake canal at a depth of about 20 feet (Figure 4). It passes through the condensers and is discharged into the main effluent canal. This canal carries the water west and then south for a distance of about 1,900 yards, then it turns eastward and returns the water to the bay. Since the canal does not extend beyond the low water mark, the effluent flows out over the shallow mud flats off the canal mouth in a sheet-like pattern. The principal direction of flow is to the northeast as has been determined by aerial infra-red temperature sensing techniques and rhodamine dye studies.

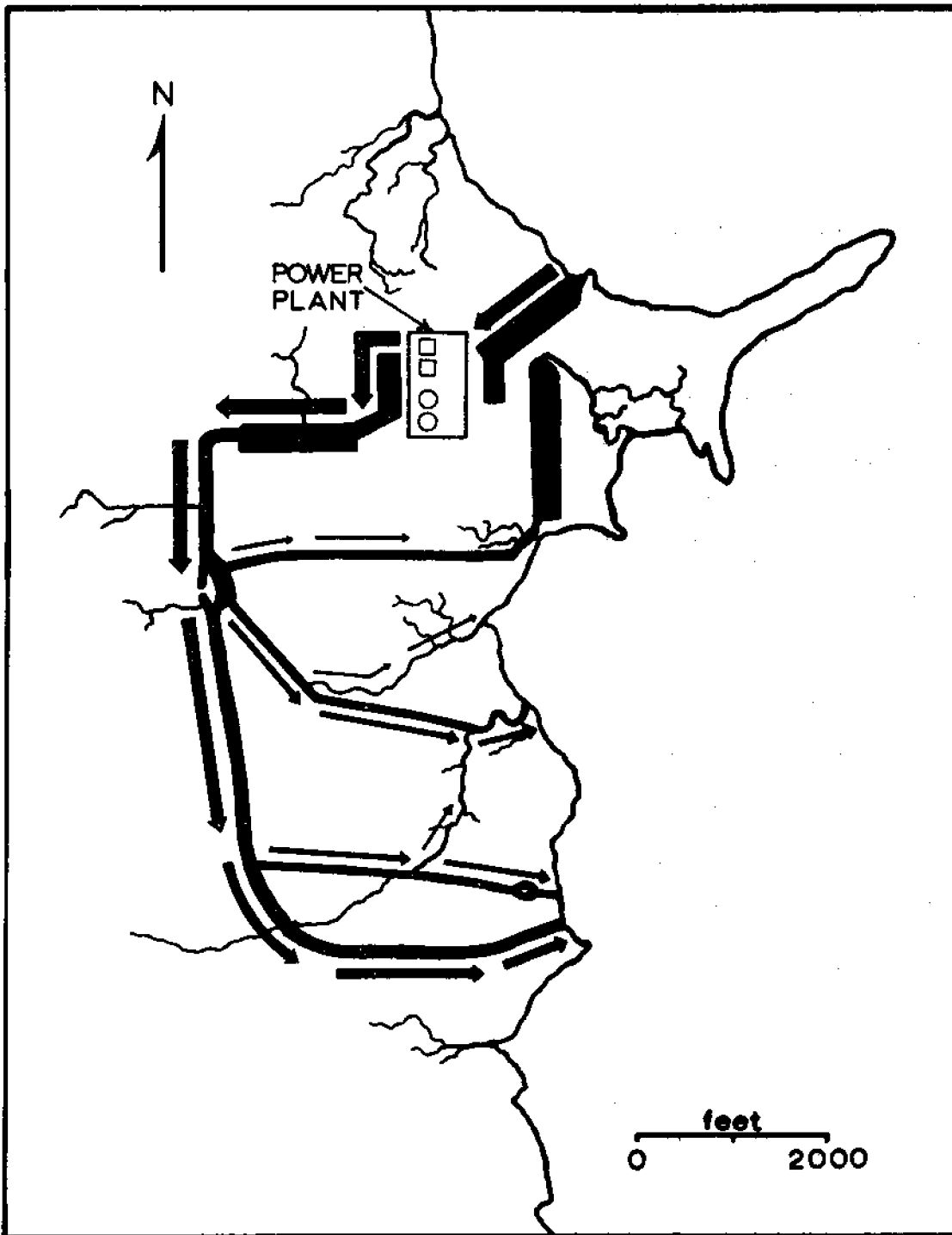


Figure 4. Map of the power plant and canal system indicating direction of cooling water flow.

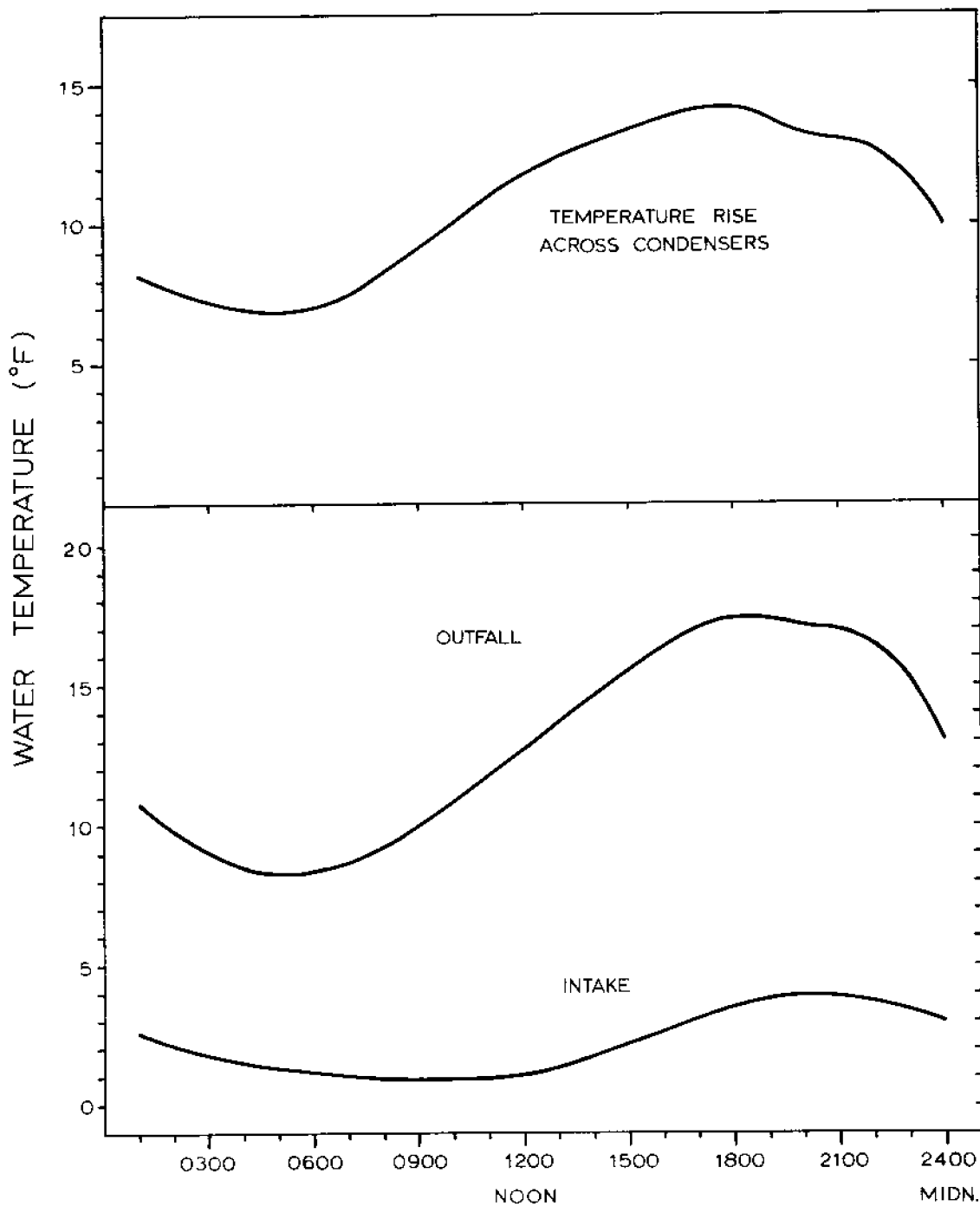


Figure 5. Water temperatures at the plant intake and outfall over a typical 24-hour period. Temperature rise across the condensers is also shown (data from Florida Power and Light Company records).

The main canal is about 3,800 yards long and has an average depth of approximately 25 feet. Its width varies from about 250 feet near the plant to about 80 feet near the bay.

There are three smaller east-west canals that connect the main canal to the bay. Each is about 50 feet wide and 3 feet deep. The northernmost canal is connected to the bay by only a small, partially covered culvert. Its main eastward connection is into Lake Rosetta, a deep (30 feet) settling basin whose northern edge is drained by a shallow (2 feet) tidal stream that flows into the bay.

Canal number 2 flows southeastward and then east and joins a natural stream (Little River) that runs into the bay. A second smaller stream also connects with this canal at its midpoint.

The third canal runs eastward, crosses Little River, and enters the bay immediately north of the mouth of the main canal.

No accurate measurements exist for the flow of discharge water through the canals; however, it can be estimated that about 80 percent of the effluent leaves through the main canal, 3 percent flows into Canal Number 1, 8 percent into Number 2 and 9 percent into Number 3.

The dredging of the canals produced large quantities of loose oolite rock which was used to elevate the plant site about 13 feet above mean high water. In addition, the debris were used to create levees along the canal system (Figure 3). These levees stand well above the levels of even the highest spring tides and thus greatly influence the circulation of water in the area. For example, effluent water can flow from the main canal into the mangrove areas to the west only through three culverts (Figure 3). Similarly, fresh water runoff



from the same areas enters the canal only at these three points. The salinity of the water passing through the culverts during periods of heavy rain was often found to be less than 2 ppt.

#### Selection of Sampling Stations

A summary of the types of sampling that were carried out at each station is given in Table 1, and the locations of the stations are shown in Figure 6.

Ideally an investigation of this nature involves a study of the area both before and after the power plant has been established. This was not possible at Turkey Point since the plant had been in operation for over a year before the research was begun. As an alternative, sampling stations were established within the area receiving heated discharge water and at locations outside of the region of influence.

Nineteen stations were set up in the canals and tidal streams around the power plant. Station 1 was the principal control station. Water temperatures there were judged to represent those of the inshore areas of the bay under normal conditions, since aerial infra-red scanning, dye studies and the measurement of water temperatures from boats all indicated that heated water did not reach this location. All the other stations were within areas influenced to some degree by the heated effluent water. The extent to which temperatures at any of these stations were elevated above normal levels was directly related to the amount of discharge water that flowed past them. Those closest to the plant were the hottest while those in locations where the effluent was diluted by bay water during the tidal cycle were cooler.

Table 1. Summary of the major sampling programs carried out at the various stations.

Station	Gill Nets	Traps	Fouling Panels	Hoop Nets	Water Chemistry
1	*	*	*		*
2		*	*		*
3					*
4					*
6					*
8					*
10					*
12			*		*
14		*	*		*
15			*		*
16	*	*	*		*
17				*	
18				*	
19				*	*

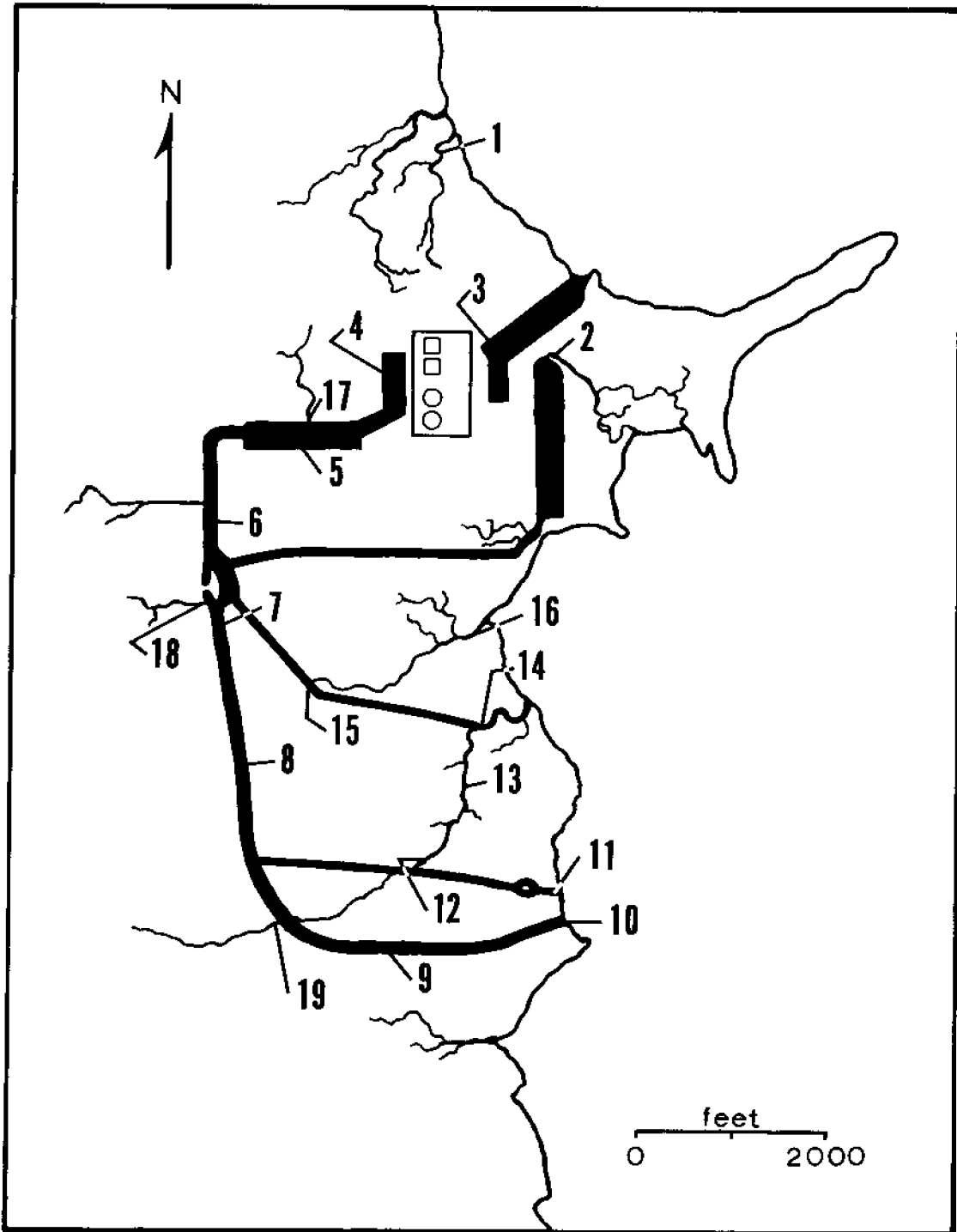


Figure 6. Map of the Turkey Point area showing the location of all the sampling stations.

Biological sampling was conducted at nine of the stations. Gill nets were fished at stations 1 and 16; hoop nets were used at stations 17, 18 and 19; traps were set at stations 1, 2, 14 and 16. Fouling panels were placed at six locations: stations 1, 2, 12, 14, 15 and 16.

The gill net stations were established in tidal streams at locations that were as similar to one another as could be found. The factors considered in making the selection included average depth and width of the stream, distance from the bay, tidal velocity, salinity and the amount and type of rooted aquatic vegetation. The principal difference between the two stations was that heated water flowed through station 16 and was present in the areas immediately offshore of this station while station 1 was unaffected.

The hoop nets were fished at three culverts that connected the main effluent canal with the mangrove swamp behind the rock levee. The stations were established along the main canal at different distances from the plant outfall.

The four trap stations were placed along a temperature gradient, station 1 was the unaffected control and the three other stations were at various locations within the area of discharge. The choice of sites was based on the same factors that went into the selection of the gill net stations. Some differences existed among the stations, these will be discussed below.

The fouling panels were also located along a temperature gradient at stations 1 (the unheated control), 2, 12, 14, 15 and 16. The major consideration in the selection of these stations was the

relative proportion of discharge water and bay water that flowed passed each location. Only one station (Number 15) received no influx of bay water on the flooding tide; at the others within the discharge area, the flow of effluent water alternated with the flow of bay water. Station 1 received no discharge water.

A brief physical description of the sampling stations is contained in Table 2. Only the biological stations will be discussed in detail.

Stations 2, 12 and 15 were all similar. Water depths at mean low tide were from 2.5 to 3 feet. The bottom was composed of a thin (1 inch or less) layer of organic mud overlying the calcareous rock substrate. Vegetation was limited to a few blades of sea grass, mostly Diplanthera and to the seasonal occurrence of some algae. Ebb and flood tides occurred at stations 2 and 12 while at station 15 the water was always moving outward toward the bay. In addition, all the water that flowed by station 15 had passed through the power plant. At station 12 about 70 percent of the flow was discharge water. The effluent was diluted in Lake Rosetta before it reached station 2, so water temperatures at this location were only slightly above normal.

Stations 1, 14 and 16 were located near the mouths of tidal streams where the composition of the bottom was very similar to that of the bay. The calcilutitic sediment varied in depth from 4 to 10 inches and supported thick growths of Thalassia mixed with patches of Diplanthera. The approximate ratios of the two grasses by station were 4 to 1 at stations 1 and 16 and about 3 to 2 at station 14. The area of the bottom covered by vegetation was approximately 70 to 80

Table 2. A brief physical description of the sampling stations.

Station	Water depth at mean low tide (ft)	Width of canal or stream (ft)	Bottom Composition	Bottom Vegetation	Tidal influence*	
					Flood	Ebb
1	3.5	30	Thick layer organic mud	Thick sea grass	50	50
2	2.5	20	Thin layer organic mud	Macroalgae	50	50
3	25.0	150	Rock rubble	Unknown	100	0
4	25.0	150	Rock rubble	Unknown	0	100
5	25.0	180	Rock rubble	Unknown	0	100
6	25.0	80	Rock rubble	Unknown	0	100
7	25.0	70	Rock rubble	Unknown	0	100
8	25.0	65	Rock rubble	Unknown	0	100
9	25.0	75	Rock rubble	Unknown	0	100
10	25.0	75	Rock rubble	Unknown	0	100
11	3.0	45	Thin layer organic mud	Some macroalgae	30	70
12	3.0	15	Thin layer organic mud	Sparse sea grass	50	50
13	3.0	15	Thin layer organic mud	Sparse sea grass	50	50
14	5.0	45	Thin layer organic mud	Some sea grass	50	50
15	3.0	55	Thin layer organic mud	Sparse macroalgae	0	100
16	3.5	25	Thick layer organic mud	Thick sea grass	50	50
17	3.0	Culvert	Culvert	Culvert	60	40
18	3.0	Culvert	Culvert	Culvert	60	40
19	3.0	Culvert	Culvert	Culvert	50	50

\*Normal tidal influence is 50-50

percent at numbers 1 and 16 and about 40 percent at number 14. Water depth averaged 2 to 2.5 feet at mean low water at stations 1 and 16 and about 4.5 to 5 feet at station 14. In addition, the widths of the streams differed, 14 was about 45 feet wide while the others were from 25 to 35 feet across. The tide ebbed and flooded at all three stations. No discharge water passed through station 1 on either tide. On ebb tide, approximately 70 percent of the water flowing by station 14 and 40 percent flowing by station 16 was heated effluent.

## PROCEDURES

### Biological Sampling Program

The biological sampling stations are shown in Figure 7 and a summary of the sampling schedule is given in Table 3.

The investigation was designed to determine what effect the heated water was having on the animals within the waterways through which the power plant effluent flowed. To accomplish this it was necessary to compare the numbers and kinds of animals within the discharge area with those from the control area. The apparent abundances of the various species within these areas could be determined from the catches made by the sampling gear. Since no single fishing gear could adequately sample all the organisms, several types of gear were employed. Gill nets were used for the larger animals and traps for the smaller ones. The hoop nets were employed to catch animals that passed through the culverts along the main effluent canal. The settlement and growth of barnacles was best studied on slate panels.

#### Gill Net Sampling

Gill nets were used to investigate the occurrence, abundance and movements of larger animals between the bay and the tidal streams draining the mangrove swamp. This type of net was employed because it was found that its fishing efficiency was not impaired by the water currents and the quantities of plant debris that occurred within



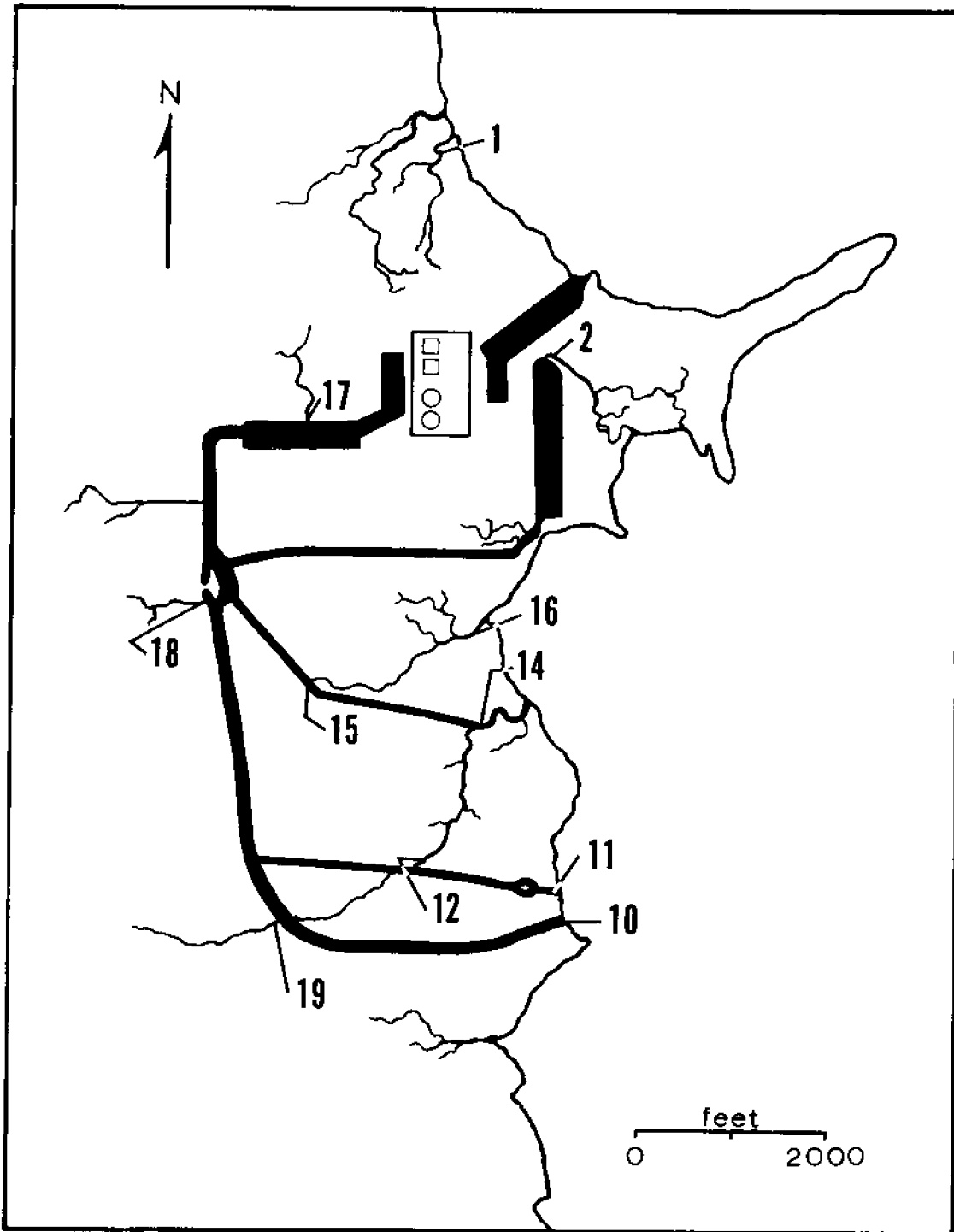


Figure 7. Map of Turkey Point area showing location of the biological sampling stations.

Table 3. Summary of the biological sampling program.

Gear	Duration of Sampling	Number of Stations	Number of Sets or Units of Gear	Duration of Sets	Times Stations Occupied
GILL NETS	3 August 1968 to 3 January 1970	2	2 sets per night per station	6 hours	4 nights per week
TRAPS	29 December 1968 to 23 December 1969	4	4 traps per set per station	7 days	2 sets per month
HOOP NETS	16 December 1968 to 18 December 1969	2	1 set per night per station	6 hours	2 nights per month
FOULING PANELS	16 December 1968 to 3 December 1969	6	5 panels per station; 1 for each exposure period	1 month 2 months 3 months 6 months 12 months	Continuous with replacement

the tidal streams. The nets were constructed of clear monofilament netting hung on a ratio of 3 to 1 on head and foot ropes of 3/8 inch polypropylene line. Nets of three different stretched mesh sizes were used: 4 1/4 inch, 3 1/4 inch and 2 1/4 inch. They were fished in sets of three, one of each size mesh. In this way, a wide size range of animals could be caught. The arrangement of the gill nets during the sampling is illustrated in Figure 8: the net with the largest mesh was placed furthest upstream, followed by the middle-sized net and the small net in order. The head ropes were tied to mangrove roots, and loops in the ends of the foot ropes were set over metal stakes driven into the bottom. The vertical edge of the 2 and 3 inch nets were against the bank of the stream, creating an impassable wall of netting. The edges of the 4 inch net were a foot or more away from the bank (Figure 8). The main purpose of the largest mesh net was to trap floating debris such as mangrove leaves and sea grass blades, and to prevent clogging the smaller nets. The gap in netting near the bank allowed the fish to get around the first net when it became filled with debris.

Gill net sampling was conducted regularly at two locations: station 16 within the area receiving heated water discharge and station 1 outside the area of influence (Figure 7). Sets were made once each week on the night of the second day following each quarter phase of the moon. This day was chosen because the tidal cycle at Turkey Point is such that the turn of the tide on these days falls at about dusk, midnight and dawn, allowing approximately equal hours of darkness for both the early and late night sets.

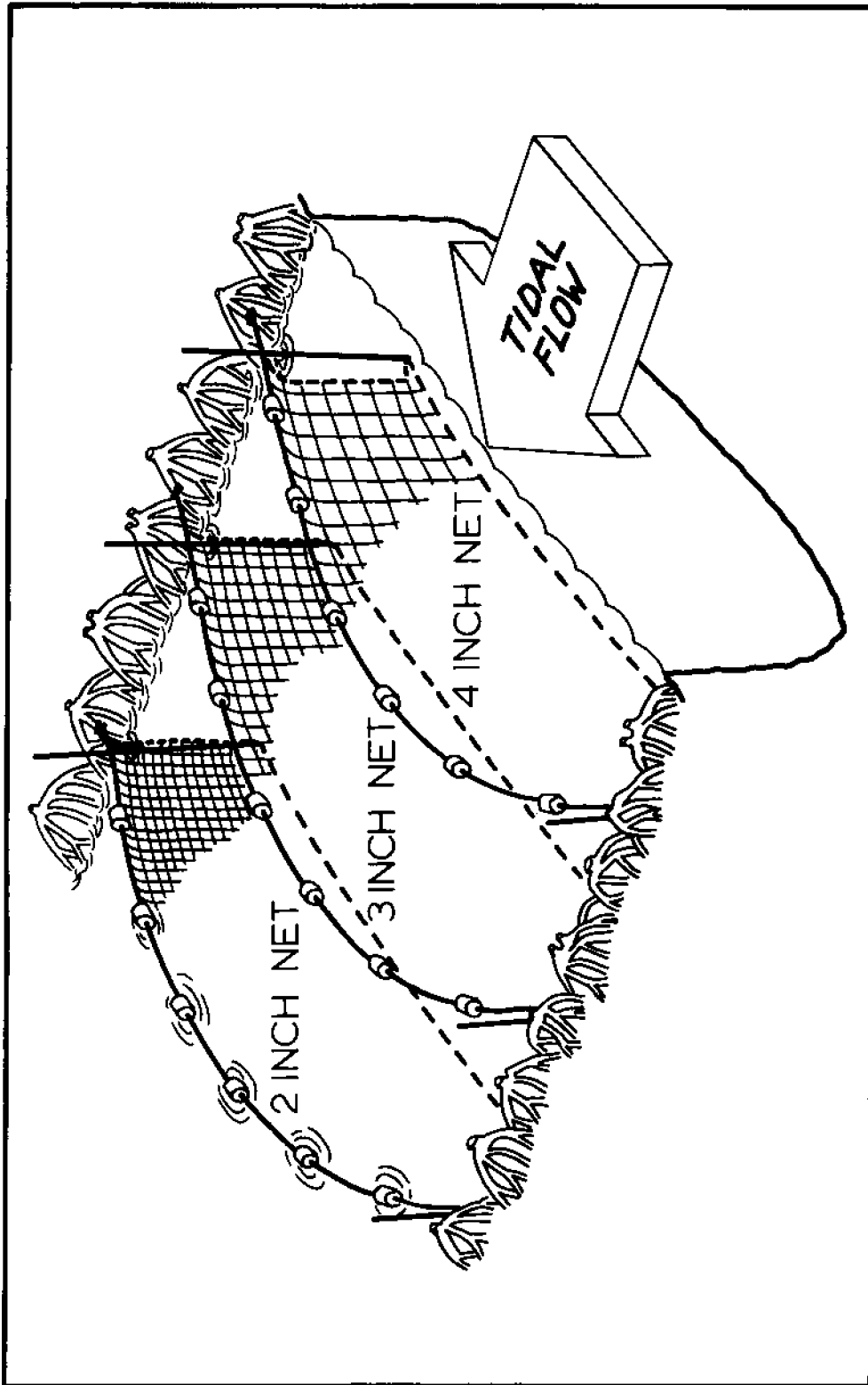


Figure 8. Diagram of the arrangement of the gill nets during sampling.

One group of nets was set at each station just before the tide turned at dusk. Shortly before the next slack tide at midnight a second set was made oriented in the opposite direction to the first. The original set was then hauled. This procedure assured that there would be nets across the stream at all times during a sample period. The second group of nets was hauled as the tide turned at dawn. In this manner both the ebb and flood tides were sampled each night.

The animals caught were removed from the nets, identified to species and measured. In the case of teleosts the length measured was from the most anterior projection of the snout to the posterior edge of the median caudal rays. Two length measurements were made on the sharks: one from the most anterior point of the rostrum to the pre-caudal pit and the second from the tip of the rostrum to the most posterior edge of the dorsal lobe of the caudal fin. In the crabs, the width of the carapace was measured: with Callinectes spp. this was the distance from the tip of one lateral spine to the tip of the other; with Menippe sp. the point at which the carapace width was greatest was measured. In addition to size measurements the stomach contents of each fish were examined and their sexual condition noted. Where possible the sex of all animals was determined.

The gill net sampling was conducted every week from 3 August 1968 to 3 January 1970, a total of 72 nights. The only break in the data occurred on 16 October 1968 when the threat of a hurricane prevented sampling.

Physical parameters monitored during gill net operations included water temperature, salinity, dissolved oxygen, turbidity,

and change in water level. The observations were made three times during each sample night: as the nets were set initially, as they were set and hauled at midnight and when they were finally hauled at dawn. Water temperatures were measured within six inches of the surface with a mercury thermometer. In addition, a continuous record of water temperature at each station was made by the thermographs attached to the fouling panel racks. A full explanation of methods used in salinity and dissolved oxygen measurements is given in the section on water chemistry. The turbidity of the water was judged subjectively and assigned a numerical value 0 to 4; zero being the clearest and four the most murky. Vertical rise and fall of the tide was measured to the nearest half inch. Initially attempts were made to measure the movement of water past the sample station with flow meters. Continual clogging of the instruments by floating plant debris made this procedure unreliable and it was abandoned.

Hourly wind speed and direction values and air temperatures for each sampling period were obtained from records kept by the power company.

#### Trap Sampling

Traps were used to gather information on the occurrence and abundance of the smaller animals in the streams and canals. This gear was chosen because it would yield quantitative, as well as qualitative, data, and because it was found to be one of the most reliable methods of collecting small organisms. The traps were constructed of wood and one quarter inch mesh wire screen. Their dimensions were 30 inches long by 20 inches high by 28 inches wide. The single entry structure

was recessed with a vertical slit opening 10 inches high by 1 inch wide. Iron weights were attached externally to sink the traps.

Sixteen traps were used in the study, four at each of four different locations (Stations 1, 2, 14 and 16; Figure 7). They were baited with about 10 grams of frozen thread herring (Opisthonema oglinum) cut into small pieces. The traps were fished on a schedule of alternate seven days in the water and seven days out. This arrangement gave two seven-day samples during each lunar month. Sets and hauls were timed to fit into the schedule of weekly sampling trips. The catch periods all fell on the new and full moon, usually beginning 3 or 4 days before each phase and ending 2 or 3 days after it. Sampling was carried out from 29 December 1968 to 23 December 1969.

The animals caught were placed in jars with 10 percent formalin and examined at the laboratory. Each animal was identified to species and measured. Measurements of fish and crabs were made according to the procedures given in the Gill Net Sampling section. Shrimp were measured from the orbital notch to the posterior edge of the carapace.

A thermograph located on the fouling panel rack at each station made a continuous record of the water temperatures. Analysis of the strip charts involved reading of the temperature curve at 90-minute intervals and the computation from these readings of a mean temperature for each 7-day sample period. Minimum and maximum readings were also determined.

#### Hoop Net Sampling

Hoop nets were used to study the movement of animals from the main effluent canal into the mangrove swamp behind the rock levee.

Three culverts were chosen along the main effluent canal at different distances from the outfall (Figure 7, stations 17, 18 and 19).

Animals captured passing through the culverts gave information on how far up the main effluent canal animals would penetrate against the temperature gradient to enter the adjacent marsh.

Sampling was carried out from 16 December 1968 to 18 December 1969. The nets were set twice a month on the nights when the tide was flooding from midnight to dawn. These nights were the same as two of the weekly gill net sampling dates and fell shortly after the first and third quarter moon phase.

The hoop nets were chosen for this phase of the study because they could be adapted very easily to sample the culverts. The nets were roughly conical in shape and were constructed of 1/4 inch mesh nylon netting stretched over seven wooden hoops about 40 inches in diameter. The distance from the net mouth to the cod end was approximately 10 feet. When set, the mouth of the net was secured against the mouth of the culvert away from the canal in such a manner that animals moving through the pipe from the canal would pass directly into the net.

This sampling involved two procedures: one of blocking the culvert with a net screen and the other of replacing the screen with the hoop net. The screen with 1/4 inch netting strung over a metal hoop was placed over each culvert at dusk before the tide began to fall. This was to keep animals from leaving the swamp through the culvert on the falling tide and then returning on the flood tide to be caught in the net. The hoop nets were placed over the culverts on the swamp side of the levee just before the tide began to flood at midnight. They were removed and emptied during slack tide at dawn.



A fourth culvert not suitable for sampling was also blocked by screening for the entire night to prevent local movement. This culvert is located in a stream just north of station 18.

The animals caught were identified and measured as described in previous sections.

Physical parameters monitored included water temperature, salinity and dissolved oxygen. Measurements were made before and after each set. Methods used are described in the section on Additional Hydrological Sampling.

#### Fouling Panel Studies

A series of test panels were set out to measure the settlement and growth of some of the fouling organisms present in the study area. Some sessile organisms, particularly barnacles, are very sensitive to certain parameters of their physical environment. They can be used as indicators of water quality. The purpose of the fouling study was to determine what effect the heated effluent water had on some of these organisms.

Cleft slate panels were used as a substrate for settlement. Each measured twelve inches square and varied in thickness from 1/8 to 1/4 inch. Five panels were suspended in a floating rack at each of six stations. The arrangement of the apparatus is illustrated in Figure 9. The panels were aligned in a single row oriented parallel to the tidal flow. The upper edges of the slate were approximately 2 inches below the surface of the water. A thermograph was attached to each rack.

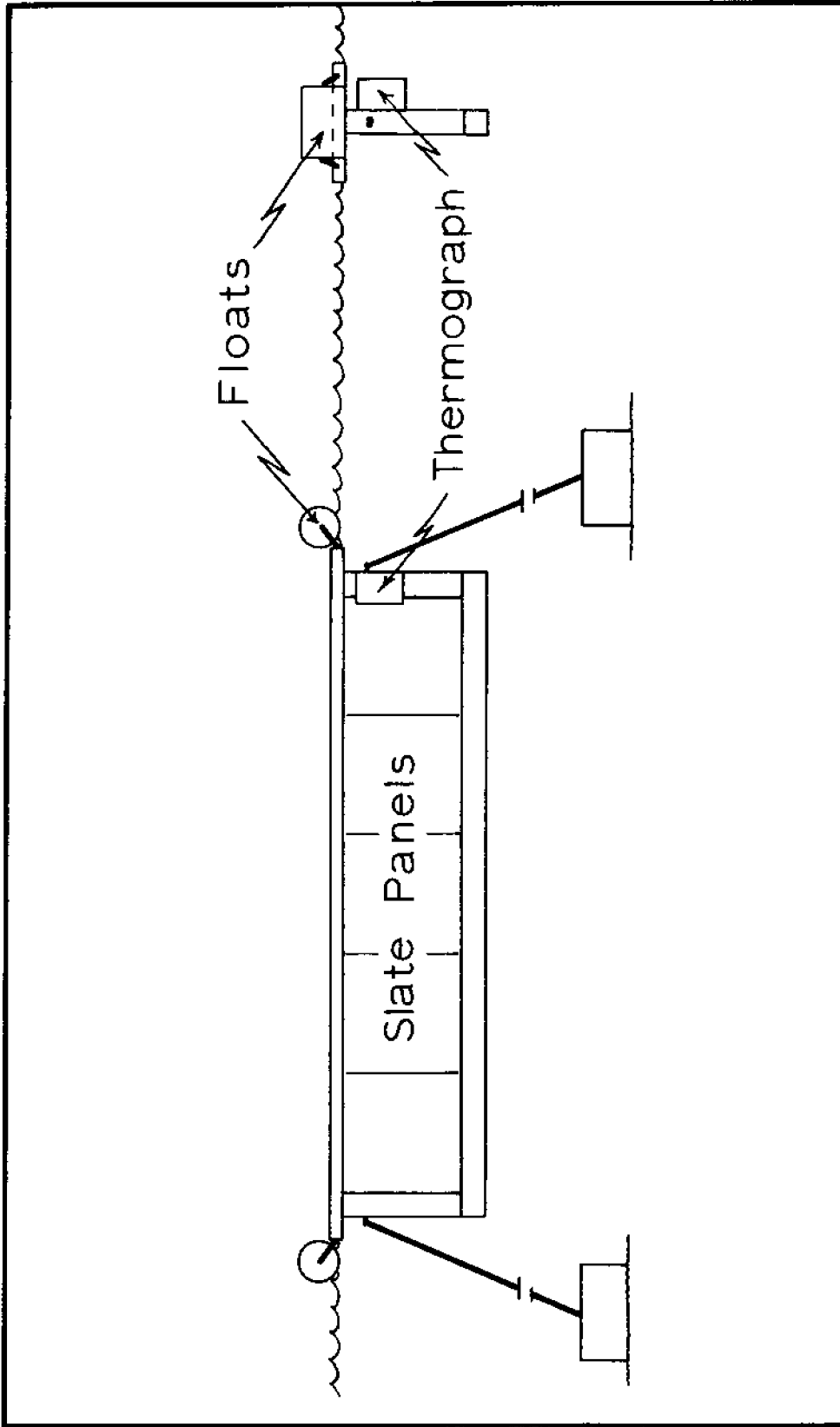


Figure 9. Diagram of the arrangement of the fouling panels on the floating racks.

Six stations were established along a temperature gradient (Stations 1, 2, 12, 14, 15, and 16, Figure 7). The panels were removed at regular intervals and replaced with clean slate. The periods of immersion were 1, 2, 3, 6 and 12 lunar months. Thus each station yielded 12 one-month slates, 6 two-month slates, 4 three-month slates, 2 six-month slates and a single twelve-month slate.

Prior to being placed in the water each panel was allowed to cure in sea water for approximately seven days. After curing they were washed with fresh water, scrubbed with a brush and allowed to stand in the sun for several days.

Panels on the test racks were changed on the second or third day after the third quarter moon phase. Table 4 contains a summary of the replacement dates and the periods of immersion. The sampling ran from 16 December 1968 to 3 December 1969.

Following the period of immersion each test slate was studied in the following manner: the panel was divided vertically into six 2-inch wide columns and the species and number of each of the attached animals within each column was recorded. The lengths of barnacles were also measured to the nearest millimeter.

A continuous record of water temperatures at each station was made by the thermographs. The method of analysis of the strip charts was to read the temperature at 90-minute intervals and to compute a mean temperature for each exposure period. Minimum and maximum readings were also determined.

Table 4. Summary of the treatments given the fouling panels. Dates of immersion and removal are listed together with the duration of exposure (in parantheses) in days.

Month	Exposure Period				
	1 month	2 months	3 months	6 months	12 months
December	16 Dec.-14 Jan. (29)				
January	14 Jan.-12 Feb. (29)	16 Dec.-12 Feb. (58)			
February	12 Feb.-14 Mar. (30)		16 Dec.-14 Mar. (88)		
March	14 Mar.-12 Apr. (29)	12 Feb.-12 Apr. (59)			
April	12 Apr.-11 May (29)				
May	11 May - 9 Jun. (29)	12 Apr.- 9 Jun. (58)	14 Mar.- 9 Jun. (87)	16 Dec.- 9 Jun. (175)	
June	9 Jun.- 8 Jul. (30)				
July	8 Jul.- 7 Aug. (29)	8 Jun.- 6 Aug. (59)			
August	7 Aug.- 6 Sep. (30)		9 Jun.- 6 Sep. (89)		
September	6 Sep.- 5 Oct. (29)	7 Aug.- 5 Oct. (59)			
October	5 Oct.- 4 Nov. (30)				
November	4 Nov.- 3 Dec. (29)	5 Oct.- 3 Dec. (59)	6 Sep.- 3 Dec. (88)	9 Jun.- 3 Dec. (177)	16 Dec.- 3 Dec. (353)

## Water Chemistry Sampling Program

Table 5 contains a schedule of the times and stations where the hydrological data were collected.

### Water Chemistry Sampling

The water chemistry monitoring program involved regular measurements of certain physico-chemical parameters at 12 stations within the study area (Figure 10). Each station was occupied once a week for a year (3 February 1969 to 31 January 1970). All samples were taken from approximately six inches below the surface of the water. Sampling consisted of temperature measurements with a 0.1°C mercury thermometer and the taking of three water samples, one each for the determination of salinity, dissolved oxygen and inorganic phosphate.

The salinity samples were collected in 70 ml screw top plastic bottles. Readings were made in the laboratory with an optical refractometer according to the method of Behrens (1965).

The samples for dissolved oxygen were collected in 125 ml glass-stoppered amber bottles and treated immediately with manganous sulfate, potassium hydroxide-potassium iodide reagents as a preparation for later analysis by Winkler Techniques.

The water for inorganic phosphate determinations was collected in 125 ml glass-stoppered bottles. A 42 ml aliquot of each sample was taken and to it was added a solution of acid-molybdate and freshly prepared ascorbic acid. All samples were so treated within two hours of collection. Analysis was conducted by the method of Murphy and Riley (1958).

Table 5. Summary of the hydrological sampling showing the number of measurements made per week: R = recorder; ( ) = biweekly totals.

Station	Temperature	Salinity	Dissolved Oxygen	Inorganic Phosphate
1	4, R	4	4	1
2	1, R	1	1	1
3	2	1	1	1
4	1	1	1	1
5	1	-	-	-
6	4	1	1	1
7	1	-	-	-
8	2	1	1	1
9	1	-	-	-
10	2	1	1	1
11	1	-	-	-
12	2, R	1	1	1
13	1	-	-	-
14	2, R	1	1	1
15	4, R	1	1	1
16	4, R	4	4	1
17	(1)	(1)	(1)	-
18	(1)	(1)	(1)	-
19	1	1	1	1

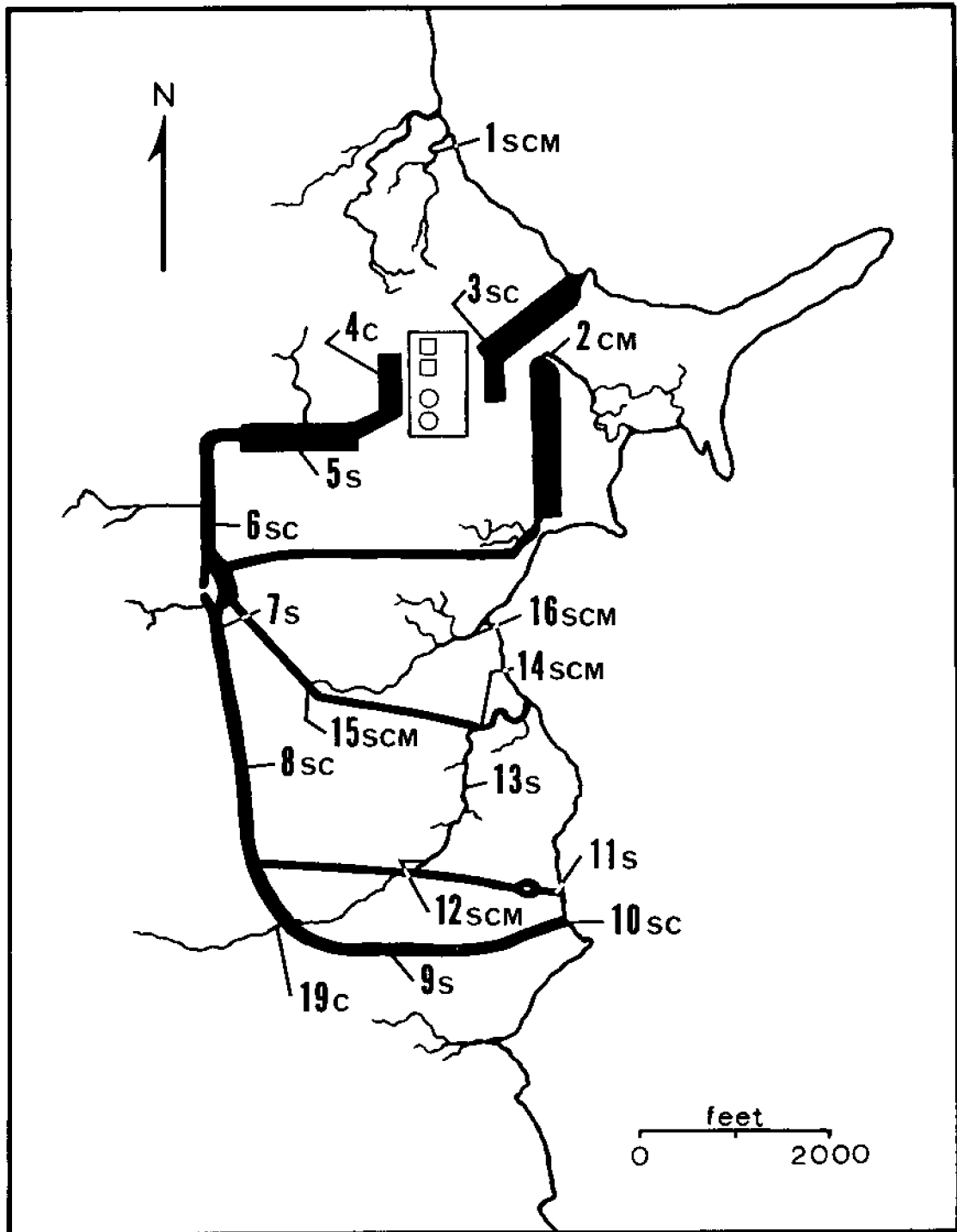


Figure 10. Map of Turkey Point area showing the location of the hydrological sampling stations.  
 S = surface temperature measurement;  
 C = major water chemistry sampling stations;  
 M = thermograph locations

### Additional Hydrological Sampling

In addition to the principal hydrological sampling program, certain physico-chemical parameters were monitored routinely in conjunction with the biological sampling.

During gill netting, water temperature, salinity and dissolved oxygen measurements were made at each station (Numbers 1 and 16). Temperature and salinity determinations were carried out by the methods described above. Dissolved oxygen was measured by means of Hach field kit (Model OX-2-P) which utilizes dry reagents. This method is accurate to within  $\pm 0.5$  ppm. In addition, on two gill net sampling trips of each of the four seasons oxygen samples were taken at the two stations at regular 6-hour intervals for a 24 hour period beginning at noon before sampling and ending at dawn the following day. These samples were also analyzed by Winkler methods.

Additional surface temperature measurements were taken at dusk once a week at 14 stations during gill net operations.

The racks which held the slate fouling panels also supported thermographs which gave a continuous record of water temperatures at the six stations for 13 months. The thermographs were Ryan Instruments Model-F with an eight-day clock and ranges of either 10-40°C or 15-45°C. Due to repeated instrument malfunction, the record for most stations is not continuous, containing gaps of from several days to several weeks.

In conjunction with the bi-weekly hoop net sampling, salinities, water temperatures and dissolved oxygen levels were measured at midnight and dawn. Salinity and temperature were measured in the usual manner, the Hach Kit was used for analysis of oxygen concentration.



## RESULTS AND DISCUSSION

In the text that follows, the word "significant" is used only to designate instances where the results of statistical tests were found to be at a probability level less than or equal to .05. Where this modifier is not employed, the differences being discussed were not statistically significant.

### Results of the Gill Net Sampling Program

#### Hydrological Data

The hydrological data collected during the gill net sampling is compiled in Appendix I. It includes temperature, salinity and dissolved oxygen values.

Water temperatures at station 16 averaged 1.6°C higher than those at station 1 during the hours the gill nets were being fished. Mean differences for the period 5 December 1968 to 4 January 1970 when temperatures were being continuously monitored by thermographs was 1.8°C. Differences between locations varied from -1.2°C (the control being warmer) to 6.0°C. The daily range of temperatures was greater at station 16 due to the flow of discharge water through the area on ebbing tide and the influx of normal or near-normal temperature bay water on the flood tide. Thus, the minimum values for both stations were often similar while the maxima varied widely.

Salinities were slightly different at the two areas. For the entire sampling period the heated station (Number 16) had salinities

averaging 1.2 ppt higher than those of the control. A maximum difference of 8 ppt was recorded after a local rain squall. The higher values at station 16 may be accounted for by the effluent water that passed the station. The cooling water was drawn from the intake canal at a depth of 20 feet and tended to be more saline than the surface waters that normally occurred in the inshore areas.

Dissolved oxygen levels were similar at both locations. The lowest of the three readings taken during each sampling night was recorded at dawn. There were some exceptions to this pattern. In all but a few instances the maximum readings (6-8 ppm) represented supersaturation (up to 225 percent); the minimum values (2-3 ppm) were usually less than full saturation but few were lower than 80 percent.

The pattern of dissolved oxygen content during a 24-hour period are shown in Table 6. Samples for Winkler determinations were taken at approximately six hour intervals at each station on two occasions during each of the four seasons. The usual daily cycle shows a peak in late afternoon and lowest levels during the early morning hours. The occasional irregularities in this pattern can be attributed to the tidal transport of water through the station.

The turbidity of the water and the occurrence of debris in the nets usually were not the same at both stations on any given sampling night. Although it is known that these factors influenced the catching efficiency of the gill nets, it was not possible to determine the exact nature of their effect. It is doubtful that the relationships were linear and without extensive experimentation it

Table 6. Daily patterns of dissolved oxygen concentrations at the two gill net stations for the dates shown. Readings are in ppm; determinations by Winkler method.

Date	Hour	Station 1	Station 16
1969 6 - 7 March	1200	5.12	6.35
	1800	5.03	7.11
	0030	3.36	3.48
	0700	2.61	2.74
11 - 12 April	1200	6.21	5.38
	1800	8.57	5.49
	0100	3.41	3.30
	0600	5.12	2.30
16 - 17 July	1100	4.50	5.09
	1700	4.63	4.31
	0000	4.40	3.32
	0700	2.36	2.04
15 - 16 August	1300	4.21	4.14
	1900	4.40	5.39
	0030	4.28	2.79
	0700	2.95	2.09
27 - 28 September	1300	4.19	4.62
	1730	3.90	4.17
	0030	4.20	3.59
	0700	4.47	2.51
27 - 28 October	1400	5.65	-
	1900	4.39	4.93
	0000	5.33	4.38
	0700	2.86	2.74
3 - 4 December	1200	5.01	5.06
	1800	7.03	6.98
	0000	4.82	4.24
	0700	4.82	4.42
1970 3 - 4 January	1200	4.62	4.81
	1730	5.95	5.85
	0030	3.62	3.57
	0700	4.24	3.63

would have been impossible to determine a correction factor. Since the occurrence of these factors appeared to be random it has been assumed that over the entire 17 months of sampling that their influence balanced out between stations.

#### Statistical Analysis of Gill Net Catches

Wilcoxon's sign rank test was used to analyze the results of the gill net sampling. The null hypothesis tested was that there were no differences in the catches of animals between stations. The null hypothesis was rejected when the critical tabular value at the 0.05 level of probability (two-tailed test) exceeded the calculated Wilcoxon's 't'.

The catch per unit effort was computed by calculating the number of fish caught per minute the gill net was set. In this way the differences in the lengths of time the nets were fished were equalized.

All the catch data for both stations were broken down into three time periods for the purpose of analysis. First, the results for the entire seventeen months of sampling (144 individual sets) were compared. After examination of average temperature conditions for Miami the year was divided into two six-month time periods: summer (mid-April to mid-October) and winter (mid-October to mid-April). All the sample dates fell into one or the other of the categories and analysis was made separately on the data in each. In this way the effects of the heated effluent during the six warmest months could be evaluated and compared with the effect during the six coldest months.

The results of the Wilcoxon's test are contained in Table 7.

The kinds and numbers of animals taken by gill net are listed in Table 8. Forty-four species of fish numbering 1,847 individuals were caught. The most abundant were the gray snapper, Lutjanus griseus (which made up 35.8 percent of the total), the white mullet, Mugil curema (12 percent), the fantail mullet, Mugil trichodon (6 percent), and the yellowfin mojarra, Gerres cinereus (6 percent).

A total of 621 invertebrates from five species were also taken. The blue crab, Callinectes sapidus, made up 90 percent of this total.

#### Catches of All Fishes

Catches of all the fish species were combined for the first analysis. Statistically significant differences in the distribution of catches by station were detectable for both the entire period and the summer period (mid-April to mid-October). No differences were detectable during the winter period (mid-October to mid-April) (Table 7). In all cases of significance, the greater number of fish were taken at the unheated control station (Number 1).

Figure 11 shows the monthly catch data for the pooled fish species. The catch followed a regular annual pattern with lows in August and September and highs in December. The mean varied from 9.8 to 52.5 fish caught per night. On only three months (November and December 1968 and January 1969) did the catch totals of station 16 exceed those of station 1. The differences in catch by station were greatest during the summer months and least during the winter.

Table 7. Results of the Wilcoxon's test on the gill net catch data. (\*\* = significant at  $P < .01$ ; \* = significant at  $P < .05$ , ns = not significant, id = insufficient data).

Animal	Entire Period (Aug. 1968 - Jan. 1970)		Summer Periods (mid-Apr. - mid-Oct.)		Winter Periods (mid-Oct. - mid-Apr.)	
	df	Computed 't'	df	Computed 't'	df	Computed 't'
All fish	132	2304.0**	64	187.0**	68	896.0 ns
Gray snapper	91	1741.5 ns	32	230.0 ns	59	721.0 ns
White mullet	83	1335.5 ns	38	170.5**	45	491.0 ns
Fantail mullet	44	227.5**	16	20.0*	28	121.0 ns
Striped mullet	36	122.0**	13	0.0**	23	83.0 ns
Yellowfin mojarra	48	291.5**	17	54.0 ns	31	87.0**
Ladyfish	57	102.5**	22	8.0**	35	52.0**
Tarpon	31	239.0 ns	20	76.0 ns	11	20.0 ns
All snook	40	158.5**	24	25.5**	16	49.5 ns
Common snook	28	104.5*	15	14.0**	13	39.0 ns
Tarpon snook	14	7.0**	11	3.0**	3	- id
Lemon shark	31	81.0**	21	51.0*	10	0.0**
Blue crab	120	614.5**	65	5.5**	55	501.5*
Species diversity	121	1084.0**	62	144.5**	59	416.5**

Table 8. A list of the species and numbers of animals caught by gill net at each station. Percentages are given in parentheses.

	Total	Station 1	Station 16
VERTEBRATES			
Gray snapper ( <u>Lutjanus griseus</u> )	661 (35.8)	300 (45.4)	361 (54.6)
White mullet ( <u>Mugil curema</u> )	222 (12.0)	129 (58.1)	93 (41.9)
Fantail mullet ( <u>Mugil trichodon</u> )	111 (6.0)	76 (68.5)	35 (31.5)
Yellowfin mojarra ( <u>Gerres cinereus</u> )	111 (6.0)	85 (76.6)	26 (23.4)
Striped mullet ( <u>Mugil cephalus</u> )	104 (5.6)	74 (71.2)	30 (28.8)
Ladyfish ( <u>Elops saurus</u> )	101 (5.5)	92 (91.1)	9 (8.9)
Crevalle jack ( <u>Caranx hippos</u> )	66 (4.6)	55 (83.3)	11 (6.7)
Striped mojarra ( <u>Diapterus plumieri</u> )	49 (2.7)	41 (83.7)	8 (6.3)
Common shark ( <u>Negaprion brevirostris</u> )	48 (2.6)	12 (25.0)	36 (75.0)
Parpon ( <u>Megalops atlantica</u> )	40 (2.2)	22 (55.0)	18 (45.0)
Barracuda ( <u>Sphyraena barracuda</u> )	39 (2.1)	13 (33.3)	26 (66.7)
Common snook ( <u>Centropomus undecimalis</u> )	38 (2.0)	27 (71.1)	11 (28.9)
Schoolmaster snapper ( <u>Lutjanus apodus</u> )	38 (2.0)	17 (44.7)	21 (55.3)
Checkered puffer ( <u>Sphoeroides testudineus</u> )	34 (1.8)	5 (14.7)	29 (85.3)
Sea catfish ( <u>Arius felis</u> )	27 (1.5)	25 (92.6)	2 (7.4)
Parpon snook ( <u>Centropomus pectinatus</u> )	26 (1.4)	24 (92.3)	2 (7.7)
Sailors choice ( <u>Haemulon parrai</u> )	22 (1.2)	19 (86.4)	3 (13.6)
Permit ( <u>Trachinotus falcatus</u> )	17 (0.9)	17 (100.0)	0 (0.0)
Pinfish ( <u>Lagodon rhomboides</u> )	16 (0.8)	12 (75.0)	4 (25.0)
Spotfin mojarra ( <u>Eucinostomus argenteus</u> )	14 (0.7)	14 (100.0)	0 (0.0)
Spotted seatrout ( <u>Cynoscion nebulosus</u> )	12 (0.6)	12 (100.0)	0 (0.0)
Gulf toadfish ( <u>Opsanus beta</u> )	8 (0.4)	2 (25.0)	6 (75.0)
Lane snapper ( <u>Lutjanus synagris</u> )	6 (0.3)	1 (16.7)	5 (83.3)
Gulf flounder ( <u>Paralichthys albigutta</u> )	4 (0.2)	4 (100.0)	0 (0.0)
Pat snook ( <u>Centropomus parallelus</u> )	4 (0.2)	4 (100.0)	0 (0.0)
Barbfish ( <u>Scorpaena brasiliensis</u> )	3 (0.1)	1 (33.3)	2 (66.7)

Table 8. Continued

	Total	Station 1	Station 16
Bull shark ( <u>Carcharhinus leucas</u> )	3 ( 0.1)	2 ( 66.7)	1 ( 33.3)
Bluestriped grunt ( <u>Haemulon sciurus</u> )	2 ( 0.1)	2 (100.0)	0 ( 0.0)
Margate ( <u>Haemulon album</u> )	2 ( 0.1)	2 (100.0)	0 ( 0.0)
Silver jenny ( <u>Eucinostomus gula</u> )	2 ( 0.1)	2 (100.0)	0 ( 0.0)
Nurse shark ( <u>Ginglymostoma cirratum</u> )	2 ( 0.1)	0 ( 0.0)	2 (100.0)
Southern stingray ( <u>Dasyatis americana</u> )	2 ( 0.1)	2 (100.0)	0 ( 0.0)
Scrawled cowfish ( <u>Lactophys quadricornis</u> )	2 ( 0.1)	1 ( 50.0)	1 ( 50.0)
Black drum ( <u>Pogonias cromis</u> )	1	1	0
Shortnose gar ( <u>Lepisosteus platyrhineus</u> )	1	1	0
Lookdown ( <u>Selene vomer</u> )	1	1	0
Jewfish ( <u>Epinephelus itajara</u> )	1	1	0
Gray triggerfish ( <u>Balistes capriscus</u> )	1	0	1
Tripletail ( <u>Lobotes surinamensis</u> )	1	1	0
Spot ( <u>Leiostomus xanthurus</u> )	1	1	0
Blue runner ( <u>Caranx crysos</u> )	1	1	0
Atlantic needlefish ( <u>Strongylura marina</u> )	1	1	0
Sargassum fish ( <u>Histrion histrio</u> )	1	0	1
Remora ( <u>Remora remora</u> )	1	0	1
<b>Totals (Species = 44)</b>	<b>1847</b>	<b>1101 ( 59.7)</b>	<b>746 ( 40.3)</b>
<b>INVERTEBRATES</b>			
Blue crab ( <u>Callinectes sapidus</u> )	561 (90.0)	440 ( 78.4)	121 ( 21.6)
Blue crab ( <u>Callinectes ornatus</u> )	41 ( 6.6)	37 ( 90.2)	4 ( 9.8)
Horseshoe crab ( <u>Limulus limulus</u> )	11 ( 1.8)	7 ( 63.6)	5 ( 36.4)
Stone crab ( <u>Menippe mercenaria</u> )	7 ( 1.1)	4 ( 57.0)	3 ( 43.0)
Spider crab ( <u>Mithrax</u> sp.)	1	1	0
<b>Totals (Species = 5)</b>	<b>621</b>	<b>489 ( 78.7)</b>	<b>133 ( 21.3)</b>



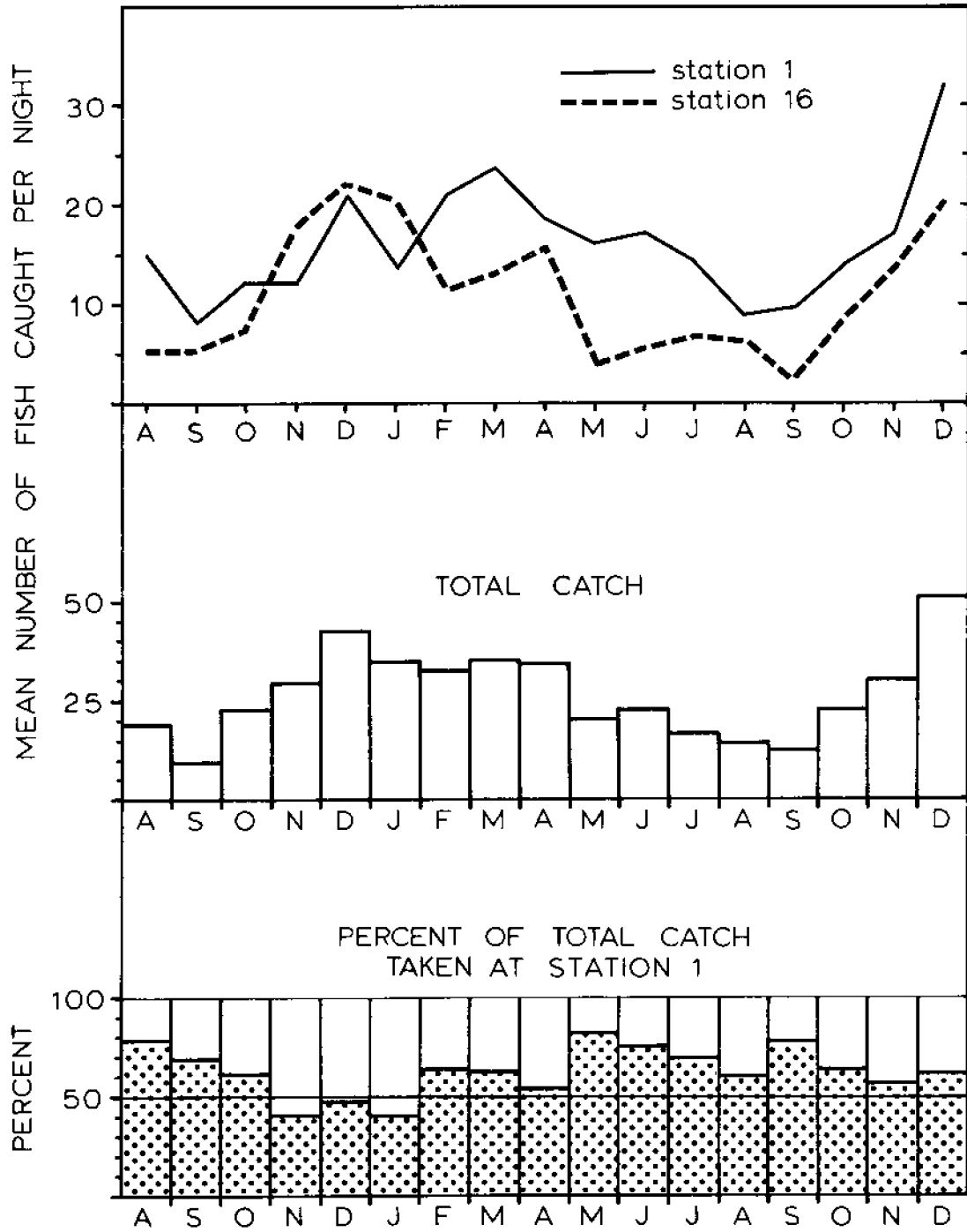


Figure 11. Graphs of the gill net catch data for all of the fish species combined.

The meaning of these results and those for each of the other species will be discussed below after all the catch data for the gill nets have been explained.

#### Catches of Gray Snapper

The gray snapper (Lutjanus griseus) was the fish caught in the greatest numbers (661 specimens); it comprised almost 36 percent of all fish taken by gill net. Approximately 55 percent of them came from the heated area and about 45 percent from the control. The gray snappers were all juveniles ranging in size from 135 mm to 380 mm.

The statistical analysis of the catches showed this species to be one of those being little influenced by temperature. The Wilcoxon's test revealed no significant differences between the numbers of fish caught at each station during any of the periods tested (Table 7).

The catch curves for the period of study (Figure 12) showed that the peak abundance occurred from December to March, with lowest numbers taken from May to October. In six months out of seventeen, more snappers were caught in the control area. There is no obvious pattern to the distribution of catch between stations.

#### Catches of Mullet

The catches of the various species of Mugil are not representative of the abundance of these fish in the sampling area since mullet were not easily caught in gill nets as employed in this study. Often individual fish were seen jumping over the float line and on numerous occasions schools of mullet were seen to approach the nets only to turn away sharply, mill around above the net and move in the

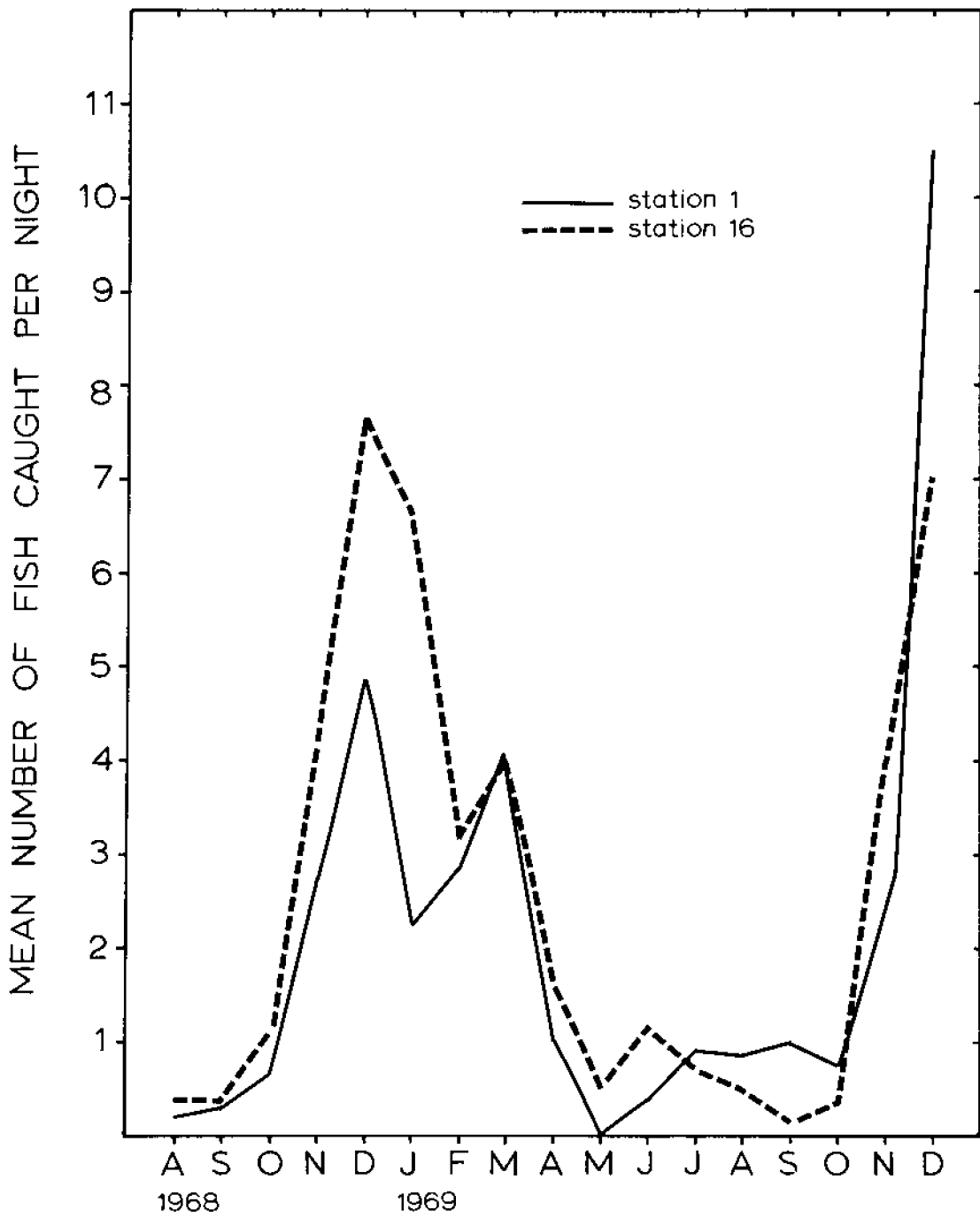


Figure 12. Graph of the gill net catch data for the gray snapper.

opposite direction. This ability of mullet to avoid nets is well known to commercial fishermen.

The second most abundant fish caught (after gray snappers) was the white mullet, Mugil curema. A total of 222 individuals were taken; this was 12 percent of the total catch. Sizes ranged from 113 to 470 mm.

The results of the statistical tests revealed that there were significant differences between the catches at the two stations only during the mid-April to mid-October (summer) period (Table 7). These differences were due to more white mullet being taken at the control station.

The catch data by month showed no seasonal patterns to the occurrence of this fish (Figure 13). On only four months of the sampling period (November, 1968; March, April and December, 1969) were the catches of M. curema greater at station 16.

The fantail mullet (Mugil trichodon) was third in order of abundance. One hundred and eleven specimens (6 percent of the total fish catch) were taken. The smallest one was 158 mm and the largest was 338 mm.

Statistically significant differences in the catches of this mullet between stations were obtained for the entire sample period and for the summer period. In both cases the results were due to higher catches at station 1. No differences were detectable during the winter period (Table 7).

The plot of the monthly catch totals by station (Figure 13) shows that the fish was most abundant during the winter, spring and

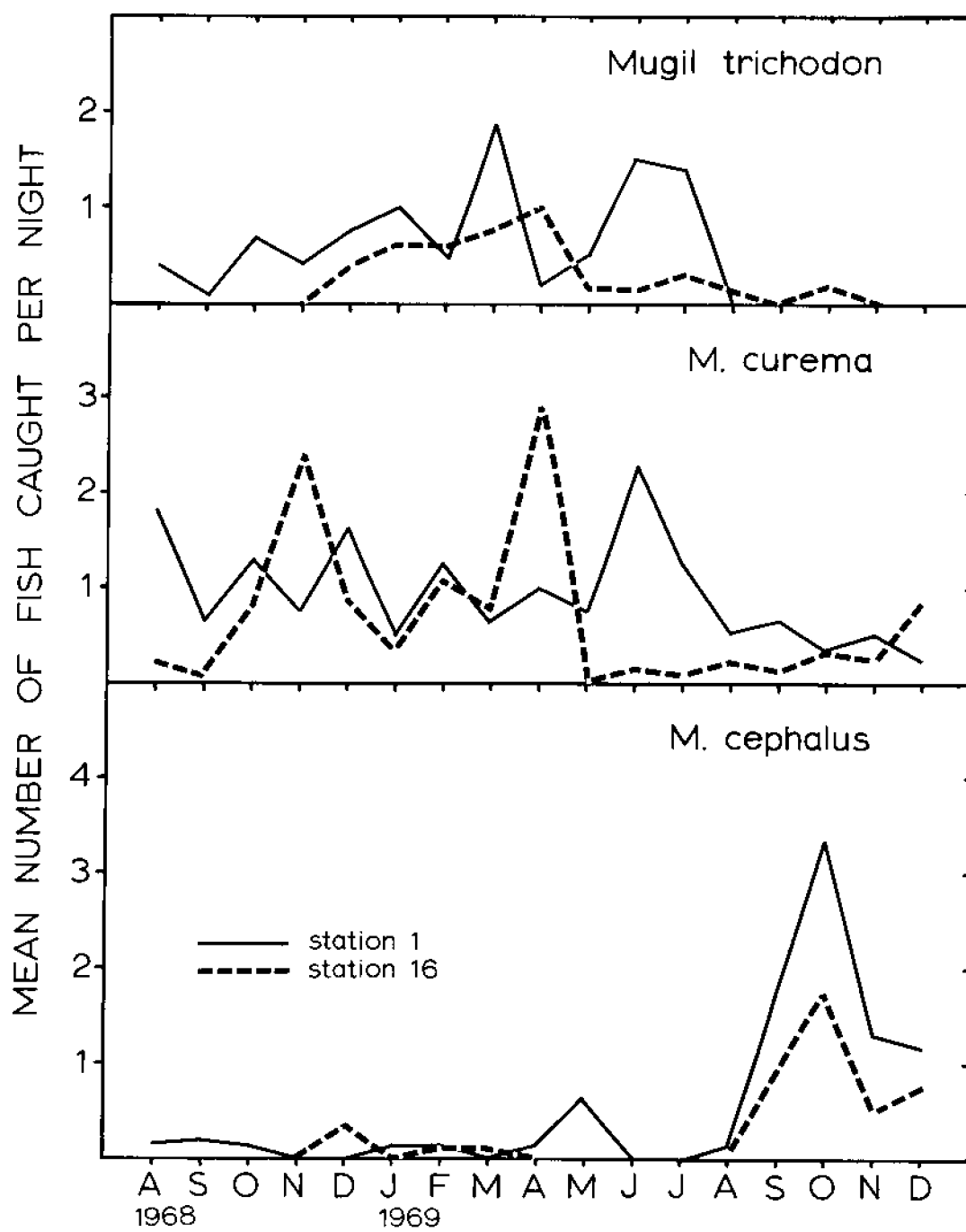


Figure 13. Graphs of the gill net catch data for the three species of mullet.

early summer with lowest catches being made during late summer and fall. Greater numbers were taken at the control station 1 on ten of the seventeen months sampled.

Mugil cephalus, the striped mullet, was caught less often than the other members of the genus. This species made up 5.6 percent of the total catch. Individuals ranged in length from 211 to 467 mm. This mullet was caught in significantly greater numbers at station 1 during both the entire period and the summer (mid-April to mid-October) period (Table 7). There were no differences detectable statistically during the winter (mid-October to mid-April) period.

Figure 13 shows the peaks of abundance which occurred during the fall and early winter with very few specimens taken during the other months.

#### Catches of Yellowfin Mojarra

The 111 specimens of Gerres cinereus caught made up 6 percent of the total fish captured by gill net. The lengths of these fish varied from 112 to 205 mm.

The Wilcoxon's test detected significant differences in the distribution of fish between stations for the entire sampling period and for the winter interval from mid-October to mid-April (Table 7). These results were due to a greater number being caught at station 1.

The catch statistics showed that this mojarra was taken most often from January to May (Figure 14). Station 1 yielded more fish on ten of the seventeen months sampled.

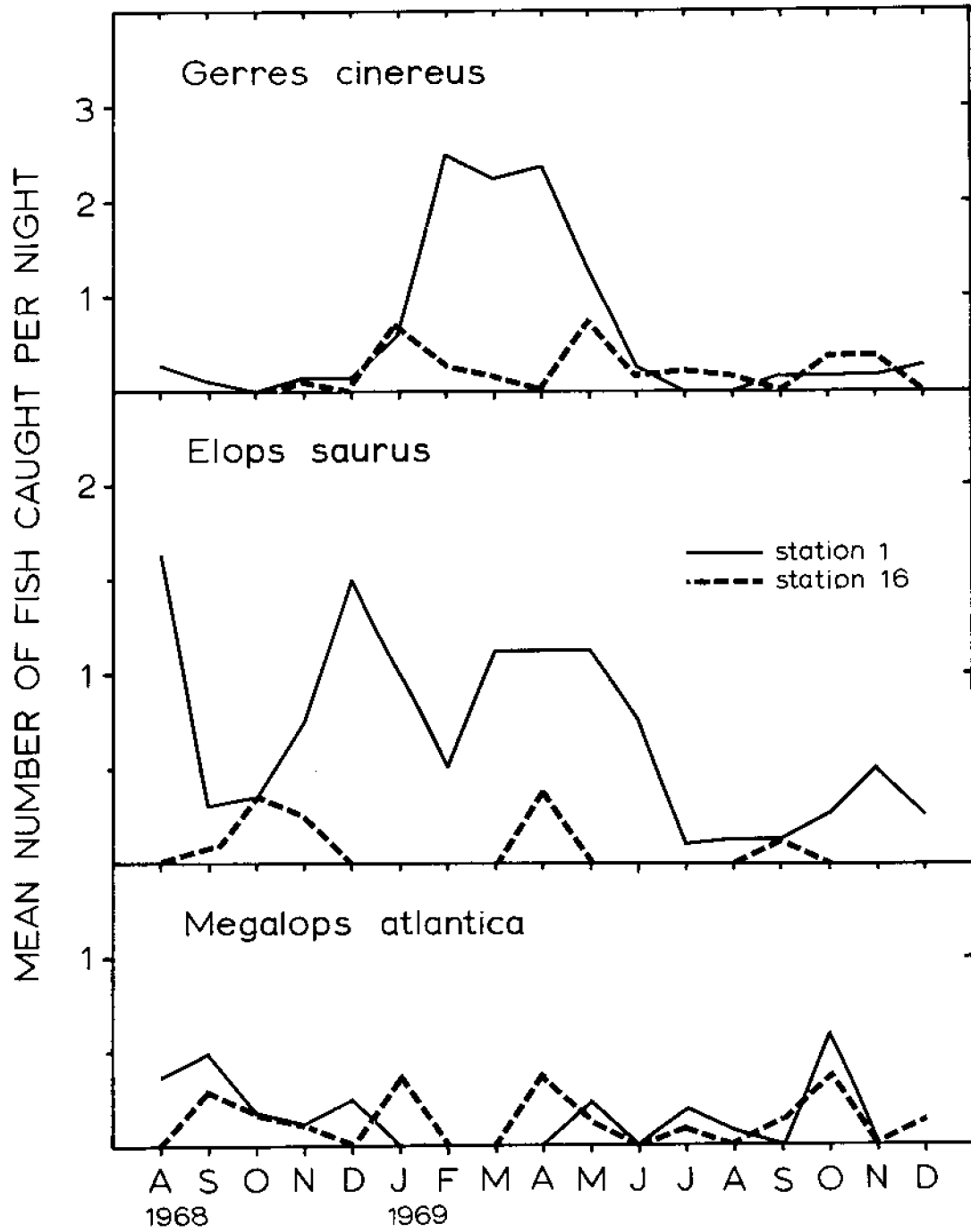


Figure 14. Graphs of the gill net catch data for the yellowfin mojarra, ladyfish and tarpon.

### Catches of Ladyfish

The ladyfish (Elops saurus) ranked sixth in catches among the species taken by gill net. Individuals from 253 to 417 mm in length were caught.

This fish displayed a markedly uneven distribution: 91.1 percent were taken in the control area. The results of the statistical test reflects this pattern (Table 7). Significant differences in catch by station were found for all three periods.

This fish was caught most often from the fall to the early summer (Figure 14). Seasonal lows in occurrence were in the late summer.

The remaining species of fish individually constituted less than 5 percent of the total gill net catch. Those discussed below are of interest either because of their patterns of occurrence or because they are of some importance to the sport fisherman.

### Catches of Tarpon

The tarpon, Megalops atlantica, is an important gamefish in south Florida. Forty specimens ranging in size from 300 to 893 mm were caught during gill net operations. Approximately 55 percent of these came from station 1, the remainder came from station 16.

No significant differences could be detected in the distribution of catch between locations for any of the periods analyzed (Table 7).

Figure 14 contains a curve of the monthly catches of tarpon. Largest yields came during late summer and fall.



### Catches of Snook

Three species of snook were caught during the gill net sampling. The common snook, Centropomus undecimalis (size range 222-565 mm) and the tarpon snook, C. pectinatus (222-532 mm) were taken most often (38 and 26 specimens respectively). Four fat snook, C. parallelus (250-309 mm) were also caught.

In addition to the analysis by species, all the catch data for snook were combined and a Wilcoxon's test run on the pooled information (Table 7). This was done because of the small numbers of both tarpon snook and fat snook caught. Significant differences in the catches between locations were found for the entire sampling period and for the mid-April to mid-October period. In both cases more snook were taken from the unheated area. There were no detectable differences during the mid-October to mid-April interval.

The snook were taken most often from April to November (Figure 15). Greater numbers were caught in the heated area on two of the seventeen months sampled.

Examining the data by species, the common snook showed significant differences in the numbers taken at each station for the entire seventeen months of sampling and for the six month summer period (Table 7). No differences were found for the winter period. The significant results were due to a greater yield from the control area.

The monthly catches were largest during the fall and spring (Figure 15). During eleven months, yields were greater at the control area.

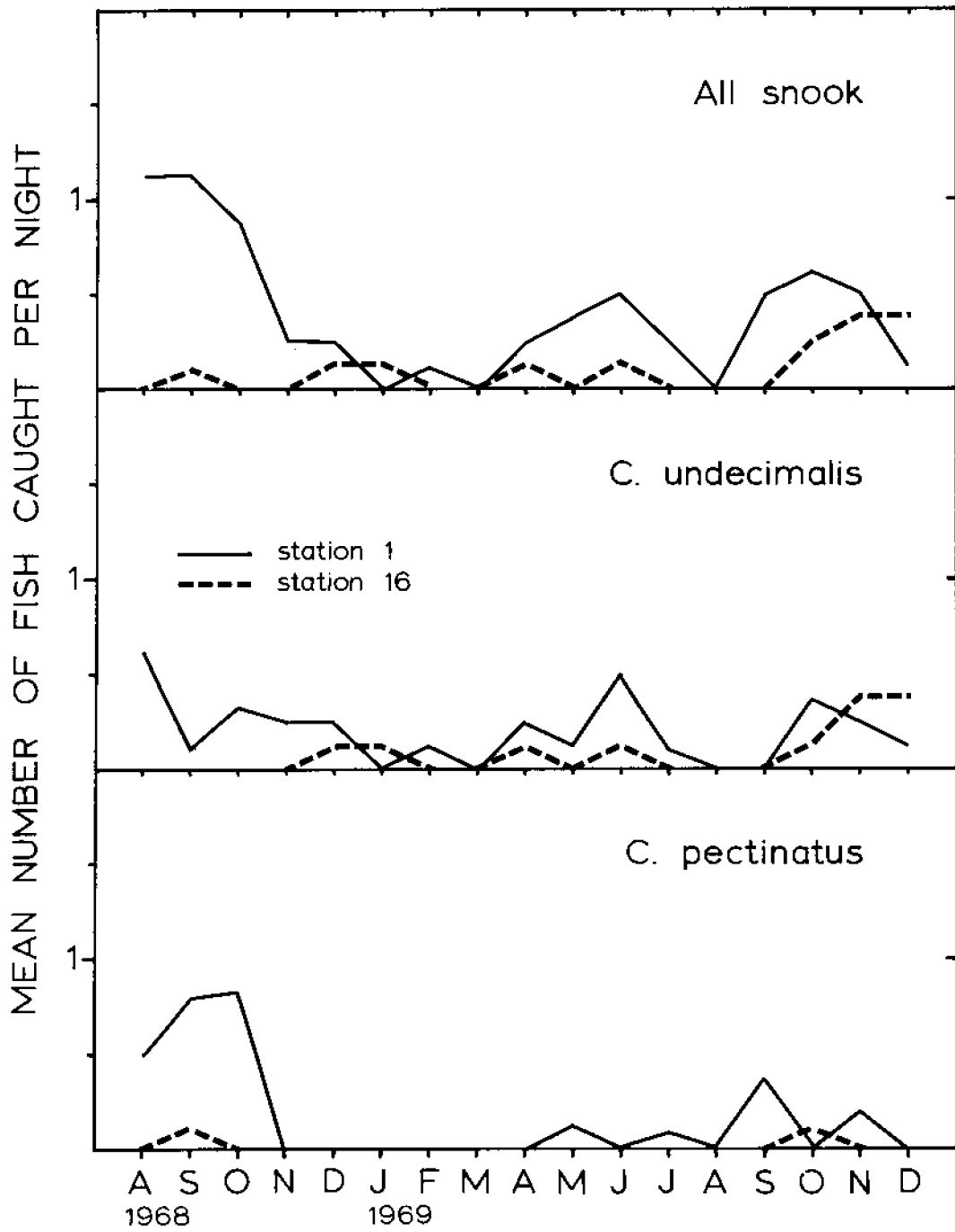


Figure 15. Graphs of the gill net catch data for the three species of snook.

The tarpon snook showed significant differences in distribution between areas during the entire sampling period and during the mid-April to mid-October (summer) interval. There were not enough data to apply the Wilcoxon's test to the catch data from the mid-October to mid-April (winter) period (Table 7).

Peaks in the abundance of this species occurred during the late summer and fall (Figure 15).

#### Catches of Lemon Sharks

The lemon shark, Negaprion brevirostris, made up approximately 3 percent of the total gill net catches of fish. Individuals taken ranged in total length from 610 to 1,261 mm.

This is the only species that was caught in significantly greater numbers at the heat-influenced station. The statistical analysis revealed these differences for all three periods tested (Table 7).

Figure 16 is a graph of the monthly distribution of catch by station. The summer and fall were the periods of greatest abundance.

#### Catches of Blue Crabs

The blue crab, Callinectes sapidus, made up 90 percent of the invertebrates caught by gill net. Five hundred and sixty-one individuals were taken; 440 (78.4 percent) came from station 1 and 121 (21.6 percent) from station 16. Sizes of females ranged from 78 to 186 mm; the males from 96 to 306 mm. The ratio of males to females (about 7 to 1) was the same for both stations.

The results of the Wilcoxon analysis are given in Table 7. Significant differences in distribution between stations was found for

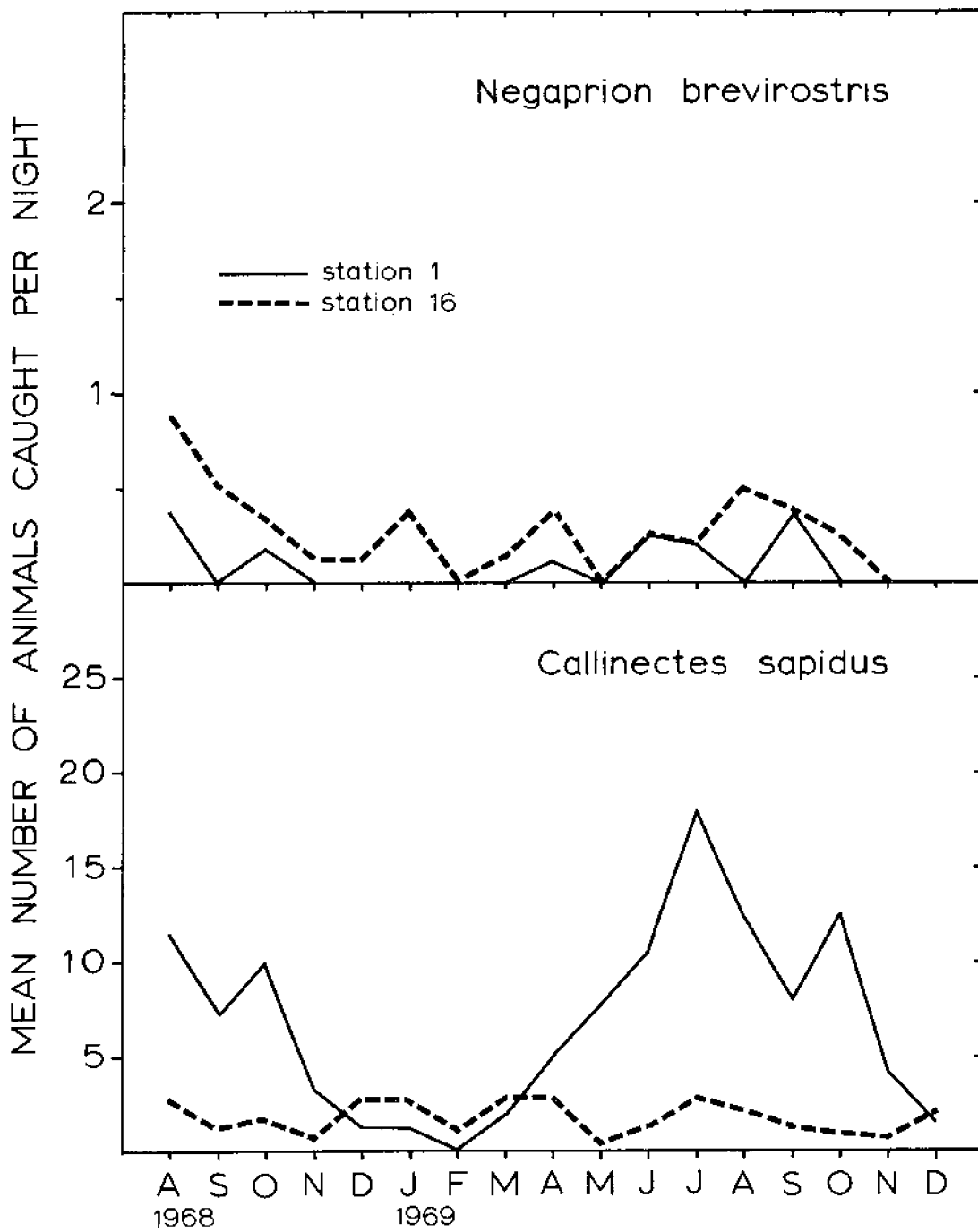


Figure 16. Graphs of the gill net catch data for the lemon sharks and blue crabs.

all three periods. In each case the numbers taken at the control station were greater.

The seasonal peaks in abundance of blue crabs occurred during summer and early fall (Figure 16). More crabs were taken at Station 16 only during the months of December (1968), January, February, March and December of 1969.

#### Discussion of the Gill Net Catches

Differences were observed in the catches of most of the larger fish in apparent response to the presence of the heated water. When considering all the fishes over the entire sampling period, a significantly greater number of the fish caught by gill net occurred in the unheated control area during all periods except winter. During the colder months, no differences between the numbers caught at each area could be detected statistically although there were more fish taken at station 16 only during November and December, 1968 and January 1969. Under no conditions were significantly more fish taken in the heated station.

It would appear that the fishes, as a group, avoided the heated area except when normal water temperatures were lowest. Additional evidence in support of this contention can be obtained by analyzing the catch data in a different manner. The percentage of the catch taken at each station during the six coldest months was compared to the percentages taken during the six hottest months (Table 9). The seventeen months of sampling were partitioned in the same manner as in the Wilcoxon's analysis, that is, with divisions made in the middle of April and the middle of October. The percentage

Table 9. Percentage of the total catch of each species taken at station 1 during the two semiannual periods. Winter includes interval from mid-October to mid-April; summer from mid-April to mid-October.

			Increase of Summer Over Winter as Percentage of Winter Values
	Winter	Summer	
Pooled fish species	53.4%	70.6%	32.2%
Gray snapper	43.8	56.4	28.8
White mullet	42.1	80.3	90.9
Fantail mullet	59.2	69.3	17.1
Yellowfin mojarra	75.8	56.9	-24.9*
Striped mullet	54.7	88.0	60.8
Ladyfish	93.8	86.1	- 8.2*
Lemon shark	5.0	26.6	432.0
Tarpon	30.0	63.8	112.7
Common snook	57.1	93.6	63.9
Blue crab	47.5	87.7	84.6

\*Represents decline in catch during summer.

of all fish caught at the control station was 53.2 percent during the winter period and 70.6 percent during the summer period. This represents an increase of about 32 percent from winter to summer. Since the major differences between the two periods were the relative water temperatures at each station, the changes in catches appear to be due to the presence of the heated effluent. This information, when considered with the statistically significant results obtained in the Wilcoxon's tests, indicate that the heated water influenced the numbers of the larger fishes in the area.

The individual species exhibited similar trends in numbers caught. The animals could be classified according to the patterns of their occurrence at the two stations. They are divided into groups according to which species showed statistically:

1. no significant differences in distribution between stations under any conditions
2. no significant differences in distribution over the entire period but exhibited some significant differences in certain periods
3. significant differences in distribution between stations under most conditions
4. significant differences in distribution under all conditions

The first group is made up of those that exhibited the least response to the presence of the heated water. It includes the gray snapper (Lutjanus griseus) and the tarpon (Megalops atlantica).

The gray snappers that were caught were all juveniles from year classes I to III. They showed no differences in catches in any of the conditions analyzed by the Wilcoxon's test. It was one of these species that exhibited only a small seasonal shift in occurrence by

station. Approximately 44 percent of the winter catch and about 56 percent of the summer catch was made at the control station.

This species has been reported from Florida waters with temperatures as low as 13.4°C (56.1°F) (Springer and Woodburn, 1960) and as high as 36°C (97°F) (Christensen, 1965). Others (Everman and Bean, 1898; Croker, 1960) have found this snapper to be unable to tolerate cold water since it has been a frequent victim of "cold kills" in Florida. However, during such a kill at Turkey Point in January 1970 only a very small percentage of the dead or dying fish observed were gray snappers even though its winter populations in the area are known to be high. This species was one of the last to leave the outfall canal when the effluent temperatures began to rise in the summer and it was one of the first to return with the cooler temperatures in the autumn. It is believed that during the summer months Biscayne Bay is usually too hot for the gray snapper and that this fish moves offshore to cooler waters during this period (C. Richard Robins, personal communication). The low catches made by gill nets at both stations during the warmest months support this contention. Therefore, the addition of heated water to an area that is naturally close to the upper temperature tolerance limit of this snapper could further restrict the occurrence of the species within the affected area.

The tarpon is the other species that exhibited no significant differences in distribution between areas. Since only forty individuals were caught, the evidence is less conclusive than with the gray snapper. However, there were other indications that this fish could



tolerate high temperatures. Groups of individual tarpon were observed rolling in the discharge canal within two hundred yards of the outfall during the summer months when effluent temperatures were continually over 36°C (97°F). This was during periods when no other fish were caught or seen within the main discharge canal. Others (Harrington, 1958) have reported tarpon taken from waters with temperatures up to 32°C (90°F). This fish is also subject to kills during periods of cold weather (Storey, 1937; Springer and Woodburn, 1960).

The ability of this species to withstand extremes in environmental conditions is due at least in part to the fact that the swim bladder is modified for breathing air. The fish is not dependent upon the oxygen content of the water and can therefore exist in areas having low oxygen content where other animals cannot. Under conditions of high temperature such as those that exist within the discharge canals, the metabolic demand for oxygen increases while the concentrations of the gas in the water decrease. The tarpon is able to meet the additional demand by breathing air and can, therefore, remain in the canal system.

The second category includes those fish that exhibited no significant differences in distribution during the whole sampling period but which showed differences during some intervals. The white mullet (Mugil curema) was the only species to fall into this category. The only time differences could be detected was during the summer when more fish were taken in the control area. In addition, the seasonal analysis showed that 42 percent of the white mullet caught

in winter came from the control station while during the summer the number was 80 percent.

In Florida this fish has been recorded in waters ranging from 16 to 36°C (61-97°F) (Tabb and Manning, 1962; Christensen, 1965). Tagatz and Dudley (1961) have reported them in waters with temperatures as low as 11.8°C (53.3°F) in North Carolina.

The white mullet reacts to the heated discharge by moving to areas of normal temperature during the summer months.

The species that are placed in the third category are those which revealed significant differences in occurrence by area when all the months of sampling are considered together but exhibited no differences during some periods. The majority of the animals have been placed in this classification. They include the mullets (Mugil trichodon and Mugil cephalus), the snook (Centropomus undecimalis) and the blue crab (Callinectes sapidus). Within this group the species vary widely in their reaction to the hot water.

In all cases where significance was found, more individuals were caught in the control area.

The fantail mullet (Mugil trichodon) showed little response to the presence of the effluent. The only significant differences found, in addition to those for the entire period, were for the summer months. Moreover, the proportion of the fish caught during each semiannual period differed only by about 17 percent. This species was caught in the present study in water of 35.5°C (95.9°F).

The striped mullet (Mugil cephalus) displayed behavior similar to that of M. trichodon. Significant differences in distribution

were found during the summer in addition to the entire sampling period. However, the six month percentages differed more widely. Fifty-five percent of the winter catch was taken at station 1 while 88 percent of the summer catch came from this area, indicating that this mullet selected the ambient temperature water during times when effluent was hottest. The highest temperatures at which M. cephalus has been reported is 35°C (95°F) in Galveston Bay, Texas (Pullen, 1960). This is slightly above the maximum levels at which it was taken at Turkey Point.

The common snook (Centropomus undecimalis) also showed a preference for the control area during times when the effluent was hottest. The gill net catches revealed a significantly higher number at station 1 for the entire seventeen months and for the summer months. The changes in occurrence at this station by semiannual period were from 57 percent during the winter to 94 percent during the summer.

This fish is a tropical and subtropical species that is very responsive to temperature. It is active during the warmer months and sluggish in the colder ones (Marshall, 1958). Snook are very sensitive to low water temperatures; large numbers have been reported killed by prolonged cold weather in Florida (Storey and Gundger, 1936) and Texas (Gunter, 1941). Storey (1937) related the winter range of C. undecimalis to its lower limit of thermal tolerance as determined from the reported kills. The highest temperature in which it has been recorded was 36°C (96.8°F) (Christensen, 1965).

The blue crab (Callinectes sapidus) exhibited significant differences in distribution at all times except during the winter

quarter. It showed the largest response to the heated discharge of any of the animals in the third category. The breakdown, by semi-annual period, of numbers taken at station 1 reveals that 47 percent of the winter catch and 88 percent of the summer catch came from this location.

Tagatz (1969), during investigations on the temperature tolerance of blue crabs in relation to salinity and acclimation time, found that both adults and juveniles were less tolerant of extreme temperatures in low salinities. The upper lethal limit in water of 34 ppt salinity was about 39°C (102°F) after acclimation at 30°C (86°F). In salinities of 6.8 ppt the upper limit dropped to 37°C (98.6°F). These tolerance limits were found to be comparable to those of more resistant fish.

At Turkey Point a kill of blue crabs in the main discharge canal was observed in late June 1969. Water temperatures in the canal exceeded 40°C (104°F) during part of the time and salinities were about 21 ppt. The conditions under which the die-off occurred are in agreement with the experimental results described above.

The power plant could also influence the reproductive cycle of the blue crab. This species mates in waters of low salinity in the upper reaches of estuaries (Williams, 1965). In the Chesapeake the mating season extends from May to October with greatest activity during July to September (Van Engle, 1958). During the present study mating pairs were caught irregularly throughout the sampling period except during the winter months when total abundance of crabs was lowest. There is no published information on the temperature

requirements of this phase of the reproductive cycle, but from the length of the mating season it appears that the temperature ranges are broad. The effects that the introduction of large quantities of heated water onto the mating grounds would have are unknown. If the areas involved are sufficiently large, significant portions of the blue crab population could be affected.

The final grouping includes those species that showed significant differences during all time periods analyzed. These were the ladyfish and the lemon shark.

The ladyfish (Elops saurus) was always caught in greater numbers at station 1; more than 90 percent of total catch came from this location. The significant results of the Wilcoxon's test reflect this pattern of distribution. Winter catches at the control station vary only by about 8 percent from those in the summer. Thus the occurrence of the ladyfish at the two stations appeared to be primarily influenced by factors other than temperature.

This species has been reported to inhabit the waters of Laguna de Unare, Venezuela where maximum temperatures reach 34.4°C (93.9°F) (Mago, 1965). It has been found in waters of 31.1°C (87.9°F) in the Everglades National Park, Florida (Roessler, 1967). The ladyfish exhibited little reaction to the presence of the heated effluent at Turkey Point.

The lemon shark (Negaprion brevirostris) was the only fish caught consistently that was taken in significantly greater numbers in the heated water. Significant differences in occurrence by station were found under all conditions tested. In addition, 95 percent of the

winter catch and about 73 percent of the summer catch were taken from the heated area. This shark appears to prefer warm water since it remains within the discharge area almost exclusively during the colder months and moves into the control area only when ambient temperatures are higher. Springer (1950), in one of the few published accounts of the ecology of this species, describes the lemon shark as being resistant to high temperatures. He notes that individuals are often taken in warm shallow waters above 30°C (85°F). The distribution pattern at Turkey Point is in agreement with this.

One of the more abundant species of fish displayed patterns of distribution that could not be easily classified into one of the above categories. The yellowfin mojarra, Gerres cinereus, exhibited significant differences in distribution for the winter and spring as well as for the entire sample period. No differences were detectable during the summer. The fish selected the colder water in winter and showed no preference in summer. There was a decrease in the percentage of the total catch taken at station 1 from winter (76 percent) to summer (57 percent). This was the only species to show such a pattern.

There is little information on the ecology of G. cinereus in the few published references on the species. Tabb et al. (1962) found it to be the most abundant mojarra in the Everglades National Park. Its occurrence there was in waters from 16 to 29°C (61-84°F). The highest temperatures from which it has been reported taken was 34°C (93°F) at Jupiter Inlet, Florida (Christensen, 1965). At Turkey Point it was caught in waters as warm as 34.6°C (94.0°F).

### Numbers of Species Caught by Gill Net

The numbers of fish species caught by the gill nets varied both between stations and during the course of the sampling (Figure 17). In all but two months, the species diversity was greater at station 1. Values for station 1 varied from ten to eighteen, those for station 16 from five to twelve.

A Wilcoxon's test was run on the diversity data from the entire sampling period (Table 7). The data was partitioned into the seven units used for the analysis of the individual species discussed above. Significant differences ( $P < 0.05$ ) were found in all conditions tested.

The principle of species diversity as an indicator of the condition of a biological community has been extensively used by ecologists (Copeland, 1967). In a stable community the numbers of species is high. When a stress is placed on the community, the diversity is lowered as those species which cannot tolerate the new conditions are eliminated (Hooper, 1969). The communities dealt with in the gill net sampling are artificial rather than natural. That is, the nets were selecting only the larger animals that passed the station, the smaller ones and those that avoided the net were not caught. Therefore, the application of any of the common diversity indices to the catch data is of doubtful validity. Thus, only the numbers of species of animals is used in the analysis.

The diversity at station 1 was continuously higher than that at station 16. There were no regular patterns to the fluctuations between stations that would indicate these changes were due to thermal

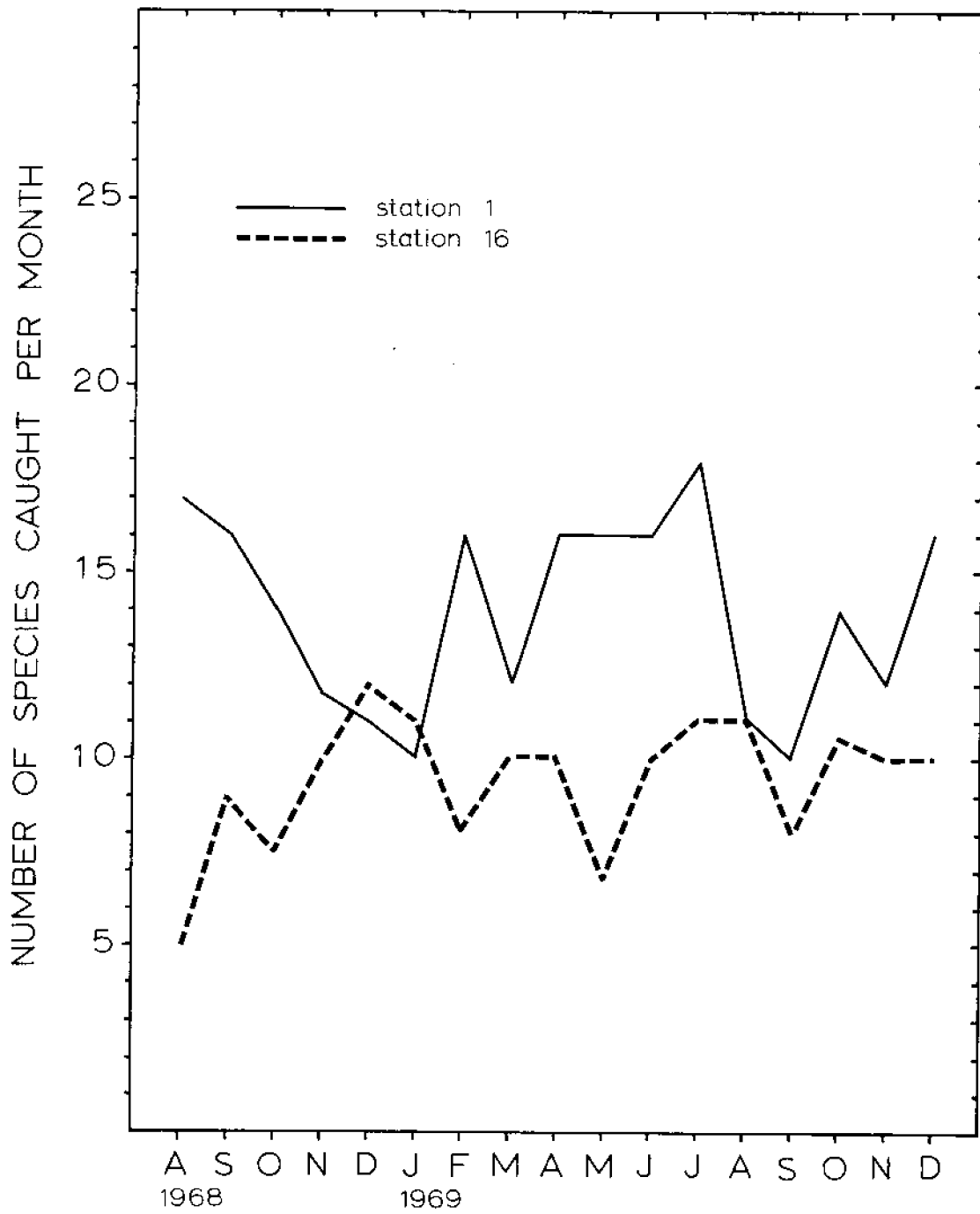


Figure 17. Graph of the numbers of species taken by gill net during the entire sampling period.



stress. If water temperature had been the principal cause of the differences, then the diversity at each station would have varied with season. During the summer months, when the heat stress in the area of the effluent was greatest, the number of species taken at station 16 would have decreased. Then, during the winter, the diversity at station 1 would have fallen, while that at station 16 would not. Analysis of the data does not reveal such a pattern. The differences in species diversity cannot be attributed to the heated effluent from the power plant.

#### Stomach Content Analysis

Heated water can affect fish either directly, by acting on the animals themselves, or indirectly, by influencing such factors as the supply of food organisms. Analysis of the stomach contents of the fishes taken by gill net was undertaken to see if any differences could be found between the food taken by fish in the two sampling areas. If differences were found it could mean that the food organisms were being affected.

The contents of the stomachs of the carnivorous fish caught were studied. Approximately 15 percent of those examined contained identifiable matter. Table 10 gives the findings for the seven species in which food was most often found.

Only the gray snapper yielded enough information from its stomach contents for conclusions to be drawn on its feeding habits. One hundred and eighty-five of the 648 gray snapper examined were found with food in the stomach. Crustaceans made up 71.1 percent of this material, fish constituted the remainder. Penaeid shrimp were

Table 10. Results of stomach content analysis of fish caught by gill net.

Number of stomachs with contents:	SPECIES EXAMINED						
	<u>L.</u> <u>griseus</u>	<u>L.</u> <u>apodus</u>	<u>S.</u> <u>barracuda</u>	<u>E.</u> <u>saurus</u>	<u>C.</u> <u>pectinatus</u>	<u>C.</u> <u>undecimalis</u>	<u>C.</u> <u>hippos</u>
	185	13	15	15	13	10	6
Fish (unidentified)	44	2	5	9	7	6	2
<u>Fundulus</u>	11						
<u>Lophogobius</u>	4						
<u>Mojarra</u>	3	1	2	1	1		3
<u>Anguilla</u>	2						
<u>Mugil</u>	1		5		2	2	1
<u>Gambusia</u>	1						
<u>Opsanus</u>	1						
<u>E. saurus</u>			1				
<u>Centropomus</u>			1				
Total Fish	67						
Shrimp (unidentified)	33				1		
<u>Penaeus</u>	50	2		6	3		2
<u>Alpheus</u>	20	1					
<u>Tozeuma</u>	4						
Total Shrimp	107						

Table 10. Continued

	SPECIES EXAMINED						
	<u>L.</u> <u>griseus</u>	<u>L.</u> <u>apodus</u>	<u>S.</u> <u>barracuda</u>	<u>E.</u> <u>saurus</u>	<u>C.</u> <u>pectinatus</u>	<u>C.</u> <u>undecimalis</u>	<u>C.</u> <u>hippos</u>
Number of stomachs with contents:	185	13	15	15	13	10	6
Crab (unidentified)	5						
<u>Callinectes</u>	27	5					
<u>Panopeus</u>	11	3					
<u>Aratus</u>	4	1					
<u>Uca</u>	<u>1</u>						
Total Crabs	48						
Multiple contents	37						
2 species crustaceans	12						
3 species crustaceans	1						
2 species fish	2						
Crustaceans and fish	22						

the most common crustacean found, followed in order by members of the genera Callinectes, Alpheus, and Panopeus. Other decapod prey included the mangrove crab (Aratus), the arrow shrimp (Tozeuma) and the fiddler crab (Uca). The killifish, Fundulus confluentus, was the most common fish eaten; its occurrence in the stomachs was limited to the months of January and February. Lophogobius and the various species of mojarras were also numerous. Twenty-two (11.9 percent) snappers contained both fish and crustaceans and thirteen (7.0 percent) had two or more species of crustaceans. These results are in general agreement with those found by others working with juvenile snappers from similar habitats (Crocker, 1960; Tabb et al., 1962; W. L. Ham, 1971). The diversity of food organisms that have been recorded from this fish indicates that it is an opportunistic feeder, consuming, within certain broad limits, whatever prey is available. Being less exact in their food requirements, such fish as these are less susceptible to elimination from an area because of the limitation of a food organism. In fact there were no discernable differences between the stomach contents of L. griseus taken from the two stations. However, there was a difference in the occurrence of food by station: 32 percent of the snappers examined from the heated area contained food while 23 percent from the control station had eaten. Of 100 individuals with food, 69 percent were caught during the late ebb. The breakdown by tide stage shows that 102 (55 percent) were taken on the flood tide and the remainder on the ebb.

The examination of schoolmaster snappers revealed a crustacean to fish ratio similar to that for the gray snapper. The barracuda and

the crevalle jack were entirely piscivorous with mullet and mojarras being the most common prey. The ladyfish had a mixed diet in the proportion of 3:2 fish to crustaceans. The two species of snook also consumed more fish than crustaceans.

There were no obvious differences between the stomach contents of any of the fish species taken from station 1 and those taken from station 16.

#### Results of the Trap Sampling Program

##### Hydrological Data

The water temperatures for the periods the traps were in use are given in Table 11. They were computed by reading the thermograph chart tracing at 90 minute intervals. The mean values as well as the minima and maxima for each seven-day set are listed. Station 1 was the coolest and is considered to represent normal temperature conditions. The other stations represent graded increases above normal: station 2 averaged + 0.7°C, station 16 + 1.6°C, and station 14 + 3.0°C. These differences were not constant but varied seasonally, monthly, weekly and with change in tidal cycle. The daily and weekly ranges of temperature also varied among stations. Those showing the widest range were stations 14 and 16 where the flow of heated effluent water alternated with an influx of ambient or near-ambient temperature bay water. These patterns of flow were usually regular, being primarily influenced by the tidal cycle, but irregularities often occurred during periods of strong winds.

Table 11. Water temperatures for the periods the traps were in use. Blanks indicate no data due to thermograph malfunction.

Date	Station 1		Station 2		Station 16		Station 14	
	Mean	Min.	Mean	Min.	Mean	Min.	Mean	Min.
29 December-5 January	-	-	21.1	17.6	22.0	18.0	23.9	19.6
14 January-21 January	19.9	16.7	-	-	20.9	16.7	22.6	19.4
28 January-4 February	21.2	18.9	21.3	17.0	22.1	18.1	-	-
12 February-19 February	17.8	14.8	-	-	20.9	15.0	22.6	18.5
27 February-6 March	-	-	21.0	17.2	-	-	23.2	19.9
13 March-20 March	23.1	16.8	23.9	16.6	-	-	24.5	31.3
28 March-4 April	22.6	18.1	-	-	25.2	19.8	29.2	24.9
12 April-19 April	24.4	21.1	27.1	24.0	28.9	24.0	33.2	27.9
27 April-4 May	26.2	23.1	27.1	31.0	28.0	23.8	31.5	27.5
11 May-18 May	27.4	24.0	29.0	27.0	29.5	25.5	32.9	27.8
27 May-3 June	29.3	25.5	29.7	26.7	30.8	25.8	-	-
9 June-16 June	28.9	25.6	29.3	26.8	30.3	26.8	32.3	27.3
25 June-2 July	30.0	25.2	-	-	31.2	25.4	32.8	25.7
8 July-15 July	30.5	26.3	-	-	34.3	30.6	35.7	31.5

Table 11. Continued.

Date	Station 1		Station 2		Station 16		Station 14	
	Mean	Max. Min.	Mean	Max. Min.	Mean	Max. Min.	Mean	Max. Min.
24 July-31 July	31.2	34.5 27.9	32.5	35.0 29.5	33.6	38.8 28.8	34.6	38.1 30.8
7 August-14 August	31.2	35.8 28.4	31.6	35.0 29.6	34.4	37.9 30.0	33.2	38.2 28.8
22 August-29 August	30.9	34.4 28.5	30.4	33.5 28.5	33.2	37.8 29.1	32.0	36.9 28.6
6 Sept.-13 Sept.	29.5	33.7 25.1	-	- -	31.7	37.0 26.3	32.4	36.8 26.0
21 Sept.-28 Sept.	29.6	34.0 26.7	29.2	31.8 27.6	-	- -	32.7	37.5 29.1
6 October-13 October	27.4	30.0 25.9	27.4	29.5 26.0	-	- -	29.5	32.8 27.0
21 October-28 October	28.0	31.0 25.1	28.7	30.6 25.4	27.8	34.8 25.2	28.4	34.0 25.2
5 November-12 November	22.7	24.5 18.8	22.6	24.5 19.4	23.7	25.7 20.5	27.9	30.0 25.8
18 November-25 November	22.4	27.5 19.5	22.9	27.0 19.9	23.4	28.1 20.1	24.1	28.5 20.7
4 December-11 December	21.7	25.1 18.1	22.7	24.8 18.0	22.8	27.5 18.4	23.3	27.2 18.0
16 December-23 December	20.4	23.1 17.2	21.0	24.4 18.5	21.4	24.8 18.5	22.5	25.5 19.6

The mean salinity values at all the trap stations were within 2 ppt of one another (Appendix II). Readings at stations 14 and 16 and, to a lesser degree, at station 2 were higher than those at station 1.

The dissolved oxygen content of the water was similar at each of the stations (Appendix III). Both the yearly and monthly means showed differences of less than 1 ppm among the four locations. Extreme values rarely differed by more than 2 ppm. The readings for station 2 were consistently the lowest, those for station 16 the highest.

#### Statistical Analysis of Trap Catches

The trap catch data were transformed according to the method of Taylor (1961). A separate transformation factor was computed for each species and then applied to the catch data. It was found that the partitioned variances were non-homogenous even after the transformation. This was due to the large number of zero values in the catch statistics. Friedman's nonparametric method for randomized blocks was employed to analyze the data. The null hypotheses were:

1. there are no differences in catch among stations
2. there are no differences in catch among lunar months

The null hypothesis was rejected if the computed chi-square value exceeded the table value of chi-square at the probability level of 0.05.

The results of the trap sampling are summarized in Table 12. Twenty-one species of fish numbering 2,999 individuals were caught



Table 12. A list of the species and numbers of animals caught by traps at each station. Percentages are given in parentheses.

	Total	Station 1	Station 2	Station 16	Station 14
VERTEBRATES					
Pinfish ( <u>Lagodon rhomboides</u> )	871 (29.0)	306 (35.1)	3 (0.3)	509 (58.4)	53 (6.0)
Silver jenny ( <u>Eucinostomus gula</u> )	523 (17.4)	111 (21.2)	101 (19.3)	172 (32.9)	139 (26.6)
Yellowfin mojarra ( <u>Gerres cinereus</u> )	379 (12.6)	43 (11.3)	28 (7.4)	44 (11.6)	264 (69.7)
Spotfin mojarra ( <u>Eucinostomus argenteus</u> )	332 (11.1)	51 (15.4)	50 (15.0)	162 (48.8)	69 (20.8)
Crested goby ( <u>Lophogobius cyprinoides</u> )	235 (7.8)	42 (17.9)	150 (63.8)	16 (6.8)	27 (11.5)
Gray snapper ( <u>Lutjanus griseus</u> )	194 (6.5)	23 (11.9)	36 (18.6)	64 (33.0)	71 (36.6)
Sailfin molly ( <u>Poecilia latipinna</u> )	104 (3.5)	100 (96.2)	0 (0.0)	4 (3.8)	0 (0.0)
Checkered puffer ( <u>Sphoeroides testudineus</u> )	97 (3.2)	0 (0.0)	4 (4.1)	81 (83.5)	12 (12.4)
Schoolmaster snapper ( <u>Lutjanus apodus</u> )	83 (2.8)	3 (3.6)	23 (27.7)	35 (42.2)	22 (26.5)
Mummichog ( <u>Fundulus heteroclitus</u> )	43 (1.4)	35 (81.4)	0 (0.0)	2 (4.7)	4 (9.3)
Barracuda ( <u>Sphyraena barracuda</u> )	41 (1.4)	4 (4.1)	1 (2.4)	18 (43.9)	18 (43.9)
Sheepshead minnow ( <u>Cyprinodon variegatus</u> )	29 (1.0)	26 (89.7)	3 (10.3)	0 (0.0)	9 (0.0)
Gulf toadfish ( <u>Opsanus beta</u> )	24 (0.8)	9 (37.5)	2 (8.3)	8 (33.3)	5 (20.8)
Sailors choice ( <u>Haemulon parrai</u> )	16 (0.5)	14 (87.5)	0 (0.0)	2 (12.5)	0 (0.0)
Sheepshead ( <u>Archosargus probatocephalus</u> )	9 (0.3)	5 (55.5)	0 (0.0)	1 (11.1)	3 (33.3)
Mosquitofish ( <u>Gambusia affinis</u> )	5 (0.2)	5 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
Bandtail puffer ( <u>Sphoeroides spengleri</u> )	4 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	4 (100.0)
Fat snook ( <u>Centropomus parallelus</u> )	2 (0.1)	0 (0.0)	0 (0.0)	1 (50.0)	1 (50.0)
White mullet ( <u>Mugil curema</u> )	2 (0.1)	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)
Common snook ( <u>Centropomus undecimalis</u> )	1	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)
Bluestriped grunt ( <u>Haemulon sciurus</u> )	1	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)
<b>Totals (Species = 21)</b>	<b>2999</b>	<b>777 (25.9)</b>	<b>402 (13.5)</b>	<b>1122 (37.4)</b>	<b>692 (23.2)</b>

Table 12. Continued

	Total	Station 1	Station 2	Station 16	Station 14
INVERTEBRATES					
Mud crab ( <u>Panopeus herbstii</u> )	210 (40.7)	30 (14.3)	108 (51.4)	59 (28.1)	13 ( 6.2)
Blue crab ( <u>Callinectes</u> spp.)	167 (32.4)	16 (10.0)	0 ( 0.0)	70 (41.9)	81 (48.5)
Pink shrimp ( <u>Penaeus duorarum</u> )	92 (17.9)	10 (10.9)	22 (23.9)	43 (46.7)	17 (18.5)
Brown shrimp ( <u>Penaeus aztecus</u> )	19 ( 3.7)	9 (47.5)	1 ( 5.3)	5 (26.3)	4 (21.1)
Arrow shrimp ( <u>Tozeuma carolinense</u> )	11 ( 2.1)	7 (63.6)	1 ( 9.1)	2 (18.2)	1 ( 9.1)
Stone crab ( <u>Menippe mercenaria</u> )	9 ( 1.7)	1 (11.1)	0 ( 0.0)	2 (22.2)	6 (66.6)
Pink spotted shrimp ( <u>Penaeus brasiliensis</u> )	5 ( 1.0)	1 (20.0)	2 (40.0)	0 ( 0.0)	2 (40.0)
Mud crab ( <u>Panopeus occidentalis</u> )	2 ( 0.4)	1 (50.0)	1 (50.0)	0 ( 0.0)	0 ( 0.0)
Totals (Species = 9)	515	75 (14.6)	135 (26.2)	181 (35.1)	124 (24.1)

during the twelve month period. The invertebrates taken included 515 specimens from 9 species.

#### Catches of Pinfish

Lagodon rhomboides was the fish trapped in greatest numbers. It made up 29 percent of the total fish catch. Sizes ranged from 34 to 156 mm.

Significant differences were detected in the catches of pinfish among the stations (Table 13). No differences were found among lunar months. Figure 18 shows the catch curve at each station. Approximately 94 percent of the fish were taken from stations 1 and 16. The pattern of distribution of catch between these two locations is distinct. From January to early July many more pinfish were caught at station 16 than at station 1, the unheated control. July was a month of uniformly low yields at both sites. Then from August to October, the distribution was reversed with the fish being more abundant in the unheated area. Catches at station 14 were greatest during the late fall and winter months. Pinfish were taken at station 2 on only one occasion.

The possible meaning of these results and those for the other species will be discussed below after the catch data for all the animals has been explained.

#### Catches of Mojarra

Eucinostomus gula was the fish caught in the second largest numbers in traps. Five hundred and twenty-three specimens ranging in length from 37 to 77 mm were taken. The greatest number (32.9

Table 13. Results of the Friedman's test run on the monthly trap catch data. (\* = significant at  $P < .05$ , \*\* = significant at  $P < .01$ , ns = not significant.)

Species	Among Stations		Among Months	
	Degrees of Freedom	Computed $X^2$	Degrees of Freedom	Computed $X^2$
<u>Lagodon rhomboides</u>	3	18.850**	11	4.019 ns
<u>Eucinostomus gula</u>	3	6.125 ns	11	13.923 ns
<u>Gerres cinereus</u>	3	5.175 ns	11	16.875 ns
<u>E. argenteus</u>	3	5.825 ns	11	13.526 ns
<u>Lophogobius cyprinoides</u>	3	8.825*	11	9.673 ns
<u>Lutjanus griseus</u>	3	4.825 ns	11	11.337 ns
<u>Sphoeroides testudineus</u>		3.270 ns	11	6.499 ns
<u>Lutjanus apodus</u>	3	4.637 ns	11	13.919 ns
<u>Panopeus herbstii</u>	3	19.450**	11	12.596 ns
<u>Callinectes spp.</u>	3	14.401**	11	5.972 ns
<u>Penaeus duorarum</u>	3	3.175 ns	11	9.990 ns
Species diversity	3	23.481**	25	33.099 ns

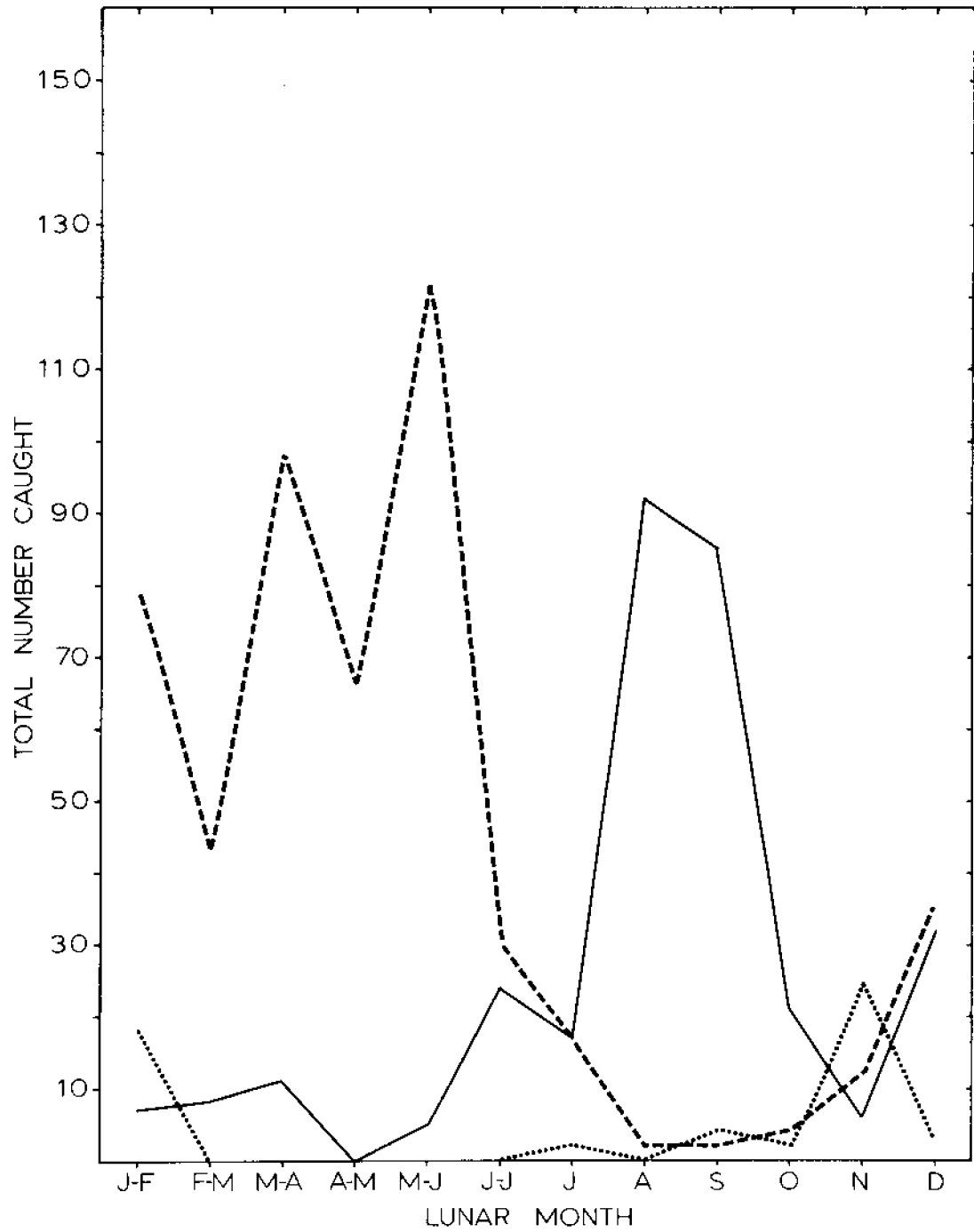


Figure 18. Graph of the trap catch data for the pinfish.

————— = station 1    ●●●●●● = station 14  
 - - - - - = station 2    - - - - - = station 16

percent) were trapped at station 16, the least (17.4 percent) at station 1. Analysis of the catch data showed no significant differences among stations or among lunar months (Table 13).

The monthly catches by station showed several peaks of abundance occurred during the sampling period (Figure 19). At station 14, the hottest one sampled, a sharp peak occurred during the February-March lunar month and a lesser peak appeared during November. The cooler stations (Numbers 1 and 2) both gave maximum catches during the May-June interval. Station 16 showed a bimodal peak during the fall. The catches for the summer months were uniformly low at all stations. Very few E. gula were taken at stations 1 and 2 from October to February while catches for the same period at the other stations were high.

The results of the Friedman's test for Gerres cinereus are given in Table 13. No significant differences could be found in catches among stations or among months. Figure 19 shows that the majority of the fish were trapped during the period from early spring to early summer. Within this interval, the peaks occurred in March and June. Catches were lowest during August and September.

The lengths of the 379 G. cinereus caught varied from 32 to 141 mm.

The third species of mojarra, Eucinostomus argenteus (size range: 27-110 mm), comprised about 11 percent of the total fishes taken by trap. Its catches and distribution were very similar to those of E. gula. Each station showed peaks of abundance at different

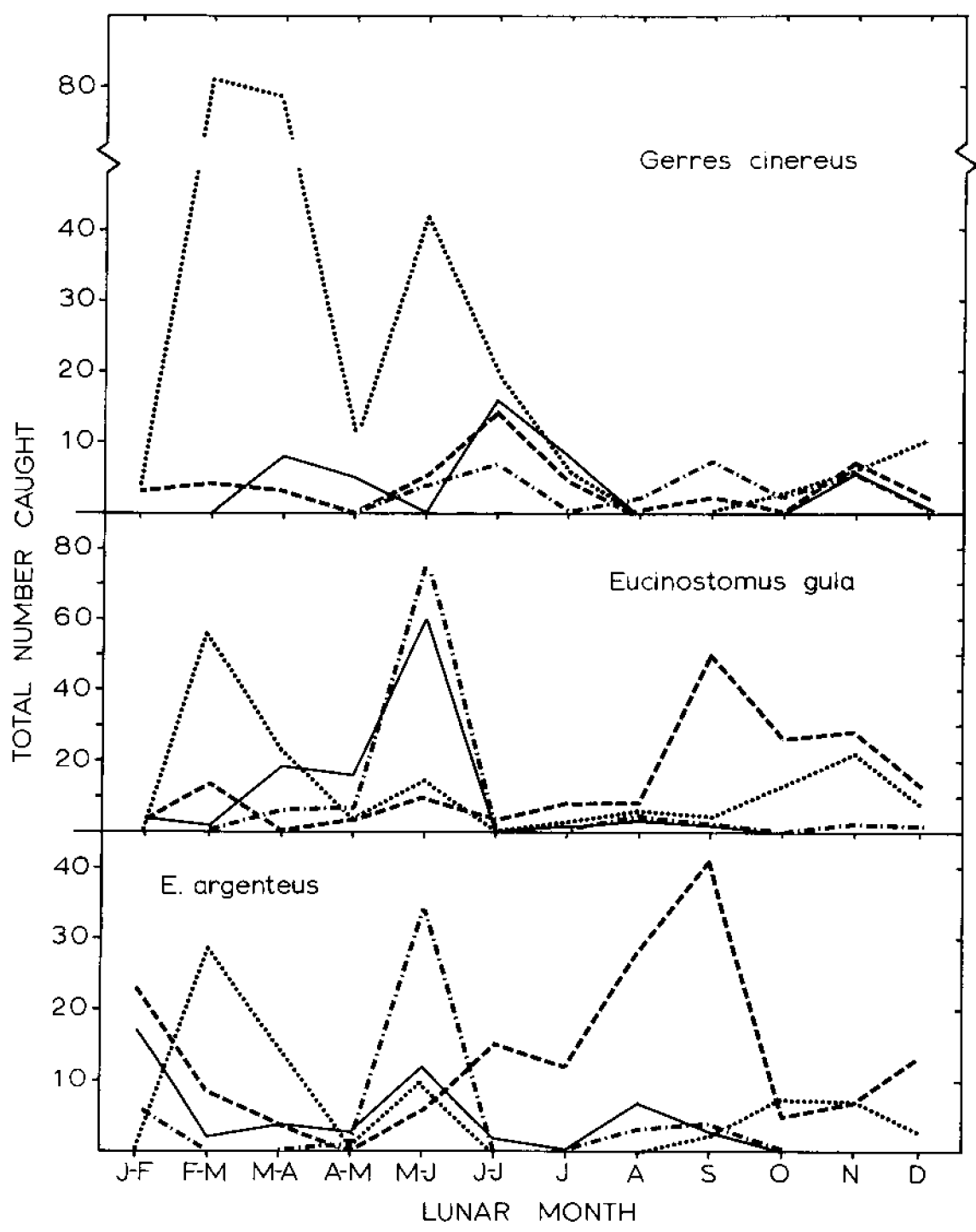


Figure 19. Graph of the trap catch data for the three species of mojarra.

— = station 1    ..... = station 14  
 - - - = station 2    - · - · = station 16

times (Figure 19). The area where the most E. argenteus were taken, station 16, gave maximum yields in September. Station 1 had two peaks: one in the May-June lunar month, the other in August. There was a major peak in February-March and a lesser one in May-June at station 4. The large catches at station 2 in May-June were due to a single large haul made on one set.

In spite of these differences the Friedman's test did not yield significant results either among stations or among months. This is primarily due to the fact that the amount of variation in the samples taken at each station was large enough to mask any differences among stations or months.

#### Catches of Crested Gobies

Lophogobius cyprinoides was taken in lengths from 29 to 77 mm. The number trapped was 235. The statistical analysis showed that the differences among stations were significant because this fish occurred almost entirely at station 2. Catches were greatest from March through August, fell off during September and peaked again during October and November (Figure 20). However, the monthly differences were not significant.

#### Catches of Gray Snapper

The gray snapper, Luvarus griseus, made up 6.5 percent of the total fish catch in traps. The 194 individuals caught ranged in length from 35 to 184 mm. The monthly patterns of distribution showed minimum catches during the late spring and peak abundances from late June through December (Figure 20). This pattern is different from



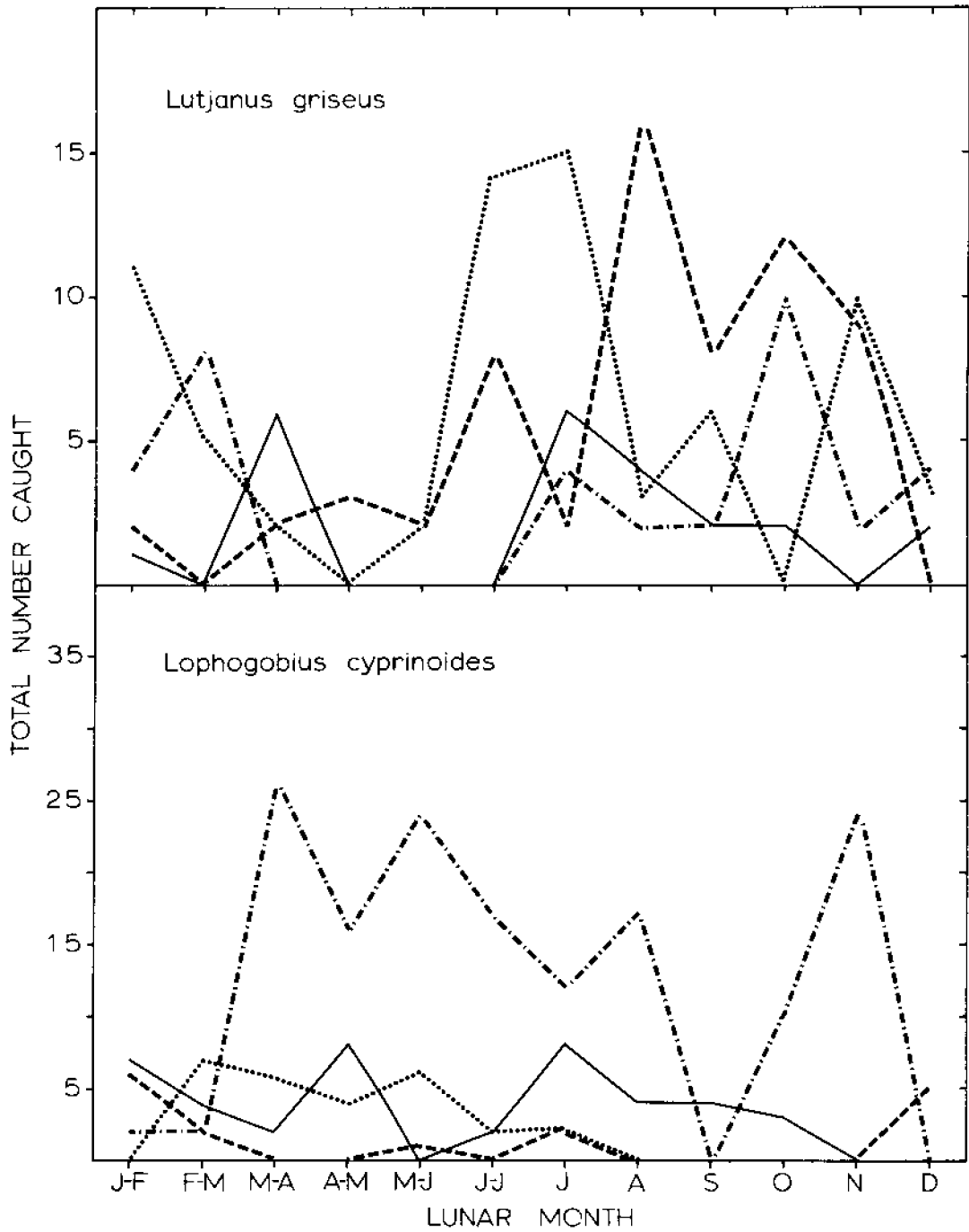


Figure 20. Graph of the trap catch data for the crested goby and the gray snapper.

— = station 1    ●●●●●● = station 14  
 - - - = station 2    - - - - = station 16

that obtained with the gill nets for the same species (Figure 12). Catches by station were greatest at number 14 (71 fish; 36.6 percent of the total) and smallest at number 1 (23; 11.9 percent).

No significant differences among months or among stations were revealed by the Friedman test. Again this was due to the large variability of trap catches at each station that observed the differences among the other factors.

#### Catches of Mud Crabs

The invertebrate caught in the greatest numbers in the traps was the xanthid crab, Panopeus herbstii. The males were in the size range of from 17 to 103 mm, the females 31 to 97 mm. Significant differences were detectable only in the distribution among stations (Table 13). Figure 21 shows the catch curves by area. More than 50 percent of the total was taken from station 2.

#### Catches of Blue Crabs

Crabs of the genus Callinectes also displayed significant differences in their distribution among stations (Table 13). Specimens were taken at only three stations; none were taken at station 2. Maximum catches at stations 14 and 16 were made during the winter (Figure 21). Catches at station 1 were limited to the period from July to October.

The size range of the males was 26-92 mm, that of the females 25-76 mm. A total of 167 of these crabs were caught.

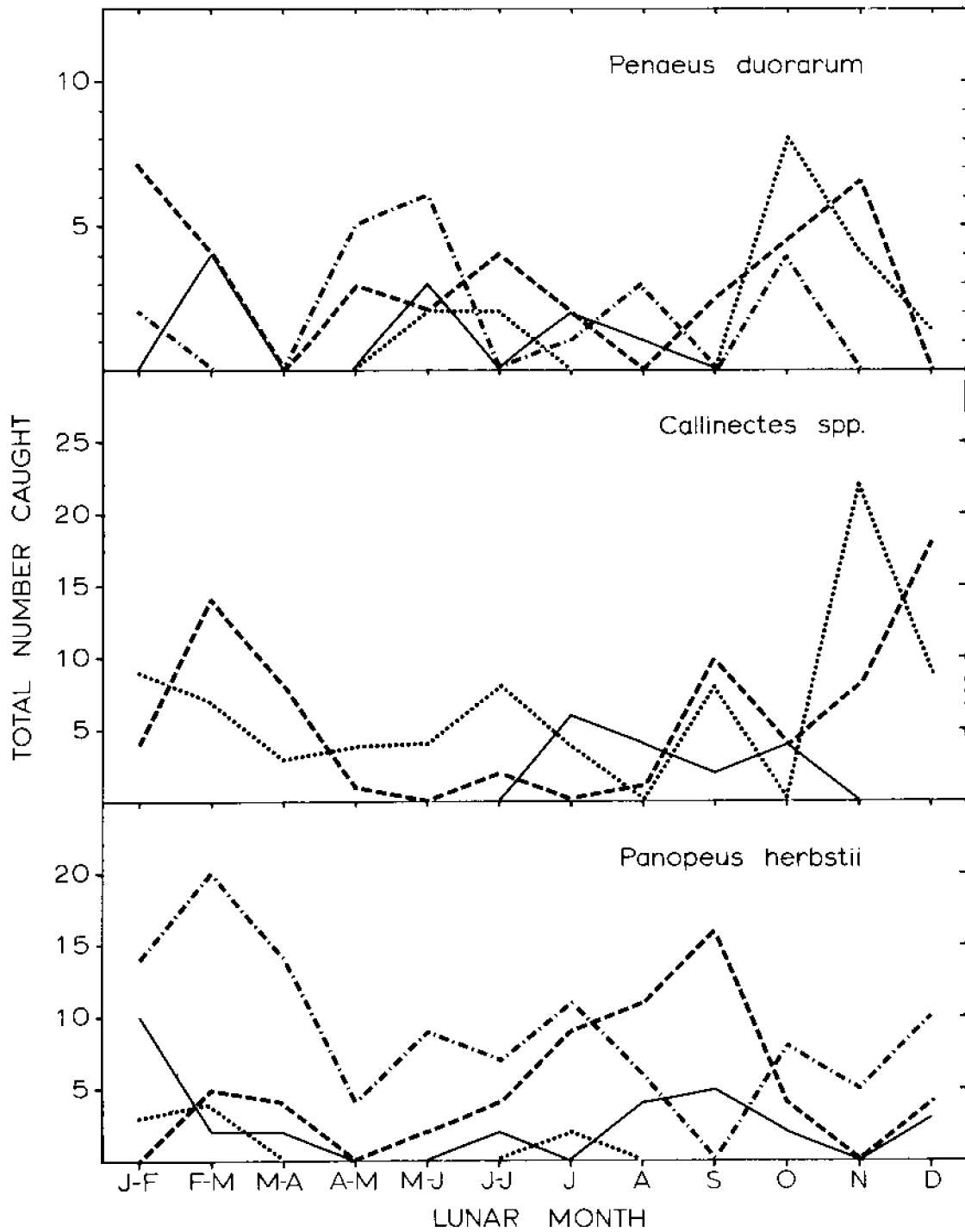


Figure 21. Graph of the trap catch data for the mud crab, the blue crabs and the pink shrimp.

— = station 1    ●●●●●● = station 14  
 - - - = station 2    - · - · - · = station 16

### Catches of Pink Shrimp

Penaeus duorarum made up 17.9 percent of the invertebrates trapped. Almost 50 percent of these were taken at station 16. No significant differences in catch were detected among months or stations by the Friedman test (Table 13). Figure 21 is a plot of the catch statistics by lunar month. Abundances were greatest during the spring and fall.

### Discussion of the Trap Catches

The small fish caught by the traps appear to be less influenced by the thermal effluent than do the larger fish taken by gill net. Only two of the species that individually made up more than 2 percent of the trap totals (the pinfish, Lagodon rhomboides, and the crested goby, Lophogobius cyprinoides) showed significant difference in distribution among stations. Of these, only the pinfish exhibited a distribution influenced by temperature.

The distribution of the total catch of pinfish appears to be related to the amount of rooted vegetation at the trap stations. The greatest proportions of the catch came from station 16 (58.4 percent) and station 1 (35.1 percent). The bottom at these locations had a heavy growth of sea grasses (70 to 80 percent cover) that was contiguous with the grass beds of the bay. At station 14, where about 6 percent of the catch was made, the grasses cover approximately 40 percent of the bottom. The smallest yield (three individual fish) came from station 2 where the cover was the most sparse (about 10 percent) and the stream bottom between the station and the bay is almost devoid of rooted vegetation.

This preference of L. rhomboides for the grass flats has often been described. Caldwell (1957), in his extensive investigations on this species, reports that, in shallow water, the characteristic of the environment that most influences local choice of habitat is the presence of attached aquatic vegetation. Tabb et al. (1962) have found the pinfish in the Everglades National Park to be most abundant over the Thalassia beds. Others have recorded similar associations for this fish throughout its range (Gunter, 1945; Springer and Woodburn, 1960; Cameron, 1969). In addition, Hansen (1970) and others (Caldwell, 1957; Darnell, 1958; Springer and Woodburn, 1960) have found evidence that the vegetation may constitute a large portion of the diet of this species.

The distribution of catch between stations 1 and 16 appears to be temperature related. From late January through early June the yield at the heat influenced station was higher than that at the control. Then for August and September the distribution was reversed and the catches were much greater at station 1. Thereafter the numbers taken at both locations were similar.

An abrupt decline in catches at station 16 occurred in late June following a period of high ambient (35°C [95°F]) and very high effluent temperatures (up to 40°C [104°F]). The area affected by the discharge water included the shallow grass flats immediately offshore from the mouth of the sample stream (station 16). It was in this area that a fish kill was reported about 25 June 1969. Pinfish were not among those species involved in the kill. However, immediately following this incident, the catches of this species at station 16 declined sharply and remained at a low level until December. Within

two weeks after the kill, the yield at station 1 rose markedly. It would appear that the pinfish were driven from the area by the same adverse conditions that caused the fish kill.

A similar pattern of local movement has been reported for pinfish on the Texas coast. Cameron (1969) found that this species moved off the grass flats and into deeper areas when water temperatures reached 35°C (95°F). They returned when levels dropped to the 30-32°C (87-90°F) range. In a study of a turtle grass community, Hoese and Jones (1963) noted that there were two peaks of abundance of pinfish in this area, one in the spring and one in the fall. This species were absent from the flats during the mid-summer period of highest water temperatures. The distribution of pinfish at Turkey Point is similar to the patterns found elsewhere. The fish moves during the summer months from the area receiving heated effluent to areas of ambient temperatures.

The other species that exhibited significant differences in distribution among stations was the crested goby. Sixty-four percent of the total catch of these fish was made at station 2. This concentration accounts for the results of the statistical test. This goby appears to prefer a mud and rock bottom habitat to that of the grass beds. Its distribution at Turkey Point was related primarily to this factor. The patterns of occurrence by station revealed no relationship to temperature.

The two most abundant invertebrates, the mud crab (Panopeus herbstii) and the blue crab (Callinectes sp.) showed significant differences in distribution among stations.

The mud crab was most abundant at station 2. As in the case of the crested goby, this appears to have been due primarily to the nature of the habitat. The absence of rooted vegetation on the mud bottom combined with the presence of broken and crushed oolite rock debris seemed to be the environment preferred by this crab. Individuals were seen in crevices among the rocks and in burrows on the mud banks of the stream. Another factor that could have contributed to the abundance of this crab at station 2 was the large numbers of oysters (C. virginica) and barnacles (Balanus spp.) in the area. The rock fill and the various manmade structures provided solid substrate upon which these sessile organisms could attach. It has been reported that P. herbstii regularly feeds upon both these animals (Menzel and Nichy, 1958; McDermott, 1960). During the present study, mud crabs were observed feeding on both barnacles and oysters on the fouling panels.

The seasonal distribution of the mud crab does not appear to be related to water temperature. This is not unexpected since Teal (1959) reports it to be one of the more eurythermal of the crabs he studied in a Georgia salt marsh.

The smaller blue crabs caught by the traps were most abundant in the area of discharge. Ninety percent of the total catch was taken at the heated stations (Numbers 14 and 16). The remainder were caught at station 1. This pattern appears to be temperature related.

The only times when the crabs were taken in the control area was from July through October. Catches were made at the two heated

stations throughout the year. Lowest yields were in August (when only two specimens were trapped) and highest ones during fall and winter. The literature yields little information on the temperature preferences of juvenile blue crabs. Tagatz (1969) found a more rapid growth during the summer than during the winter. He associated this with warmer water temperatures. Others have also noted a reduction or cessation of growth during the winter months (Van Engle, 1958; Darnell, 1959).

It should be noted that the ability of the smaller crabs to actively select one area over another is much more limited than with the adults. In the size ranges that predominated in the trap catches (20-50 mm) the distribution of the animals is very much influenced by tidal currents. Individual crabs of about 30 mm were occasionally seen "rowing" a mangrove leaf in a tidal stream. The crab gripped the leaf with its walking legs and, by movement of its swimming legs, kept the leaf afloat while the tide carried them along. If such passive transport is representative of the methods the young crab use for moving from one area to another, then their ability to chose a particular area is restricted.

#### Hoop Net Sampling Program

##### Hydrological Data

The hydrological data collected in conjunction with the hoop net sampling is contained in Table 14. Water temperatures during sampling varied from a low of 18.8°C (65.8°F) in December to a high of 39.9°C (103.8°F) in August. Mean differences in temperature among the three stations were less than one degree Celsius: station



Table 14. Water chemistry data collected during hoop net sampling. Readings were taken at the beginning of each set (midnight) and at the end (dawn). Salinities at all stations were within 1 ppt of value given for station 17. (Temperature in °C, salinity in ppt and dissolved oxygen in ppm.)

Sample Date		Station 17		Station 18		Station 19	
		Start	End	Start	End	Start	End
1968							
16 December	Temp.	21.2	19.8	20.9	19.3	20.6	18.8
	Sal.	25.3					
	D.O.	5.5	5.0	5.5	5.0	5.0	4.0
29 December	Temp.	26.7	24.9	26.4	24.7	26.0	24.1
	Sal.	28.1					
	D.O.	5.0	5.0	5.0	4.0	5.0	4.0
1969							
14 January	Temp.	23.8	21.2	23.5	20.7	22.9	20.5
	Sal.	25.1					
	D.O.	6.0	5.0	5.5	4.5	5.0	4.0
28 January	Temp.	26.4	25.1	26.0	24.7	26.0	24.3
	Sal.	25.5					
	D.O.	5.5	5.0	5.5	5.0	5.5	4.0
12 February	Temp.	24.8	23.4	24.3	23.0	24.2	22.7
	Sal.	29.7					
	D.O.	5.0	4.5	5.0	4.5	4.5	4.5
26 February	Temp.	24.9	20.9	24.5	20.2	24.2	19.7
	Sal.	28.9					
	D.O.	5.5	4.5	5.0	4.5	5.0	4.5
14 March	Temp.	20.9	20.1	20.5	19.5	20.0	19.1
	Sal.	31.2					
	D.O.	5.0	4.5	5.0	4.0	5.0	4.0
28 March	Temp.	24.2	21.4	23.9	21.2	23.2	20.0
	Sal.	29.7					
	D.O.	3.5	3.0	3.5	3.0	3.0	3.0

Table 14. Continued

Sample Date		Station 17		Station 18		Station 19	
		Start	End	Start	End	Start	End
12 April	Temp.	30.9	30.2	30.6	30.0	29.8	29.4
	Sal.	25.3					
	D.O.	4.5	4.0	4.5	4.5	4.5	4.0
27 April	Temp.	30.6	27.3	30.3	26.8	30.0	26.2
	Sal.	33.3					
	D.O.	4.0	3.5	4.0	3.5	4.0	4.0
11 May	Temp.	33.0	30.4	32.5	30.1	32.1	29.7
	Sal.	32.9					
	D.O.	4.0	3.5	4.0	3.5	3.5	3.0
27 May	Temp.	34.2	32.7	34.0	32.4	33.8	32.2
	Sal.	20.7					
	D.O.	5.0	4.0	4.5	4.0	4.5	4.0
9 June	Temp.	32.7	30.9	32.5	30.5	32.0	29.7
	Sal.	19.3					
	D.O.	4.5	4.0	5.0	4.0	4.5	4.5
25 June	Temp.	39.6	37.8	39.3	37.5	38.6	36.9
	Sal.	17.7					
	D.O.	5.0	3.0	5.0	2.5	4.5	3.0
8 July	Temp.	37.2	34.3	36.8	33.8	36.4	33.1
	Sal.	19.9					
	D.O.	4.0	4.0	4.0	3.5	4.0	3.0
25 July	Temp.	36.9	35.4	36.5	35.1	35.9	34.5
	Sal.	25.9					
	D.O.	4.0	3.5	4.0	3.5	4.0	3.5
7 August	Temp.	37.7	36.5	37.1	36.2	36.5	35.7
	Sal.	29.1					
	D.O.	5.0	4.5	5.0	4.5	4.5	4.5

Table 14. Continued

Sample Date		Station 17		Station 18		Station 19	
		Start	End	Start	End	Start	End
23 August	Temp.	39.9	37.0	39.5	36.7	39.1	36.0
	Sal.	29.5					
	D.O.	4.5	3.5	4.5	3.5	-	3.0
6 September	Temp.	35.7	33.2	35.4	32.9	35.1	32.6
	Sal.	28.5					
	D.O.	5.0	4.0	5.0	4.5	5.0	4.5
21 September	Temp.	36.9	35.4	36.3	35.1	35.5	34.7
	Sal.	19.7					
	D.O.	5.0	4.5	5.0	4.5	5.0	4.5
6 October	Temp.	36.3	33.9	36.0	33.6	35.7	33.0
	Sal.	24.9					
	D.O.	4.5	4.5	5.0	4.5	4.5	4.0
21 October	Temp.	35.3	34.7	34.8	34.4	34.4	33.7
	Sal.	23.3					
	D.O.	5.5	5.0	5.5	5.5	5.0	4.0
5 November	Temp.	31.1	26.4	30.6	26.0	30.2	25.5
	Sal.	16.1					
	D.O.	4.5	4.0	4.0	4.0	3.5	3.0
19 November	Temp.	27.6	25.2	27.4	24.9	27.0	24.4
	Sal.	18.9					
	D.O.	6.0	4.5	5.5	5.0	5.0	5.0
4 December	Temp.	25.2	22.1	24.9	21.9	24.1	21.4
	Sal.	21.5					
	D.O.	5.5	5.0	5.0	5.0	4.5	4.0
18 December	Temp.	26.2	23.6	25.8	23.2	25.0	22.6
	Sal.	21.3					
	D.O.	6.0	5.0	6.0	4.5	5.5	4.5

17 was the hottest; station 18 was about 0.3° cooler and station 19 was 0.8° cooler than 17. Salinities at each of the stations were all within 1 ppt of each other. Values ranged from 16.1 ppt to 33.3 ppt. The dissolved oxygen content of the water was essentially the same at all stations. Levels were, with few exceptions, uniformly lower at the end of the sampling period than at the beginning. The lowest oxygen readings (2.5 ppm) were encountered during periods of high fresh water runoff and when canal water temperatures were the highest.

#### Biological Data

The hoop nets yielded the least information of any of the biological sampling programs. The results of this phase of the study are given in Table 15. Thirteen species of fish and three species of crustaceans totalling 229 animals were caught. The fewest animals and the fewest species were taken at station 17, the one closest to the plant. Station 18 yielded the highest catches and station 19 the largest number of species. Statistical analysis of the catch data was not possible because of the large percentage of zero or low catches. However, patterns can be seen in the occurrence of animals along the length of the canal. No animals were caught at any station from late June to late August. This interval coincided with the period of highest effluent temperatures beginning on 24 June when water temperatures of 40°C (104°F) were recorded in the main effluent canal near station 17. These high readings were followed by a kill of numbers of blue crabs (Callinectes sp.) and some fish (Haemulon sp.) in the main canal. From the date of the kill until 23 August no animals were caught in the hoop nets. Catches were made at station

Table 15. A list of the animals caught by hoop nets on each sampling date.

	Station 17	Station 18	Station 19
1968			
16 December	2 <u>Lutjanus griseus</u> 1 <u>Lutjanus apodus</u> 1 <u>Haemulon sciurus</u> 1 <u>Mugil curema</u>	1 <u>L. griseus</u>	None
29 December	None	1 <u>Haemulon parral</u>	1 <u>L. griseus</u> 1 <u>Mugil trichodon</u>
1969			
14 January	None	None	1 <u>Callinectes sapidus</u>
28 January	1 <u>S. barracuda</u> 1 <u>L. griseus</u>	1 <u>L. griseus</u> 2 <u>Penaeus duorarum</u>	None
12 February	1 <u>L. apodus</u> 1 <u>Gerres cinereus</u>	1 <u>C. sapidus</u>	1 <u>S. barracuda</u> 1 <u>L. griseus</u>
26 February	None	1 <u>L. griseus</u>	None
14 March	2 <u>L. griseus</u>	None	1 <u>P. duorarum</u> 1 <u>P. aztecus</u>

Table 15. Continued

	Station 17	Station 18	Station 19
28 March	None	None	2 <u>G. cinereus</u>
12 April	None	2 <u>C. sapidus</u> 2 <u>Eucinostomus gula</u> 1 <u>M. trichodon</u>	1 <u>S. barracuda</u> 1 <u>C. sapidus</u>
27 April	None	7 <u>M. curema</u>	None
11 May	1 <u>M. curema</u>	None	1 <u>C. sapidus</u> 2 <u>P. duorarum</u>
27 May	None	1 <u>C. sapidus</u> 5 <u>E. gula</u>	1 <u>S. barracuda</u> 1 <u>M. curema</u>
9 June	None	1 <u>M. curema</u>	None
25 June	None	None	None
8 July	None	None	None
25 July	None	None	None

Table 15. Continued

	Station 17	Station 18	Station 19
7 August	None	None	None
23 August	None	None	1 <u>L. griseus</u>
6 September	None	None	2 <u>L. griseus</u>
21 September	None	2 <u>M. curema</u>	None
6 October	1 <u>M. cephalus</u>	1 <u>S. barracuda</u> 1 <u>L. apodus</u>	1 <u>L. griseus</u> 1 <u>C. sapidus</u>
21 October	None	1 <u>M. cephalus</u> 2 <u>C. sapidus</u>	1 <u>C. sapidus</u> 2 <u>G. cinereus</u>
5 November	2 <u>L. griseus</u> 1 <u>H. parrai</u> 1 <u>G. cinereus</u>	1 <u>C. sapidus</u> 1 <u>L. apodus</u> 86 <u>Cyprinodon variegatus</u>	1 <u>E. argenteus</u> 2 <u>E. gula</u> 29 <u>C. variegatus</u>
19 November	None	2 <u>P. duorarum</u> 20 <u>C. variegatus</u>	1 <u>H. sciurus</u> <u>Anchoa mitchilli</u>

Table 15. Continued

	Station 17	Station 18	Station 19
4 December	1 <u>S. barracuda</u>	1 <u>L. griseus</u> 4 <u>A. mitchilli</u>	None
18 December	None	None	1 <u>S. barracuda</u>
Number of Species	9	12	14
Number of Animals	18	148	63



19 on 23 August, at station 18 on 21 September and at station 17 on 6 October. Thereafter animals were taken irregularly at all stations. Both the largest variety and greatest numbers of animals were caught during the period from October to May.

The animals caught by the hoop nets do not represent all the species present in the main effluent canal during the period of sampling, nor do the numbers taken indicate their relative abundance.

The animals that occurred in the main canal originate either from the bay or from the mangrove swamp to the west. Those that came from the swamp were the killifish, mosquito fish and mollies. These species complete their entire life cycle in the streams and back waters of the mangrove area. Their occurrence in the canal was limited to the months of November through February when large numbers emerged from the streams, passed through the culverts and spread out along the canal banks for some distance. One of these species, the sheep-head minnow (Cyprinodon variegatus) made up almost 65 percent of the total number of fish caught by hoop nets. However, these catches were made only during two sets. Because of the nature of their occurrence, these fish are of only incidental importance in the following discussion.

The animals enter the main canal from the bay either through the large canal or from one of the three smaller discharge canals. Passage through the plant is limited to those organisms that can pass through the three-quarter inch square mesh of the traveling screen at the intake. Those that enter the canal move against the flow of discharge water and up a slight temperature gradient (from 1 to 2°C [1.8-3.6°F]).

Some species move in and out of the canal system throughout the cooler months. These include both schooling types such as mullet, jacks and some tarpon and solitary species such as sharks. In most cases, however, the fish enter the canals in the fall and remain there throughout the winter and spring. These were principally the snappers, grunts, and the yellowfin mojarras and some barracuda. As the temperature of the effluent began to rise in early summer most of these species moved out of the main canal. Those that could not or did not were subject to kills such as occurred in late June 1969.

During the summer months the only fish observed in the main effluent canal were occasional tarpon (as discussed above).

The animals began to return to the canal following the decline in water temperatures in the fall. From the hoop net catches and from observations, it was determined that the gray snapper and the mullet (M. curema and, possibly, M. cephalus) were the first to repopulate the canal. The animals were, at first, restricted to the lower ends of the canal, particularly to around the culverts and entrances to the smaller canals. By October, fish were observed at the outfall; these were a few snapper and barracuda. The following month various grunts and yellowfin mojarra were observed in the same area. The numbers and kinds of fish remained about the same throughout most of the cooler months. With the exception of such schooling species as the bay anchovy (A. mitchilii) the hoop net catches remained about the same.

The heated water offered some animals protection from the cold kills that occasionally occur along the southeast Florida coast in winter. Such a kill took place during early January 1970. Large

numbers of dead fish were reported from inshore areas extending from south of Miami into the Florida Keys. In the area of the power plant as many as five hundred dead or dying fish were observed along the edges of the intake canal and an equal number were removed from the travelling screen at the plant intake. The greatest number of these fish were either grunts of sailor's choice (Haemulon sp.). Other dead included mojarras, barracuda and a few snapper. Dead fish were also observed in the bay and in the tidal streams. No dead fish were found in the main effluent canal although the populations there were as great as those at the intake canal. Those fish that were seen in the outfall side appeared to be behaving in a normal manner.

Normal temperatures, as recorded on the thermographs, were at or below 10°C (50°F), the lower limit of the instruments, for most of the 48 hour period preceding the kill. Readings of about 9°C (48°F) were made with a mercury thermometer at about 0900 hours. Temperatures in the main effluent canal were approximately 6°C (11°F) higher than ambient.

#### Fouling Panel Study

##### Hydrological Data

The water temperature data for the six fouling panel stations are contained in Table 16. The means, and minimum and maximum values for each month are given. Station 1 was considered to represent normal bay temperature conditions. The other stations were located along a temperature gradient. In ascending order they were: station 2 (+ 0.7°C), station 16 (+ 1.8°C), station 14 (+ 3.2°C), station 12

Table 16. Water temperature (in °C) data for the periods the fouling panels were in the water. Values calculated from thermograph recordings except where indicated.

Date		Station					
		1	2	12	14	15	16
1969 16 Dec.-14 Jan.	Mean	19.8	20.1	22.3	22.3	22.6	20.9
	Max.	25.3	26.4	30.0	29.4	29.0	28.0
	Min.	15.1	17.0	21.1	19.4	19.8	16.3
14 Jan.-12 Feb.	Mean	20.7	-	24.3	23.5	24.5	21.8
	Max.	25.9	-	33.1	31.9	33.5	29.9
	Min.	16.0	-	18.3	17.4	21.1	17.1
12 Feb.-14 Mar.	Mean	21.8*	22.4	-	23.8	26.1	23.2*
	Max.	26.9	27.4	-	34.6	35.1	-
	Min.	17.7	18.1	-	18.2	24.0	-
14 Mar.-12 Apr.	Mean	23.4	24.0	28.4	27.5	28.1	25.3
	Max.	31.2	33.0	36.0	38.0	37.5	36.8
	Min.	18.1	22.0	20.5	24.9	26.1	19.1
12 Apr.-11 May	Mean	25.7	27.0	31.5	32.7	33.2	28.6
	Max.	32.6	33.8	36.8	37.9	38.2	37.1
	Min.	23.1	24.3	27.4	27.0	27.5	23.8
11 May-9 June	Mean	28.2	29.2	32.0	32.8	34.5	29.9
	Max.	35.4	36.5	39.0	40.3	40.5	37.6
	Min.	25.2	25.9	25.5	26.3	27.8	25.4
9 June-8 July	Mean	29.6	30.2*	33.5	32.9	34.0	31.5
	Max.	36.0	-	40.0	39.5	41.3	39.3
	Min.	26.3	-	28.8	27.6	28.7	27.7
8 July-7 Aug.	Mean	30.9	31.6	33.5	34.5	35.2	33.0
	Max.	36.5	37.9	39.0	39.0	39.4	38.0
	Min.	27.4	28.3	28.2	27.2	29.5	28.2
7 Aug.-6 Sept.	Mean	30.9	31.0	34.1	32.6	34.9	32.1
	Max.	34.0	34.8	37.8	35.9	38.1	36.3
	Min.	25.1	26.0	26.0	24.7	26.3	25.6

Table 16. Continued

Date		Station					
		1	2	12	14	15	16
6 Sept.-5 Oct.	Mean	29.1	30.1	33.1	31.2	33.4	30.9*
	Max.	32.7	33.6	36.4	34.9	36.9	-
	Min.	23.2	22.8	24.0	23.9	25.6	-
5 Oct.-4 Nov.	Mean	26.7	27.3	31.0	29.1	31.3	27.8
	Max.	30.0	31.2	34.2	33.2	35.5	32.1
	Min.	20.4	21.1	24.1	22.0	24.5	22.2
4 Nov.-3 Dec.	Mean	22.3	23.3	25.4	25.1	25.8	23.0
	Max.	26.9	27.0	30.0	29.0	29.5	28.7
	Min.	15.0	16.1	17.9	17.4	18.0	15.6
Mean		25.4	26.5	29.5	28.6	29.9	27.0
Degrees above ambient		0.0	0.7	3.8	3.2	4.5	1.8

\*Indicates less than 21 days of possible thermograph recordings available for calculation of mean

-Indicates thermograph malfunction; no recordings

(+ 3.8°C) and station 15 (+ 4.5°C). These temperatures are yearly mean differences; under actual conditions, the differences were not constant but varied both on a daily, and monthly basis. The temperatures given above and those included in Table 16 are taken from thermograph recordings.

The monthly salinity values for the six stations can be found in Appendix II. The mean differences among stations were less than 2 ppt. Readings ranged from a high of 34.5 ppt in April at station 16 to a low of 12.5 ppt in November at station 1. Those areas receiving discharge water tended to have higher salinities.

The levels of dissolved oxygen varied only slightly from station to station (Appendix III). Differences among both monthly and yearly means were 1 ppm or less. Individual readings rarely differed by more than 2 ppm. The highest measurements (6-8 ppm) were recorded regularly at station 16 the lowest (3-4 ppm) at station 2.

#### Statistical Analysis of Barnacle Settling

The distribution of the barnacles on the panels was found to be not normally distributed. A significant correlation ( $P < .05$ ) existed between the means and variances of the number of organisms in each of the six columns on the fouling panels. A transformation was then made according to the method of Taylor (1961). A separate transformation factor was calculated for each group of data to be statistically compared. Each observation in that group was then raised to the appropriate power. A Cochran's test for homogeneity of variance was run on the transformed data as described in Dixon and

Massey (1957: 180). The variances were found to be homogeneous. A randomized complete block design model analysis of variance was performed to test the differences in settlement rate both among stations, which were considered treatments, and among months which were considered blocks.

All the panels of the same exposure time were compared with respect to differences both among stations and among months as well as interaction of months and stations. Three null hypotheses formulated were:

1. no differences exist in the distribution of barnacles on the panels among the stations
2. no differences exist in the distribution of barnacles on the panels among the months
3. there are no significant interactions of months and stations

The null hypothesis was rejected if the computed F-ratio exceeded the table value of F at the probability level of 0.05.

The floating rack at station 12 disappeared during the final week of the experiment and was not recovered. It contained five panels, one for each exposure period. Since it was impractical to regenerate the missing data mathematically, all the information from the other stations for the final month (November) were eliminated from the major statistical tests. The randomized complete block analysis was run on only eleven months of the study data. Separate one-way analysis of variance tests were run on the November data.

#### Organisms Collected on the Fouling Panels

The fouling panels yielded a wide diversity of sessile organisms. Balanus eburneus (the ivory barnacle) was the most

numerous of the barnacles making up about 84.7 percent of the total. B. improvisus constituted 12.6 percent, and various members of the amphitrite complex made up the remaining 2.6 percent. Several specimens of B. tessalatus were also found and identified, but the other members of the amphitrite group were not identified to species because of the taxonomic reorganization that the complex is presently undergoing. There was no pattern to the distribution by station of the various barnacle species. With the exception of the few B. tessalatus which all occurred at station 14, the various species were found at all locations sampled. A larger proportion of the amphitrite group were found at stations 12 and 14.

The American oyster, Crassostrea virginica, was found at all stations except 12 and 15. It was especially numerous at stations 1 and 2 where, on the six- and twelve-month panels, it covered from 50 to 80 percent of the surfaces. Isignoman, the flat tree oyster, was less abundant than C. virginica by a ratio of about 1 to 12. It occurred primarily at station 2 although a few individuals were found on panels at station 16. No individuals of Isignoman larger than 8 mm in diameter were found.

The Serpulid tube worms were very numerous on almost all panels from every station. They were second in abundance only to the ivory barnacle. No attempts were made to identify these animals to genus.

Other animals found on the panels included Brachidontes exustus, Crepidula spp., and various tube dwelling amphipods.



### Settlement of the Ivory Barnacle

The study of settlement and growth of attached organisms was limited to one species, B. eburneus. It was the single most abundant organism and one of the easiest to identify. In addition there is a large volume of literature on the various aspects of the biology and ecology of this species so comparisons could be made with results of the present study.

Since the barnacles were often difficult to identify at sizes smaller than about 4 mm, the unidentifiable individuals in this size range were divided into the various species according to the observed percentage of occurrence in the larger sizes. Thus approximately 85 percent of the small barnacles were considered to be B. eburneus.

Settlement was measured by counting the individual barnacles on each panel, as described in the procedures section.

In the statistical analysis of the settlement during each exposure period, the interaction term (M x S in Table 17) was used to compare the combined effects of months and stations.

The one-month exposure panels showed significant differences both in settling among months and in the interaction of months and stations (Table 17). No differences were detected among stations. The plot of the mean numbers of B. eburneus that settled by month is given in Figure 22. The total number of barnacles for the entire test period was nearly the same for all stations. However, the total for each of the months was different. This is apparent in the Figure 22 the largest settlement occurred during the two yearly peaks in spring and autumn with very little attachment in the other months.

Table 17. Analysis of variance tables for the study of the settlement of Balanus eburneus. Tests were run on transformed data. (\*\* = significant at  $P < .01$ ; \* = significant at  $P < .05$ ; ns = not significant).

Source	Degrees of Freedom	Mean Squares	F
		ONE MONTH EXPOSURE	
Months	10	119.4306	3.57 **
Station	5	31.4938	0.94 ns
M x S	50	33.4560	81.62 **
Error	330	0.4099	
		TWO MONTH EXPOSURE	
Months	4	39.2811	2.50 ns
Station	5	36.3806	2.32 ns
M x S	20	15.6911	27.08 **
Error	150	0.1984	
		THREE MONTH EXPOSURE	
Months	2	68.8374	7.43 *
Station	5	24.4792	2.64 ns
M x S	10	9.2637	37.26 **
Error	90	0.2486	

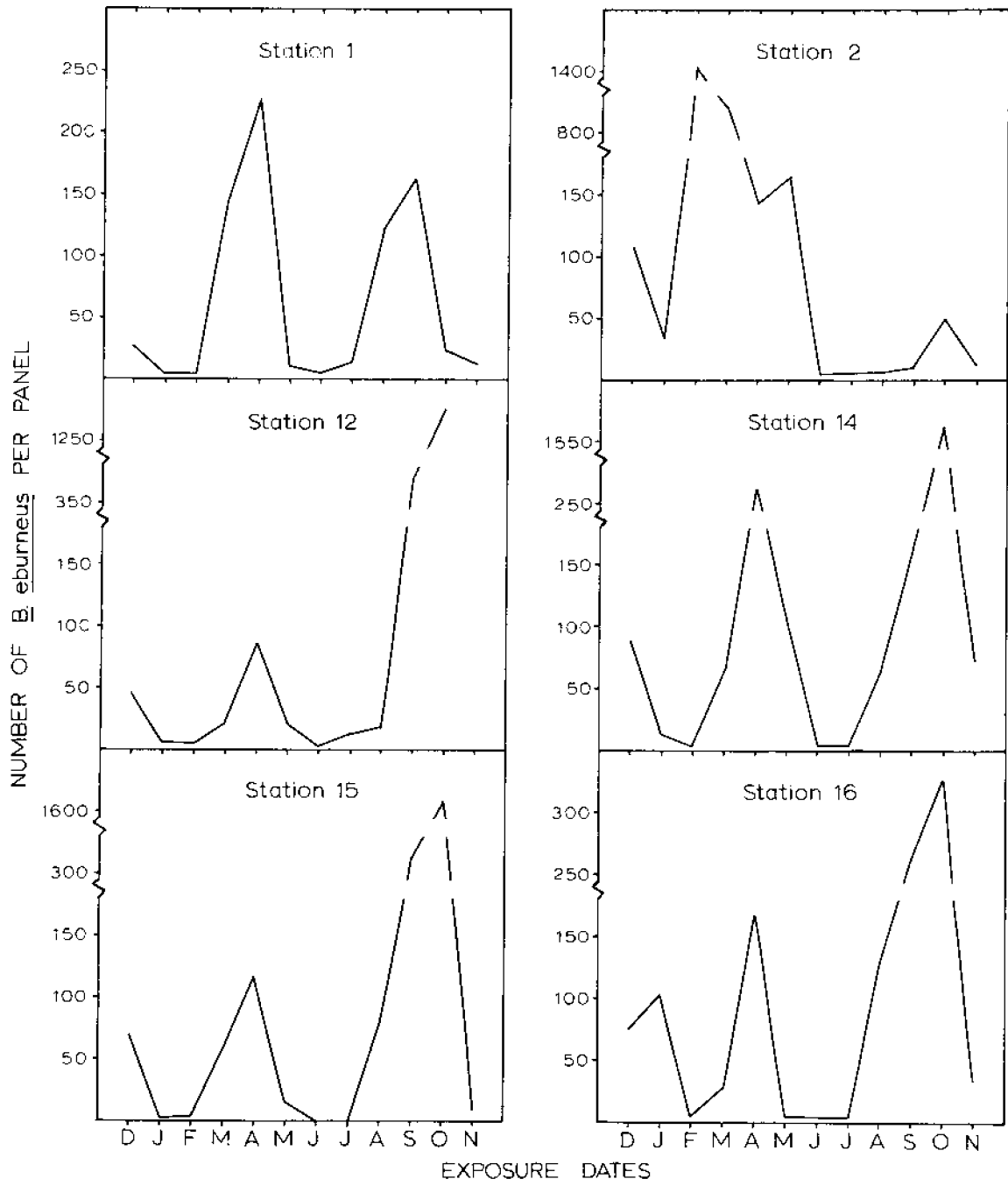


Figure 22. Seasonal settlement of *B. eburneus* on the one month exposure panels.

The statistically significant interaction indicates that the relative amount of settlement at each station varied from month to month; in any one month, the station with the largest numbers of barnacles was usually different than that in any other month. All the one month panels showed similar seasonal patterns except for station 2. At this location, a single large settlement occurred in early spring about three months before the peak occurred at other stations. In addition, the fall settlement at number 2 was smaller than at the other locations. These distribution patterns were the source of the significant interaction term.

The monthly differences were significant after this interaction was accounted for but most of the station variation was related to monthly changes and no significant difference occurred above that explained by the interaction.

It is important to note that no settlement took place at station 15 during June and July, while at all the other locations some barnacles occurred. All the water passing this station has passed through the plant; there is no tidal circulation of bay water in this area.

In the analysis of the two-month panels, significance was detected only in the interaction of blocks and treatments (Table 17). The patterns of settlement (Figure 23) were consistent with those for the one-month series. The significant interaction again appears to be due to the results at station 2 and, to a lesser degree, to those at station 1. The spring peak at station 2 was both larger and earlier than those at the other stations. The spring maximum for station 1 (the control area) was delayed until the June-July interval.

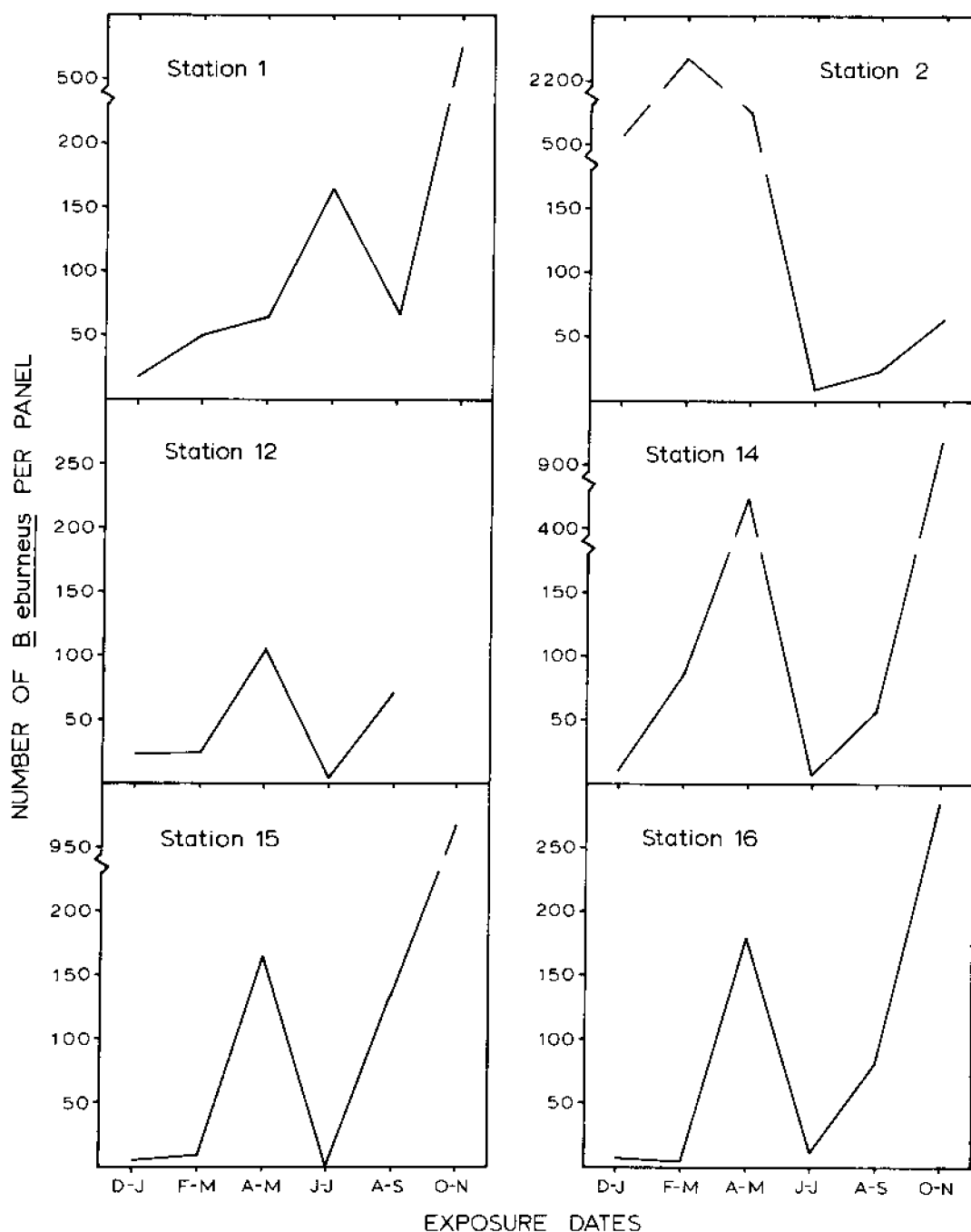


Figure 23. Seasonal settlement of *B. eburneus* on the two month exposure panels.

The three-month exposure study revealed significant differences among months and in the interaction (Table 31). Figure 24 is a graph of the settlement by station. It must be remembered that the results of the last exposure period (September-November), although they are plotted on the graph, are not included in the statistical test. Number 2 is the only station that exhibited a different pattern of distribution.

A one-way analysis of variance test was run separately on each of the two six-month exposure graphs and also on the twelve-month group. The results are contained in Table 18. Significant differences were found among stations in all cases tested. In the panels examined in May for the previous six months settlement, the greatest attachment was at station 2; in the six month panels collected in November, settlement was greatest at stations 14 and 15. The largest numbers occurred at station 15 during the twelve month exposure, the least at station 16.

The December panels for the one-, two- and three-month experiments were also analyzed by the one-way test (Table 18). In all cases tested, significant differences were found among the stations.

The barnacle sampling program was a study of the combination of settlement and survival. The numbers of barnacles collected at the end of each sample period represented only those which had settled and were subsequently able to survive and grow. In the discussion that follows, the terms "settlement" and "attachment" will be used to refer to the combined effects of settlement and survival.

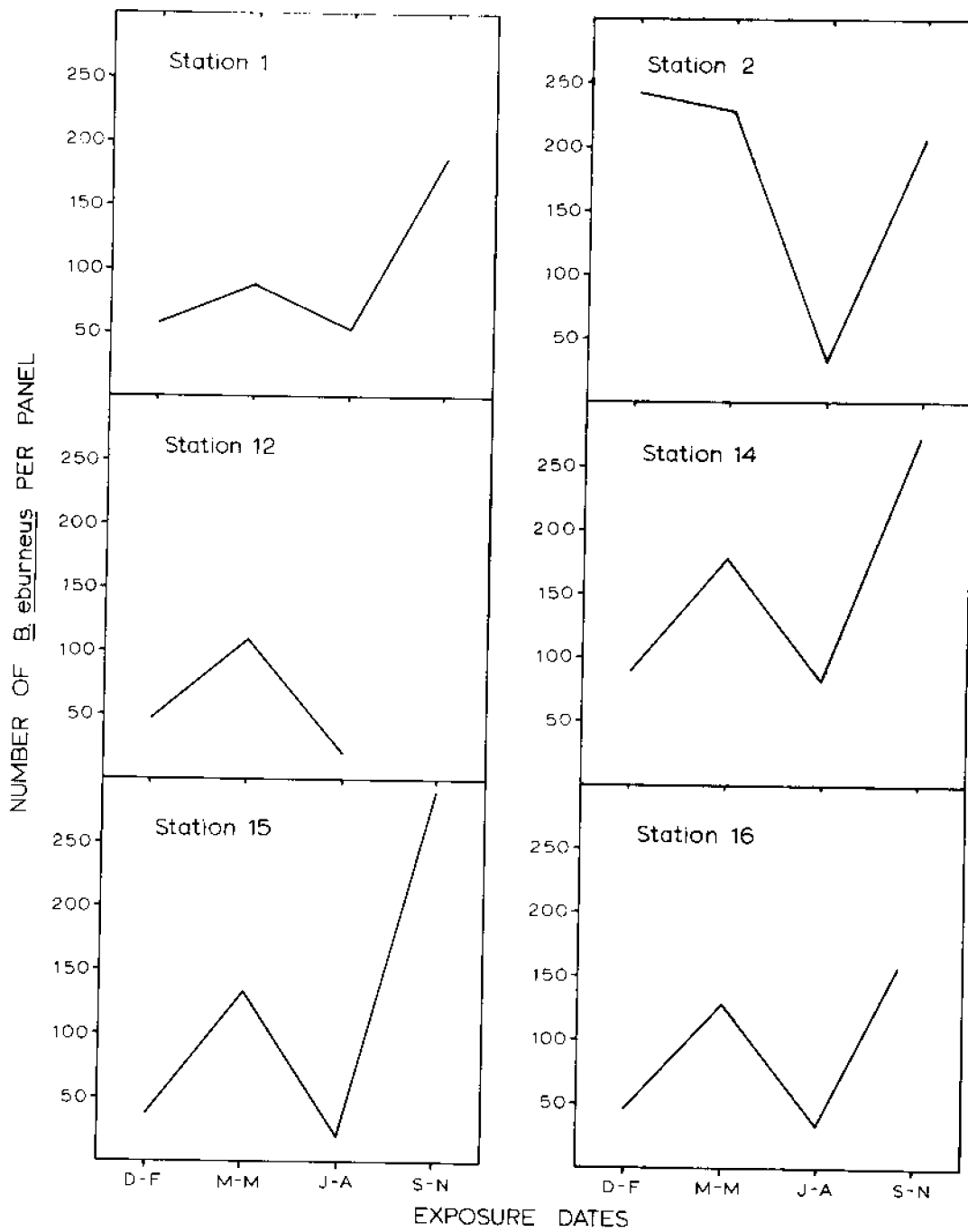


Figure 24. Seasonal settlement of *B. eburneus* on the three month exposure panels.

Table 18. One way analysis of variance on settlement data for some of the groups of fouling panels (\*\* = significant at  $P < 0.01$ ).

Source	Degrees of Freedom	Mean Squares	F
	DECEMBER - ONE MONTH EXPOSURE		
Station Error	4	0.749	4.762 **
	25	0.157	
	DECEMBER - TWO MONTH EXPOSURE		
Station Error	4	10.510	63.986 **
	25	0.164	
	DECEMBER - THREE MONTH EXPOSURE		
Station Error	4	660.364	133.559 **
	25	4.944	
	JUNE - SIX MONTH EXPOSURE		
Station Error	5	1.223	38.362 **
	30	0.032	
	DECEMBER - SIX MONTH EXPOSURE		
Station Error	4	44.160	227.315 **
	25	0.194	
	TWELVE MONTH EXPOSURE		
Station Error	4	479.412	168.854 **
	25	2.839	



The data collected on the attachment of Balanus eburneus at Turkey Point revealed that there were two peaks in settlement, a small one in April and a larger one in October. These results are in general agreement with those obtained by others working in northern Biscayne Bay. Weiss (1948) reported, after three years of study, that the attachment of the ivory barnacle occurred in two peaks, a minor one in May and June and a major one in October and November. Lowest settlement took place during mid-winter. In a continuation of the same study, Moore and Frue (1959) found in the analysis of twelve years of data that there were two definite peaks in settlement, in the spring and fall, with a possible third one in early summer. The autumn peak was usually the largest. Both the time of occurrence and the relative heights of the peaks varied from year to year.

At Turkey Point, the patterns of maximum settlement were similar at all stations except number 2. At this station, the spring peak was the larger of the two and it occurred in February and March, two months before the other stations. The fall peak was much reduced in size but corresponded in time to those at the other stations. The differences in timing and size at this location are not known. The environmental parameters monitored: salinity, temperature and dissolved oxygen, did not vary appreciably from the values recorded for the other areas. The only unique characteristic of station 2 was the large population of adult barnacles on the surfaces of manmade structures in Lake Rosetta. No such populations existed near any of the other stations.

There were differences in the numbers of barnacles that settled at each station. The height of the autumn peaks at the three hottest stations (Numbers 12, 14, and 15) were regularly greater than those of the control station. On the one month panels the attachment at the heated stations was about ten times that at station 1. On the two month panels it was about twice as great. No such differences were found in the spring settlement.

Nauman and Cory (1969) working in the Patuxent River estuary of the Chesapeake Bay found that spring attachment of B. improvisus was four times greater in the effluent canal than in the intake. In addition, they found that maximum settlement occurred in April within the discharge area of the plant whereas elsewhere in the river it occurred in May. Moore and Frue (1959), studying the same species in Biscayne Bay, found a marked positive correlation of both settlement and survival with temperature. They also reported a 13 percent increase in settlement (as distinguished from survival) for every one degree Centigrade rise in water temperature. The same investigators also found a positive correlation of survival with temperature for B. eburneus.

In the light of this information, it appears that the power plant increased the settlement during the fall but not during the spring.

The plant also prevented all barnacle attachment at station 15 during June and July. Neither the one-month nor the two-month panels for this period collected any barnacles. All the water that flowed through this location had previously passed through the condensers. Whereas, at the other stations, each of which showed some

settlement, there was some circulation of bay water during the tidal cycle. The plant could have acted in two ways. First, the planktonic larval stages of the barnacles could have been killed during the passage through the condenser cooling system and the subsequent time spent in the heated effluent water. Or, if the nauplii survived the trip through the plant and down the discharge canals, the high temperature of the water could have prevented their attachment, metamorphosis or subsequent growth. It cannot be determined from the results obtained in this study which mechanism was in operation at station 15. However, it would appear that it was a matter of survival rather than an inhibition of attachment or metamorphosis. Maximum temperatures of 40°C (104°F) are known to have occurred and levels above 37°C (99°F) were not uncommon. Normal larval development of B. eburneus has been shown to take place at 26°C (78.8°F) (Costlow and Bookhout, 1957). There has been no information published on the thermal tolerances of the larvae of this species. The only investigations reported in this area were on Balanus balanoides a boreo-arctic species (Crisp and Ritz, 1967). It was found that the nauplii stages were very tolerant of high temperatures (up to 41°C) while the cyprid stage was the least tolerant. The tolerance of this species greatly increased after the cyprids had metamorphosed. Comparisons to the current study are limited since B. balanoides is an intertidal animal while B. eburneus is not. However, it would appear that the plant has its greatest effect on the barnacles in those stages before metamorphosis.

### Growth of the Ivory Barnacle

The length of the largest barnacle on each panel was used to determine growth rates during the period of immersion. The barnacles generally grew faster during the warmer months. The average maximum length for all stations during the summer period of April through September was 6.0 mm. For the winter months (October through March) it was 4.1 mm. At individual stations, the monthly growth rates were highly variable. The largest size was attained at four stations in September and at the others during May. Values ranged from 1 mm to 11 mm (Table 19).

In order to determine the influence of the heated water on growth, the data from the control station (Number 1) were compared with the mean values obtained from the two hottest stations (Numbers 12 and 15). It was necessary to use the combined data from stations 12 and 15 because both yielded no growth data for certain months. At station 15 there was no settlement during June and July and at station 12 the December panels were lost. By using the mean values, comparisons could be made with station 1 for all twelve months.

The maximum lengths of barnacles at station 1 exceeded those at the two heated stations from May to September (Table 19). Sizes were the same during March. The largest barnacles occurred at station 1 during September; at the other two stations they occurred in May. A comparison of growth during the two semiannual periods reveals that at the two warm stations the mean maximum sizes were essentially the same for both the summer (5.0 mm) and the winter (4.5 mm). At the control station the mean winter maximum was 2.5 mm

Table 19. Maximum size attained by Balanus eburneus on each panel for the exposure period indicated

	Station 1	Mean of Stations 12 & 15	Mean of all Stations
ONE MONTH EXPOSURE			
December	2	4.0	3.7
January	3	6.0	4.5
February	1	3.5	3.8
March	4	4.0	4.7
April	4	4.5	4.3
May	10	9.5	7.8
June	8	2.0	5.0
July	10	5.0	5.6
August	7	6.5	5.5
September	11	2.5	7.7
October	3	6.0	4.7
November	2	4.0	3.2
Mean	5.4	4.8	5.0
TWO MONTH EXPOSURE			
December-January	8	11.5	10.7
February-March	9	9.5	9.7
April-May	13	14.5	13.0
June-July	12	4.0	9.6
August-September	16	16.0	13.8
October-November	3	6.0	3.8
Mean	10.2	10.2	10.1
THREE MONTH EXPOSURE			
December-February	14	17.5	16.0
March-May	16	16.5	14.7
June-August	14	15.0	12.0
September-November	7	12.0	9.4
Mean	12.8	15.3	13.0

while during the summer it was 8.5 mm. Under the ambient conditions the barnacles grew slower in the colder months and faster in the warmer months than those within the area of discharge.

Figure 25 is a plot of the length of the largest barnacle against the mean water temperature for the month of immersion. In general, the maximum size increases with increasing temperature, however the sizes show wide variability at any given temperature. The largest sizes (11 mm) were attained in water temperatures that averaged between 30 and 32°C (86-90°F). There appears to have been a decline in length at temperatures above this level; however, the wide range in sizes shown at other temperatures makes such a judgement uncertain.

On the two-month panels, the rates of growth were higher during the months of warmer water temperatures. The mean maximum size for all panels during summer immersion periods (April-May, June-July, August-September) was 12.1 mm; that for the winter periods was 8.1 mm (Table 19).

A comparison of the results from station 1 with the mean from stations 12 and 15 reveals that only on the June-July panels did the maximum size attained under ambient conditions exceed that achieved in the heated water.

The average maximum length of barnacles at station 1 during the six month summer (13.7 mm) was double that for the winter (6.7 mm). The differences at the heat influenced stations were not as large: 11.5 mm on summer panels and 9.0 mm on the winter ones. Growth was

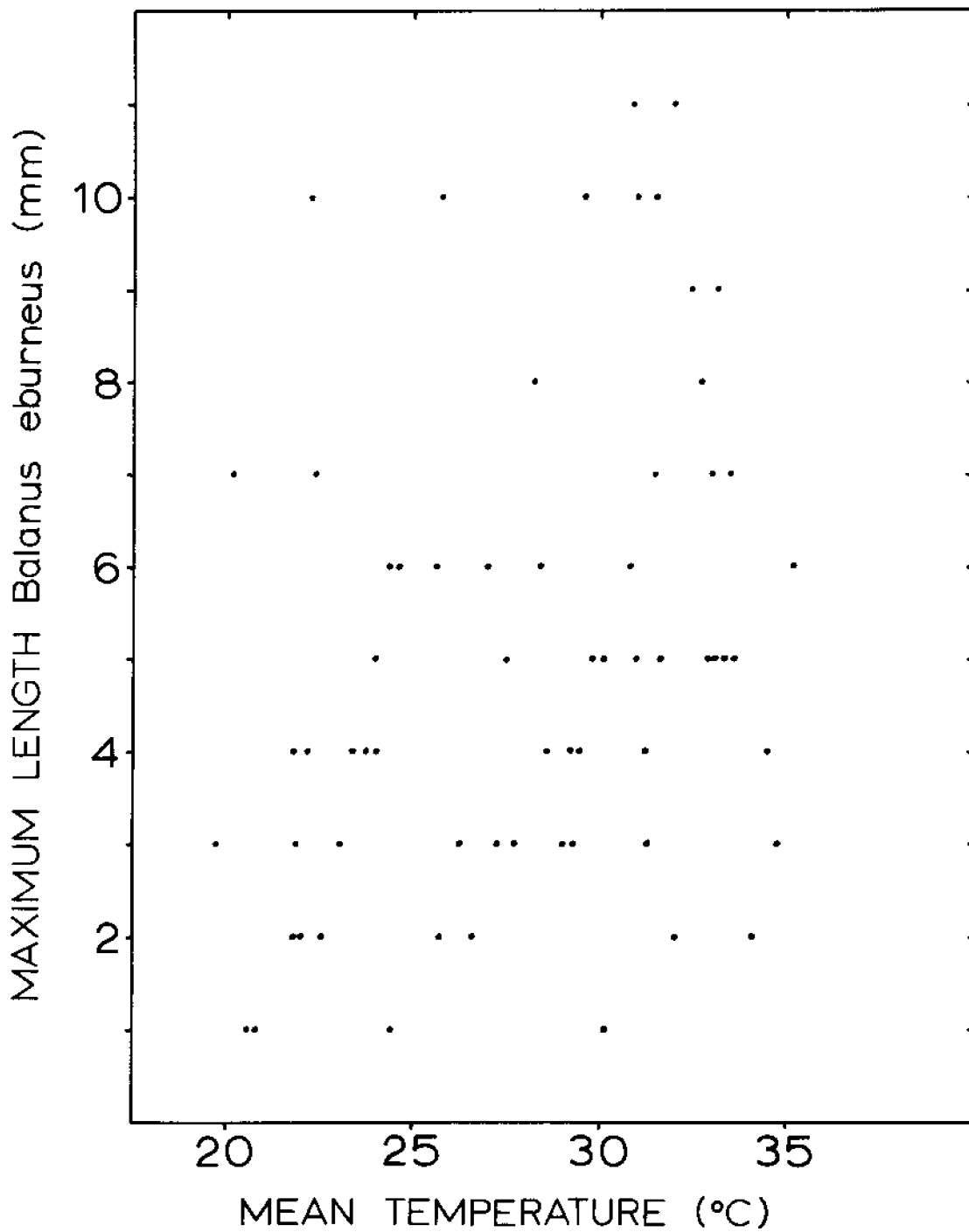


Figure 25. Scattergram of the maximum size attained by *B. eburneus* in one month versus the mean water temperature for the exposure period.

greater in the heated water than the ambient water in winter and less in the summer.

A distinct bimodality of size distribution was observed at most of the locations during the two month immersion period. This indicates that there were two distinct concentrations of settling during the two months the panels were immersed.

It was found that for the October–November period a large percentage of the barnacles at station 1 and some of the barnacles at station 2 were dead at the time of removal. There was little mortality at any of the other stations during the same interval. No settlement was found at station 15 during the June–July set.

The three-month panels revealed growth patterns different from those of the 1 and 2 month periods. In all stations except number 1, the greatest lengths were achieved during the winter quarter (December to February). At station 1, largest size occurred in the spring period (March to May). Lengths among all the panels ranged from 7 mm to 19 mm. Average maximum size for the six month summer was slightly higher than for the winter period: 13.3 mm to 11.9 mm.

Growth at the control station never exceeded that at the two hottest stations (Table 19). The summer semiannual average size of the largest barnacles at station 1 was 15.0 mm; for winter it was 10.5. The corresponding means for stations 12 and 15 were 15.8 (summer) and 14.8 (winter).

No analysis of growth could be made on the six and twelve-month panels due to the effects of crowding. As the number and size of the



barnacles in a given area increases, the competition for both food and space influences the growth rates of the animals. This crowding effect was apparent on most of the semiannual and all of the twelve-month panels. In addition, at station 1 and 2 the settlement and growth of Crassostrea virginica severely restricted the growth of the barnacles.

The maximum sizes attained by the ivory barnacles in one month at Turkey Point were consistently less than those recorded by Moore and Frue (1959) in northern Biscayne Bay. In their studies lengths greater than 12 mm (the largest measurement made) occurred throughout the summer months. One month winter growth ranged from 8 to 11 mm and fell below 10 mm during only two months. At Turkey Point, under ambient conditions, maximum winter sizes were from 1 to 4 mm and those for summer were from 4 to 11 mm. These differences are believed to be due to the limited supply of food organisms available to the barnacles at Turkey Point when compared to the supply present in north Biscayne Bay.

The heated water influenced the growth of the barnacles. The maximum sizes recorded at the two hottest stations during the winter were greater than those at the control station during the same period. The situation was reversed during the six warmest months. In addition, at the heated stations, the summer growth of the barnacles was only slightly greater than the winter growth. Under normal conditions, the growth during the summer was more than three times that for the winter. This resulted in the average monthly maximum lengths being almost the same for both areas (about 5 mm).

This information indicates that the power plant promoted barnacle growth during the colder months and depressed it during the warmer months. It could have affected growth either directly, by influencing metabolic processes, or indirectly, by acting on the supply of food organisms.

In the summer the decline in growth is at least partially due to a decrease in the amount of food available. Plankton studies at Turkey Point have indicated that there is a substantial reduction in certain zooplankters during passage through the plant in the warmer months (Michael Reeve, personal communication). Moreover, the absence of settlement at station 15 during June and July indicates that at least some planktonic forms are affected.

The accelerated winter growth would appear to be primarily due to effects on physiology rather than on food supply. Results obtained in other investigations indicate that temperature affects growth directly. At Woods Hole, summer growth of B. eburneus is about 10 mm per month (Grave, 1933). This is comparable to winter growth in Miami as recorded by Moore and Frue (1959). These same authors found a strong positive correlation of the growth of both B. improvisus and B. amphitrite with water temperature. In the same study, there was insufficient data to draw any conclusions about B. eburneus. Weiss (1948) showed that one month growth in the ivory barnacle increased with increasing temperature up to 30°C (86°F) the highest ambient temperatures he encountered. In B. improvisus, growth leveled off at 25°C (77°F). In a study of a power plant in the Chesapeake, it was found that the maximum size B. improvisus

attained in monthly growth under ambient conditions was 5.3 mm. In the cooling canal of the power plant it grew to 7 mm (Nauman and Cory, 1969).

The two-month panels yielded growth data similar to that obtained from the one-month study. Winter growth was greater in the area of discharge than at the control station, while summer growth was less. Differences between winter and summer growth in the heated area were less than those in the control. The average maximum sizes for sixty days growth were identical (10.2 mm). The same processes that were discussed above were in operation on these panels.

The bimodality in the size frequency distribution of B. eburneus appears to be related to the lunar cycle. Without daily records of cyprid settlement, it is difficult to determine exactly when the maximum settlement occurred during each period. From the data it appears that the peak is at about the time the panels were set, that is, during the third quarter phase. Moore and Frue (1959) analyzed their daily settlement data specifically to look for a lunar influence. They found a monthly cycle with maximum attachment shortly after the full moon. From this they concluded that the pattern was most probably the result of a lunar rhythm in spawning.

The three month growth of the barnacles differed somewhat from the patterns of the first two groups. As before, the differences between the summer and winter maximum sizes at the heated stations was less than that at the control. However, the growth under ambient conditions never exceeded that in the heat influenced area even during

the warmer months. The average three month growth was also higher at stations 12 and 15 (15.3 mm) than at station 1 (12.8 mm).

The effects of crowding and of the presence of other fouling organisms was greater on these panels than on the others. In spite of the weekly cleaning, there was a buildup of filamentous algae on most of the panels. This growth tended to increase the amount of sediment that coated the surfaces. During the summer months the algae was much more dense at station 1 than at stations 12 and 15. This may account for the patterns of barnacle growth during this period.

#### Water Chemistry Sampling Program

The results of the water chemistry analyses are summarized in the Appendices. The monthly means for each of the twelve stations are given for temperature (Appendix II), salinity (Appendix III), dissolved oxygen (Appendix IV) and inorganic phosphate (Appendix V).

#### Water Temperature

The annual pattern of ambient inshore water temperatures is illustrated in Figure 26. The curve was made from individual measurements taken by the thermograph at station 1. Individual values ranged from 13.0°C (55.4°F) in December 1968 to 36.5°C (97.7°F) in August 1969. The month during which lowest water temperatures occurred was January 1969 when the mean was 19.6°C (67.2°F). The warmest month was August 1969 with a mean water temperature of 31.1°C (88.0°F).

The temperature data at the six biological sampling stations has been explained above.

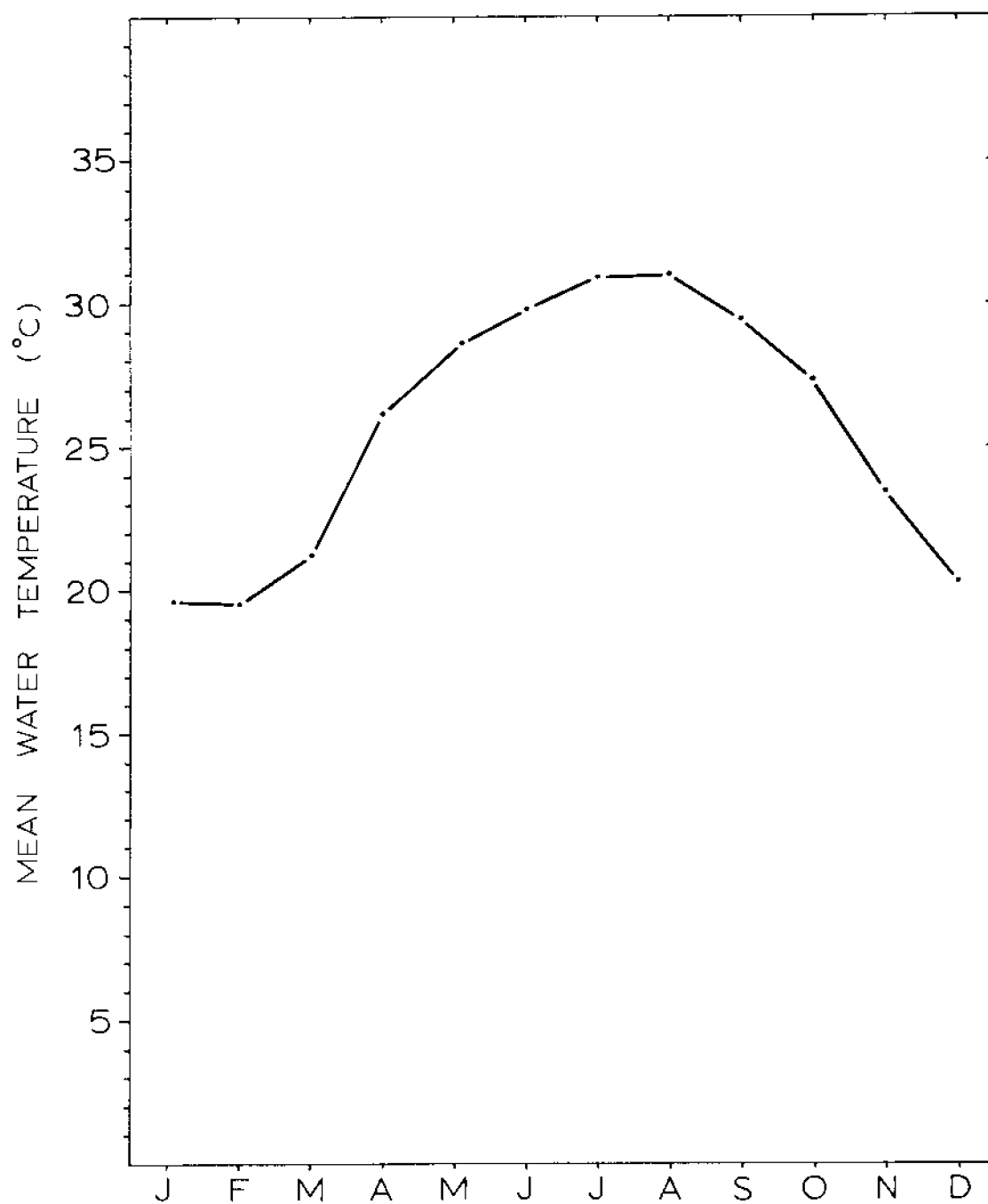


Figure 26. Normal monthly average inshore water temperatures around Turkey Point.

The rise in temperature across the condensers has been discussed in the Introduction (Figure 5). Data recorded by the power company shows that the cooling water is heated an average of about 5°C (11°F) during a single pass through the plant. Minimum increases of about 3°C (6°F) occur in early morning and maxima of about 8°C (15°F) are recorded in the evening. I found effluent temperatures to be highest from late June to early September 1969. During this period, water temperatures were regularly found to be in the range of 37 to 39°C (93.6-102.2°F) during the late afternoon. On three occasions, once each in June, July and August, temperatures between 40 and 41°C (104.0-105.8°F) were measured in the effluent canal.

After leaving the plant, the discharge water enters the effluent canal and is carried back to the bay. The time required to pass the entire length of the main effluent canal is estimated to be between one and two hours depending upon the tide. Flooding tide decreases the outward flow of effluent water. A drop in temperature of about 1°C (1.8°F) has occurred by the time the water enters the bay. The rate of cooling is affected by such factors as freshwater runoff from the adjacent areas and the amount of effluent water that overflows the canal banks and spreads out over the marsh.

Both the means and ranges of temperature at any station varied annually, seasonally, diurnally and with changes in tide. The widest ranges were measured at those locations where the flow of effluent water alternated with bay water during the tidal cycle. Highest mean temperatures were at the stations located within the main effluent canal.

## Salinity

The yearly cycle of inshore salinities was illustrated (Figure 2) and explained in the Introduction. The lowest values (17-19 ppt) occurred at times of heavy fresh water runoff during the periods of peak rainfall in the spring and fall. During the drier months, levels reached 34 ppt.

The salinities throughout the study area were essentially the same at all stations on any given sample date (Appendix III). The one exception was at station 19, a culvert through which fresh water runoff from the large areas of marsh to the west entered the main canal. On almost every sample date, values were lowest at this station. These differences were greatest during the months of June and July when mean salinities at station 19 were about 5 ppt whereas those at the other locations were all between 17 and 20 ppt.

The measurements at station 1 were also consistently lower than those at other stations by about 1.5 ppt. As mentioned above, this was primarily due to the more saline nature of the effluent water that flowed throughout the area receiving discharge. The channelization of fresh water runoff by the levees into the main canal only through the culverts may also have contributed to the higher salinities since, under normal conditions such as existed around station 1, the flow of fresh water would have spread out over a wider area.

The slight, but regular, increases in salinity recorded as the water passed through the plant reflect the fact that the readings at station 3 were made at the surface while the cooling water was being

drawn from a depth of about 20 feet and may have been more saline. At station 4, the outfall, the water was thoroughly mixed so no such stratification could exist.

#### Dissolved Oxygen

The annual variations in dissolved oxygen concentration and in percent of oxygen saturation of water around Turkey Point are shown in Figure 27. The shapes of the two curves are very similar. Highest oxygen values were recorded from October through March when levels averaged 5 ml/l (ppm) or more. These represented supersaturated conditions. Oxygen content was lowest during July when measurements averaged about 3.70 ml/l. This was the only month when mean saturation values fell below 100 percent. After returning to higher levels (4.78 ml/l) in August, a slight drop was recorded in September. Thereafter mean concentrations rose steadily to an annual peak of 5.90 ml/l (115 percent saturation) in November.

The dissolved oxygen values were similar at all stations except number 19. Monthly means (Appendix IV) rarely varied among the other eleven stations by more than 1 ml/l; those at station 19 were consistently lower than the others by as much as 2 ml/l.

The highest levels of both total content and percent saturation were regularly recorded at those locations where photosynthetic activity by sea grasses was high. These included stations 1, 14 and 16 although others also yielded high values when the tide carried water into them from the grass flats at the bay edge.

The single highest reading (9.08 ml/l; 225 percent saturation) was made at station 16 during August. The lowest was 1.43 ml/l taken



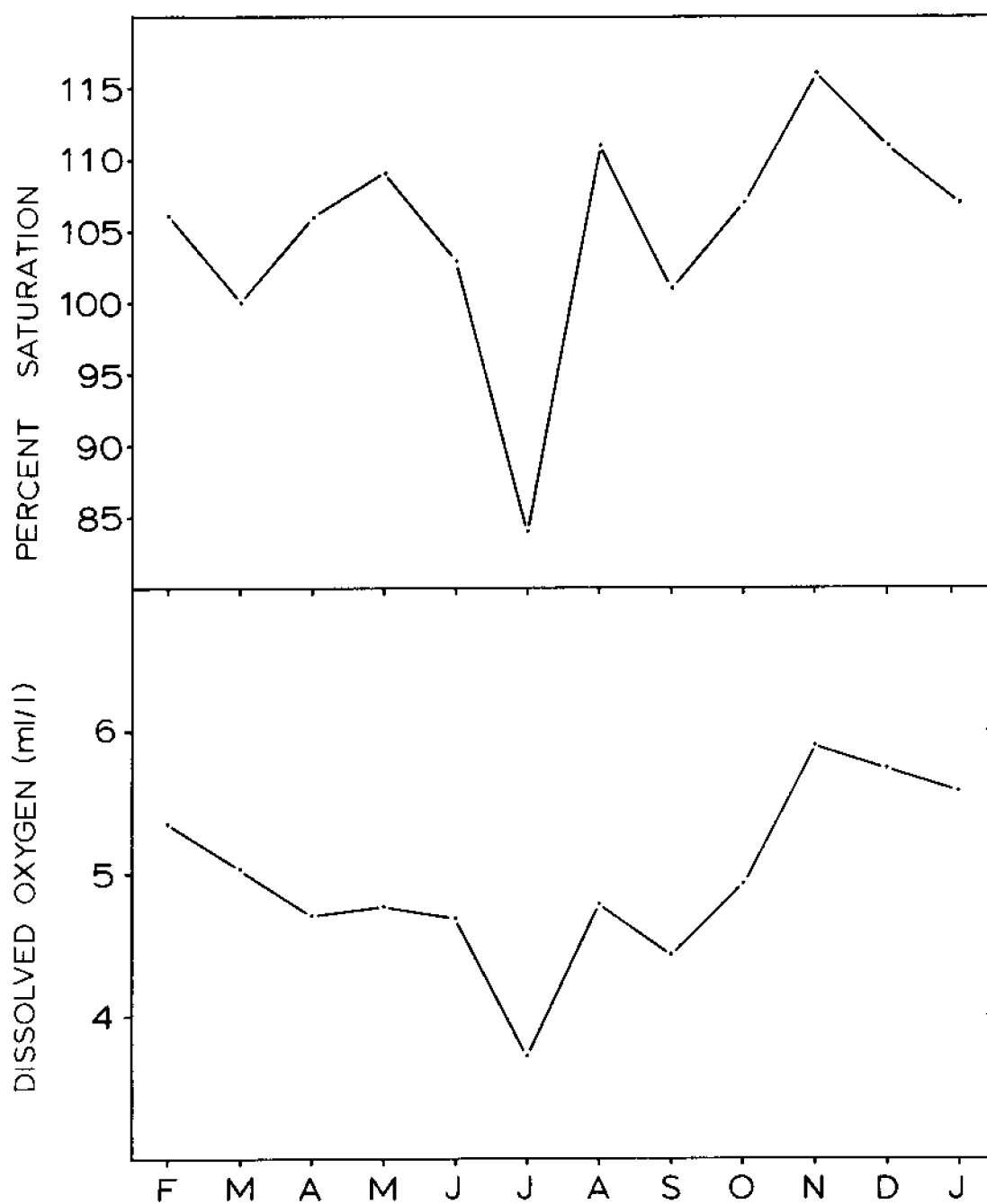


Figure 27. Monthly average dissolved oxygen values and percent of oxygen saturation. Four weekly readings from twelve stations comprise each monthly mean.

at station 19 during a period of high fresh water runoff in July. It represented saturation levels of 28 percent.

The oxygen content of the water near the plant was regularly slightly lower at the outfall than at the intake. The mean difference was less than 0.4 ml/l. Supersaturation existed at both locations but the percentages were usually higher at the outfall.

As the cooling water passed down the discharge canal, both the oxygen content and percent saturation gradually decreased (Figure 28). Lower measurements were recorded at each succeeding station. The trend can be seen most clearly in a comparison of the readings at the outfall (Station 4) with those at the edge of the bay (Station 10). Mean differences between these two locations over the twelve months of sampling was 0.63 ml/l.

The diurnal changes in dissolved oxygen was explained (Table 6) in the gill net sampling section. Lowest values occurred in the early morning, followed by a steady rise to peak levels in late afternoon and then a gradual return to minimum values during the night.

The seasonal lows in the concentrations of dissolved oxygen were closely associated with the amounts of fresh water runoff. During the period of little rainfall, from February to May, decaying organic matter accumulated in the mangrove areas. At the onset of the spring rainy season in June, quantities of partially decomposed material were washed into the tidal streams and into the bay. The decay and oxidation processes continued at an accelerated rate due to the high water temperatures and to the increased surface of the suspended matter.

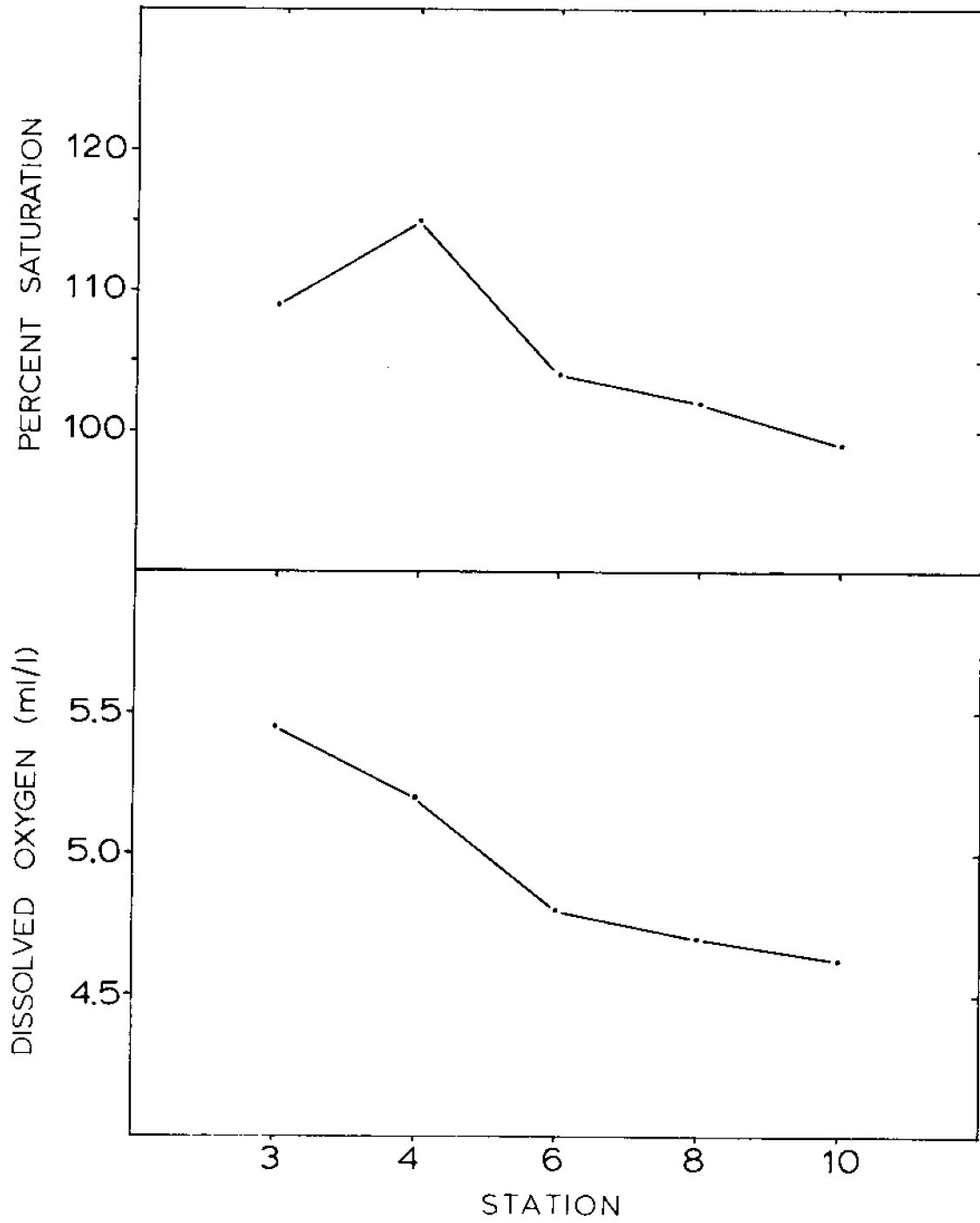


Figure 28. Changes in dissolved oxygen concentration and percent of oxygen saturation at five stations along the main effluent canal.

Consequently, the dissolved oxygen in the water was rapidly depleted as is indicated by both low total content and low saturation recorded for July.

In August, the oxygen values rose sharply, primarily due to the absence of large amounts of runoff. The slight declines recorded in September followed the onset of the autumn rains. The continued rise in concentrations from September to November, even in the presence of lowering salinities, indicates that the runoff from the fall rainy season carried a smaller organic load than did that of the spring season. The first rainy period was preceded by five months during which quantities of organic debris accumulated. No such build up had occurred by the onset of the autumn rains. In addition, water temperatures declined during this period so that the decomposition that did take place was not as rapid as had occurred during the summer and, hence, the drops in oxygen were not as sharp.

Similar seasonal oxygen cycles caused by much the same processes have been described for other estuarine areas in south Florida (Tabb et al., 1962; Heald, 1969).

In theory, the Turkey Point plant could contribute to the deoxygenation cycle through the release of large quantities of heated water. The dissolved oxygen concentrations, which are naturally lower during periods of high ambient temperatures and large organic loads, would be further depleted by the increased decomposition promoted by the addition of significant volumes of heated effluent. Normal summer inshore temperatures, as recorded by the thermographs, rarely exceeded 36°C (96.8°F) and daily averages were never higher than 33°C (91.4°F)

Summer water temperatures in the areas receiving the discharge were regularly higher than 37°C (98.6°F) and on several occasions exceeded 40°C (104.0°F). However, no differences were detected in the levels of dissolved oxygen or in percent saturations that could be attributable to the influence of the discharge water on organic decomposition. It must be stated, however, that in order to most accurately detect such an effect it would have been necessary to continuously monitor at many locations such environmental parameters as temperature, salinity, dissolved oxygen and B.O.D. of the water. The methods used in this study involved taking individual samples once a week and therefore the chances of detecting subtle differences among the stations was greatly reduced.

The comparison of the dissolved oxygen content of the water at the intake with that at the outfall showed that a slight decrease regularly occurred during passage through the plant. At the same time, the level of saturation increased. Most of the other investigations that have been made on this aspect of power plant operation have shown similar results. Markowski (1959) studying eight power stations in Great Britain found that the oxygen content of the cooling water was changed very little, or even increased, after passing through the condensers. The ambient water temperatures in his study varied from 14.4 to 22.8°C (58-73°F) and the temperature rise was from 4.6 to 9.5°C (8-17°F). Similar findings were made at four other British plants (Alabaster and Downing, 1966). In the United States, Adams (1968) has reported dissolved oxygen concentrations at the outfall to be the same or slightly higher at the Morro Bay Power Plant in California.

Mason (1962) has found in his investigations in Pennsylvania that at two locations no depletions were recorded while at a third the drop was less than 1 mg/l.

However, Trembley (1960) in an investigation of a power plant on the Delaware River in Pennsylvania found that passage through the condensers almost invariably reduced the dissolved oxygen of the cooling water, but seldom to a critical level. The mean decrease of the fourteen readings given was 1.7 mg/l; the range was from 0.0 to 4.3 mg/l. The lowest levels recorded at the outfall were 3.4 mg/l.

At Turkey Point the factors that caused the observed pattern in the oxygen content of the cooling water as it passed through the plant were primarily physical in nature. The water was exposed to a rapid rise in temperature (up to 8°C in less than 8 seconds) as it was pumped through the condensers. Then it was subjected to considerable turbulence as it left the discharge structure and entered the effluent canal. These conditions forced more oxygen into solution causing the total content to remain about the same in the presence of elevated temperatures thereby producing supersaturated conditions.

As the water passed down the discharge canal, the oxygen concentrations dropped. The supersaturation at the outfall was reduced to levels at or near saturation by the time the water entered the bay. The decrease was due primarily to the release into the air of the oxygen forced into solution by the physical processes described above. During periods of low salinities the concentrations were reduced to levels slightly below saturation by the decomposition of the organic materials in the water column.

### Inorganic Phosphate

The results of the inorganic phosphate analyses are contained in Appendix V. The differences among the stations were, with a few exceptions, slight.

The yearly pattern of occurrence is shown in Figure 29. The points on the curve are the means of all the readings taken each month. The highest levels occurred during July (.15  $\mu\text{gA/l}$ ) and October (.16  $\mu\text{gA/l}$ ) in conjunction with the peaks in fresh water runoff. Lowest values (.08  $\mu\text{gA/l}$ ) were during periods of low runoff when no inorganic phosphate could be detected in some samples.

There were a few instances when large differences in measurements were encountered. Two of the four samples taken during March at station 3 and one of those taken at station 1 gave readings from two to four times higher than those at other locations. Although these variations may have been due to errors in collection or analysis, the values were used in the computation of the March station means included in the Appendix. However, they were not used in calculating the pooled monthly mean used in plotting Figure 29.

Levels were consistently higher at station 19 than at any other location during periods of heavy runoff when the highest values recorded during the study were made (.39  $\mu\text{gA/l}$ ).

The data collected do not indicate that the operation of the power plant directly influenced the levels of inorganic phosphates in the waters around Turkey Point. The natural fluctuations that occurred, particularly during periods of high fresh water runoff, were of such a

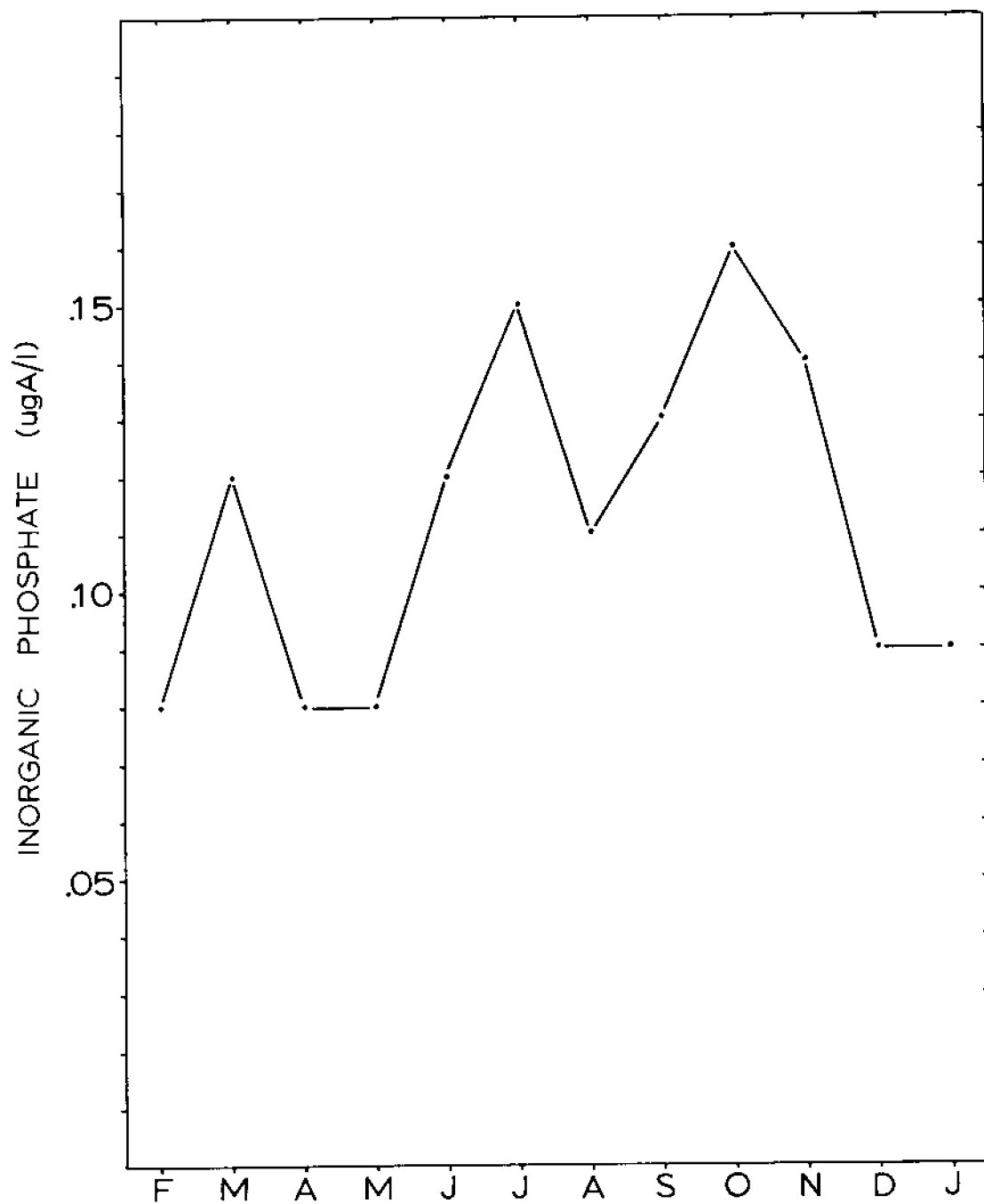


Figure 29. Monthly average inorganic phosphate values. Four weekly readings from twelve stations comprise each monthly mean.



magnitude that any influence the plant may have had could not be detected by the sampling program used.

The seasonal cycles of inorganic phosphate are closely associated with periods of high rainfall. The quantities of organic debris, which have accumulated within the marshes during the dry months, enter the tidal streams and the bay with the first volumes of fresh water runoff. The inorganic phosphate is regenerated from the organic matter by autolytic or bacterial decomposition (Barnes, 1957). Phosphate concentrations in the water reach peak levels shortly after the onset of the rainy periods. However, once the influx of decaying material has stopped, the nutrient content drops sharply to the low levels (less than  $.10 \mu\text{gA/l}$ ) that are found regularly in the inshore areas during periods of low rainfall. Although there have been some indications that the utilization of inorganic phosphate by algae and rooted aquatics is responsible for this rapid decline (Daiber, 1959), other investigations employing radio-tracer techniques have found that it is the uptake by sediments and bacteria that is primarily responsible (Pomeroy *et al.*, 1966).

In estuarine systems there appears to be a dynamic equilibrium between the water and the sediment that maintains a fairly constant, though low, concentration of phosphate in the water (Pomeroy *et al.*, 1965). There are two sets of reactions involved in this exchange process. One, involving microorganisms, is of minor importance. The other, major system, involves two types of sorptive reactions: a rapid, initial surface sorption and a slower, secondary chemical combination of the phosphate into the sediment particles. The level

of this equilibrium depends on a number of factors including dissolved oxygen content, pH, redox potential and the types and concentrations of other ions in solution (Hepher, 1958; Pomeroy *et al.*, 1965). At Turkey Point there are two substances in solution that may play a major role in the phosphate balance. These are calcium carbonate and iron.

It is known that in waters with a high calcium ion concentration, or to which calcium carbonate has been added, phosphate is precipitated as calcium phosphate (Zicker *et al.*, 1956; Hepher, 1958). Phosphate also reacts chemically with calcium carbonate in the sediments to form the same compound (Hepher, 1958). The calcium phosphate is insoluble in a neutral or alkaline medium. At Turkey Point, the inshore waters are saturated with calcium carbonate due both to the large areas of exposed limestone rock and to the high calcium content of the sediments. The pH of the water ranges from about 7.8 to 8.2. Therefore, the proper conditions exist for the removal of inorganic phosphate from solution and the binding of it into the sediments. However, since the water is only slightly alkaline, the amount of phosphate removed by this mechanism is believed to be small.

The high inorganic phosphate levels (.25-.40  $\mu\text{g}/\text{l}$ ) at station 19 coincided with the lowest oxygen values (1.4-2.4 ml/l). This indicates that a second mechanism involving iron may be operating in the regeneration of these nutrients. Under conditions of high oxygen saturation the phosphate is bound as insoluble ferric phosphate in the sediment. If oxygen saturation levels drop, the ferric compounds are reduced to the ferrous state and both the iron and phosphate ions

are released into the water. Such a process has been proposed to explain the seasonal cycling of phosphates between the sediment and water column in a nearby subtropical marine basin in central Biscayne Bay (Miller, 1952).

This type of exchange can take place at Turkey Point only under conditions of low oxygen concentrations such as exist during the seasonal rainy periods. During the remainder of the year, the shallow waters that characterize the region are thoroughly mixed by winds thereby limiting the occurrence of vertical stratification and anaerobic conditions for any significant period of time.

The exchange mechanisms just described raise a question concerning a possible indirect effect of the power plant on the nutrient levels in the area. The effluent water has been found to contain quantities of iron (50-60  $\mu\text{g}/\text{l}$ ) that are much larger than those normally present in an estuary (Roessler *et al.*, 1970). The form in which the iron occurs is not known, but the largest proportion is believed to be in solution. It is known (Harvey, 1958) that the addition of iron salts to a volume of water will cause the removal of the inorganic phosphates present by precipitation as ferric phosphate. Thus, the power plant could act indirectly to lower the levels of phosphate within the receiving waters in this manner.

Another possible influence of the plant effluent on inorganic phosphate content is through its effect on the decomposition rates of organic debris. The elevated temperatures of the discharge water could accelerate the rate of breakdown and thereby increase the rate

at which inorganic phosphate is released from the decaying matter. Secondly the increased decomposition would promote deoxygenation of the water which, in combination of any thermal stratification caused by the discharge water, could augment the release of phosphate from the sediments.

In a system such as that at Turkey Point, the release of additional nutrients at times when the normal levels are at their peak, would appear to be of only incidental importance. However, the removal of inorganic phosphate by chemical combination with iron, particularly during the long periods of low concentrations, could potentially be of significance. This study was not designed to investigate in detail these aspects of nutrient cycling. Thus, little information can be gathered from the data collected regarding the existence or importance of these processes. The considerations are brought forward only for the sake of completeness and to point out further research needs.

#### Factors Other Than Temperature That Could Have Influenced the Biological Results

Variables of the physical environment other than temperature may have been at least partly responsible for the patterns of catches reported in this study. Among the major parameters to be considered are salinity, dissolved oxygen, water currents, trace metals in the effluent water, and chlorine, used to prevent fouling in the condenser tubes.

Evidence against a major influence of any of these variables is the seasonality of the observed effects. The analysis of the data for the six coldest and the six warmest months clearly shows differences in catches according to season. For example, catches of animals by gill net within the heated area were highest in winter and lowest in summer; to a lesser degree the same is true of the catches of smaller animals taken by traps. Both settlement of barnacles and their growth were greater in the discharge area during the colder months than during the warmer ones. This seasonality of effects can be explained only in terms of differences in water temperature.

Further evidence that temperature was the principal factor operating to control catches may be found by examining the influence of other factors individually.

#### Salinity

In order for an animal to utilize the estuary as a source of food and shelter, it must be able to withstand the wide fluctuations that naturally occur in the physical conditions within these waters. The animals studied in this investigation were estuarine forms known to be tolerant to wide ranges of salinity. For example, the ladyfish has been reported from waters of 2.5 to 32.0 ppt salinity (Gunter, 1945); the tarpon, 0 to 37 ppt (Tabb *et al.*, 1962); the gray snapper, 1 to 36 ppt (Christensen, 1965); the pinfish, 3.7-35.1 ppt (Springer and Woodburn, 1960); the spotfin mojarra, 1.5 to 38.8 ppt (Christensen, 1965); the striped mullet, 0-37 ppt (Tabb *et al.*, 1962);

and the white mullet, 1.5-37.3 ppt (Christensen, 1965). It seems probable that in view of the above the small regular differences (1.2 ppt) observed in salinity values between the sampling areas were not responsible for the results obtained.

#### Dissolved Oxygen

The dissolved oxygen concentrations were similar throughout the areas sampled (Appendix IV). The differences that were observed were random, and cannot account for the patterns of the catch data. The regular decrease in oxygen content that was observed as the cooling water passed through the plant and down the effluent canal (Figure 28) was restricted to the main discharge canal. In the areas where most of the sampling was conducted, and where the effects were detectable, the alternate tidal flow of effluent and bay water resulted in the concentrations of dissolved oxygen being similar to those at the control station. The photosynthetic activity of the marine plants kept the oxygen content of these inshore waters high. In fact, the highest values recorded (6-8 ppm) were from station 16 the heat-influenced gill net station.

#### Water Currents

In the areas where most of the sampling was carried out there was a normal ebb and flood of the tide that was essentially the same at both the heated and unheated stations. Hence, the effects of current on the catches would have been the same at all locations. Within the main effluent canal and in the inshore areas of the bay immediately offshore of its mouth the water flows continuously in

one direction. Yet in the main canal there was a distinct seasonality to the sampling data that cannot be related to this constant flow of water.

#### Trace Metals

High concentrations of both iron (40-60  $\mu\text{g}/\text{l}$ ) and copper (15-25  $\mu\text{g}/\text{l}$ ) have been found in the effluent water (Roessler *et al.*, 1970). Both of these metals influence biological systems: they are essential in small quantities for certain physiological functions in most animals; in large concentrations they may be toxic to some organisms, including fish (Doudoroff, 1957). However, these substances are not believed to be the cause of the results obtained in this study because their occurrence in the area was relatively constant throughout the year whereas the catch patterns varied with the season.

#### Chlorine

Chlorine is used by the power company to prevent fouling within the condenser tubes. The chemical is introduced into the cooling system once a day, the pumps are stopped and the solution is allowed to remain within the condenser tubes for fifteen minutes. The amount of chlorine added is controlled so that the concentration of the chemical at the outfall should not exceed 1 ppm. Even taking into account the possibility of accidental overapplication (which should be a random event), chlorine could not have caused the effects observed during sampling.

Hence it is concluded that temperature was the factor chiefly responsible for the differences in catches (and therefore, at least

in part, for the kinds and abundances) of certain fishes and invertebrates in the area unaffected by the heated effluents compared to those where the water temperature had been elevated by effluent from the power plant.



## CONCLUSIONS

In making a judgement on whether the Turkey Point power plant has been detrimental to the populations of larger animals in the canals and adjacent areas, a list can be compiled of the beneficial and harmful effects of the operation of the plant as observed in this study.

### Beneficial Effects

1. The heated effluent water afforded some protection to fishes from a cold kill that occurred during severe weather in January 1970. At that time as many as a thousand dead or dying fish, mostly grunts (Haemulon sp.), were observed in the intake canal. No dead fish were seen in the main effluent canal even though it is known that large populations of fishes were present in this area.

2. The warm discharge water and the canal system served to concentrate the fish during the winter and made angling more successful in some areas during this period. Although the fish were not significantly ( $P < .05$ ) more abundant in the heat-influenced area than in the control area, they were more accessible to the fishermen. In order to gather data on the numbers and kinds of fish caught and the amount of angling effort that was involved a questionnaire was prepared for the anglers. Very few of the forms

were returned. However, from interviews and observations that were irregularly made it was found that the fish caught in the greatest numbers was the gray snapper. Blue crabs were also taken frequently, and tarpon, snook and jacks were caught occasionally. It was the consensus among those interviewed that more fish could be caught during the colder months in the effluent canals of the power plant than in the other unheated canals in the area.

#### Harmful Effects

1. The heated effluent water contributed to the death of certain organisms in the hot summer months. Kills occurred both within the main discharge canal and in the area immediately offshore of its mouth in late June 1969. In the main canal blue crabs and grunts were killed; in the offshore areas the principal victims were toadfish.

2. In the warmer months (mid-April to mid-October) there was a significantly greater ( $P \leq .05$ ) number of animals taken by gill net outside the discharge area than within it. In the cooler months (mid-October to mid-April) no significant differences ( $P \leq .05$ ) could be detected in gill net catches made in the affected and unaffected areas.

3. For catches made over the entire seventeen months of sampling there was a significant reduction ( $P \leq .05$ ) in the numbers of animals taken by gill net in the heat-influenced area compared to the control area.

4. The settlement of the ivory barnacle, Balanus eburneus, was increased in the heated area during September and October, when settlement is normally highest. Despite the reduced settlement of barnacles during June and July, over the year there would be increased fouling on immersed structures.

5. Growth of the ivory barnacle was greater at the stations receiving heated effluent water than at those under normal conditions during the period October through February.

6. The concentration of dissolved oxygen in the cooling water was decreased about 1 ml/l as it passed through the plant and down the effluent canal. This could be detrimental to the animal populations in the canals and adjacent areas, particularly if other stress conditions are also present.

Some of the influences of the heated water on the occurrence and abundance of fishes and other animals in the canals and adjacent waters appear to counteract one another. For example, the heated water contributed to the death of some animals during period of high water temperatures yet it protected others from cold kills in winter. The absence of fish from the main effluent canal during the hottest summer months was offset to some degree by the increased availability of fish there in the winter months. Also barnacle settlement and growth was increased during the winter but was decreased during the summer. The one consideration that appears to be of greatest significance and that suggests that the power plant has had a detrimental effect on the animals studied is the lower apparent abundance of the fishes, particularly the larger ones, within the heat-influenced area over the entire year.

In the cases of most species of fishes these differences were statistically significant ( $P < .05$ ). This means that the attraction of the animals to the heated water during the cold months is less than their avoidance of it during the warm months. The analyses of the catch statistics both in terms of numbers and percentages by season support this conclusion: during the winter the animals were caught in about equal numbers at the control and experimental stations yet during the summer many more animals were taken outside the heated area than within it. The winter catches in the discharge area did not equal the summer deficit.

It is concluded that the Turkey Point power plant, as it is presently operated, is detrimental to many of the economically valuable animals of the waterways of the mangrove area through which the heated discharge water flows. The evidence seems clear that the artificially heated water is directly or indirectly the cause of the results obtained in this study: the observed effects are due to the added heat, and perhaps also to the heat acting with other factors, such as lowered dissolved oxygen content, and trace metals in the discharge water.

It would be useful to determine a maximum temperature which the effluent water could reach without causing damage to the environment of the bay. Such a decision cannot be made on the basis of this study alone. It is necessary to have detailed information on both the kinds and abundances of all the organisms that occur within the affected area and on their interrelationships with each other and with the various parameters of the physical environment. Such knowledge can come only from a well planned research program that encompasses the various aspects

of the ecology of the area. This type of investigation is now underway; it involves many scientists from the University of Miami and is sponsored jointly by the Federal Water Quality Administration and the Atomic Energy Commission. When all the results of this far-reaching study have been analyzed and considered together then judgements can be made on the maximum temperature limits that must be set at Turkey Point.

## SUMMARY

The Florida Power and Light Company operates an electric generating facility at Turkey Point on the mainland shore of Biscayne Bay, a subtropical estuary, south of Miami, Florida. Two conventional units are in operation and two nuclear units are in advanced stages of construction. The two oil-burning plants together produce 864 megawatts of electric power and require 1,270 cubic feet per second of bay water for cooling purposes. The temperature of the cooling water is raised between 5 and 6°C (9-11°F) during a single pass through the condensers. The effluent is discharged into a system of canals and tidal streams that carry it back into the bay.

The present study, sponsored by the Florida Power and Light Company, was undertaken to determine what effects the heated discharge water was having on the populations of some of the fishes and other larger animals in the waterways of the mangrove region through which the effluent flowed. The investigation involved qualitative and quantitative observations on the kinds, distribution and abundance of several species of fishes and invertebrates. Gill nets, traps and hoop nets were used to sample the fishes and larger invertebrates, and slate panels were employed to collect fouling organisms. Various hydrological parameters were monitored routinely at various stations throughout the study area.

Gill nets were used to study the occurrence, abundance and movements of the larger animals between the bay and the tidal streams. Two stations were sampled one night a week for seventeen months. One station was within the area receiving discharge water, the other was outside the influenced area. Two sets were made at each station on each sampling night: one from dusk to midnight and one from midnight to dawn.

Gill nets yielded a total of 1,847 individual fish from 44 species. The most abundant fish was the gray snapper (Lutjanus griseus) followed, in order, by the white mullet (Mugil curema) and the fantail mullet (M. trichodon). The invertebrates numbered 621 specimens from five species. The blue crab (Callinectes sapidus) was the most common of these.

For all species where there were statistically significant ( $P \leq .05$ ) differences in the gill net catches between stations, the greater numbers were taken at the unheated station. The only exception was for the lemon shark.

There were changes in the catches of most of the larger fish in response to the presence of the heated effluent.

When considered together over all the months of sampling, a significantly ( $P \leq .05$ ) greater number of the fish caught by gill net were taken in the unheated control area during the entire sampling period and during the mid-April to mid-October period. No differences in catch by area were detectable from mid-October to mid-April.

The gray snapper (L. griseus) and the tarpon (M. atlantica) exhibited the least response to increase in water temperature of any

of the fish. No differences in numbers caught were found that could be attributed to the operation of the plant.

Catches of the white mullet (M. curema) showed no statistical differences in the number of fish taken between stations when the sampling period was considered as a whole but catches were significantly greater ( $P < .05$ ) at the unheated station from mid-April to mid-October.

No differences could be detected in the numbers of fantail mullet (M. trichodon), striped mullet (M. cephalus) and common snook (C. undecimalis) caught during the six coldest months. During the warmer seasons, all were taken in greater numbers at the control station.

The adult blue crabs (C. sapidus) were caught in significantly greater numbers outside the area of elevated temperature during all periods tested.

The lemon shark (N. brevirostris) was the only species taken in significantly greater ( $P < .05$ ) numbers at the heated station. For all periods tested, it was statistically more abundant in the discharge area.

The contents of the stomachs of the carnivorous fishes were examined to determine if there were any differences in the food consumed by the fish in the heated area compared to those in the unheated area. Differences in prey organisms could indicate that the power plant was affecting the fish indirectly by influencing the supply of food organisms.

The gray snapper was the species in which identifiable ingested matter was most often found. This fish preyed upon crustaceans and fish in a ratio of about 3 to 1. The food consumed was substantially the same in both the affected and unaffected areas.



The stomach analysis data on the other fish species were not sufficient for conclusions to be drawn on their diet or on the differences between areas.

Traps were used to gather information on the occurrence of smaller animals in the waterways around Turkey Point. Sixteen traps were used in the study, four at each of four stations. They were baited and set on a schedule of alternate seven days in the water and seven days out. Sampling was carried out from 29 December 1968 to 23 December 1969.

A total of 2,999 fish from 21 species were taken by trap. The most abundant of these were the pinfish, L. rhomboides and the mojarra, E. gula, G. cinereus and E. argenteus. Nine species of crustaceans numbering 515 individuals were also caught. Those taken most often were the mud crab (P. herbstii) and the blue crab (Callinectes spp.).

Only two of the fish species exhibited significant differences ( $P < .05$ ) in numbers caught among stations. These were the pinfish (L. rhomboides) and the crested goby (L. cyprinoides).

The catches of pinfish were probably related to the presence or absence of rooted vegetation at each of the stations. The seasonal differences in catch were probably related to the heated effluent. During the cooler months, the pinfish were more abundant in the area receiving discharge water. Following a short period of very hot weather, which coincided with effluent temperatures of about 40°C (104°F), yields declined sharply. Shortly thereafter catches at the control station increased markedly while those within the discharge area remained low.

The catches of the crested goby were primarily due to the nature of the habitat at each station. Abundance could not be related to water temperature.

Two species of invertebrates taken by trap, the mud crabs and the juvenile blue crabs, showed significant differences ( $P \leq .05$ ) in catches by station.

The catches of juvenile blue crabs were greatest in the heated area during all periods except July and August. These animals were taken at the control station only from July to October. The catches were apparently influenced by the presence of the heated water.

The differences in catches of the mud crab were apparently primarily due to factors other than temperature; the nature of the habitat appears to be the primary influence on the choice of area by this species.

Hoop nets were used to investigate the movement of animals along the main effluent canal. Three culverts that connected the main canal with the mangrove swamp were sampled twice a month for one year.

Thirteen species of fish and three species of crustaceans totalling 229 animals were caught by hoop nets. The fewest animals and the fewest species were taken at the station closest to the plant.

The animals in the main effluent canal left as the temperature of the discharge water increased during early summer. Among the last fish to leave was the gray snapper.

The only animals seen in the canal from late June to late August were a few tarpon. No animals were caught by the hoop nets during this period.

Animals returned to the canal in the fall as the effluent temperature declined. Among the first fish to return were the gray snapper and the white mullet. The populations of animals remained in the canal throughout the winter and spring.

Those animals that remained in the main canal as the water temperature rose were subject to kills, such as the one that occurred in late June 1969. The species involved at that time were principally blue crabs (C. sapidus) and grunts (Haemulon spp.).

The heated effluent protected the animals from a widespread cold kill that took place outside the area of heated water influence in January 1970. Dead fish were seen in the intake canal but not in the discharge canal.

Slate fouling panels were set out to measure the settlement and growth of barnacles in the study area. Six stations were established along a temperature gradient. Five panels were suspended in a floating rack at each station. The panels were removed and replaced at intervals of one, two, three, six and twelve months.

The barnacles that settled on the fouling panels were Balanus eburneus, Balanus improvisus and members of the Balanus amphitrite complex. The most abundant of these was B. eburneus which comprised about 85 percent of the total. There were no major differences among stations in the numbers of the various barnacle species settling.

Peaks in settlement of B. eburneus were recorded in the spring and in the fall with lowest attachment during the summer. Patterns of settlement were the same at all stations except number 2. At this station the spring peak was larger and occurred earlier than at any other location. The autumn peak at station 2 was much smaller than the others.

The heated effluent water increased the number of B. eburneus that settled during the fall. The peaks of numbers attaching were much higher at the stations within the discharge area than at the control station.

The power plant acted to prevent settlement of barnacles at station 15 during June and July; no barnacles settled on either the one month or two month panels in this period.

The power plant influenced the patterns of growth of B. eburneus. The maximum sizes attained by barnacles at the heated stations was about the same for both the six warmest months (summer) and the six coldest months (winter). Growth at the control station was much less during the winter than during the summer. The growth at the heated stations exceeded that at the control during the winter but was less than that at the control during summer. The average maximum size of the barnacles for the one and two month exposure periods was about the same at both the heat-influenced and ambient stations at the end of one year.

These patterns were all found in both the one and two month test panels.

Barnacles on the three month panels showed about the same growth during both summer and winter at the stations within the discharge area. There was a much greater summer growth than winter growth under normal temperature conditions. However, the maximum sizes at the control station never exceeded those at the heated stations.

The results of the three month immersion were more influenced by the effects of crowding and the buildup of other fouling organisms than those of the shorter exposure periods.

The largest size attained by B. eburneus during one month was 11 mm; mean water temperatures for this period were about 32°C (90°F). There was an apparent decline in maximum length at temperatures above this level.

Regular measurements were made of certain physico-chemical parameters at 12 stations within the study area. Sampling consisted of the measurement of water temperature and the determination of dissolved oxygen, salinity and inorganic phosphate. Each station was occupied once a week for a year.

The seasonal cycles in the dissolved oxygen content of the water at Turkey Point were primarily related to the amount of rainfall and consequent fresh water runoff from the land. Lowest levels occurred during July and highs were recorded during the winter months.

The diurnal patterns in dissolved oxygen are associated with the photosynthesis of aquatic plants and the respiration of all organisms.

The power plant decreased the dissolved oxygen content of the cooling water an average of about .4 ml/l during passage through the condensers. At the same time, saturation levels were increased, usually to supersaturated conditions.

There was an additional drop in oxygen concentration of about .6 ml/l as the discharge water passed down the effluent canal. This was primarily a return to the air of the oxygen forced into solution by the physical processes involved in passage through the plant.

The seasonal cycles of inorganic phosphate concentrations was associated with the fresh water runoff. Maximum levels were reached in July following the spring rains while the lowest readings were found during the periods of little rainfall in the winter.

The power plant had no detectable effect on the levels of inorganic phosphate at Turkey Point.

On the basis of decreased apparent abundances of many fish species within the heat-influenced area during the entire year, and from other evidence, it is concluded that the Turkey Point power plant as it is presently being operated is detrimental to many of the animals of the waterways within the mangrove region through which the effluent water flows.

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1: 296-303.

**APPENDICES**

Appendix I. Water chemistry data collected during gill net sampling. Temperatures are taken from thermograph records except where indicated. (Temperature in °C, salinity in ppt, dissolved oxygen in ppm.)

Sampling Dates		Station 1			Station 16		
		Mean	Max.	Min.	Mean	Max.	Min.
1968							
3 - 4 Aug.	Temp.*	27.6	28.5	27.1	28.3	30.4	27.2
	Sal.		25.7	23.3		26.5	24.2
	D.O.		4.5	2.0		5.0	2.5
9 - 10 Aug.	Temp.*	29.6	31.2	26.4	31.0	33.6	26.1
	Sal.		22.5	18.5		24.9	16.9
	D.O.		5.5	2.0		5.5	2.0
17 - 18 Aug.	Temp.*	30.7	32.5	29.0	32.5	33.9	31.6
	Sal.		30.1	29.7		31.3	29.7
	D.O.		4.5	2.5		5.0	2.5
25 - 26 Aug.	Temp.*	28.6	30.0	27.6	29.9	32.2	28.7
	Sal.		30.5	27.3		30.1	29.7
	D.O.		4.5	3.0		4.0	2.0
1 - 2 Sept.	Temp.*	29.4	30.2	28.4	30.3	31.2	29.3
	Sal.		32.1	29.7		30.5	28.9
	D.O.		5.5	3.0		6.0	3.0
8 - 9 Sept.	Temp.*	30.0	31.1	27.7	32.0	33.4	28.8
	Sal.		29.7	28.9		32.5	30.5
	D.O.		5.0	2.5		6.0	3.0
16 - 17 Sept.	Temp.*	28.4	29.7	27.0	29.4	30.5	27.5
	Sal.		26.5	25.7		28.5	28.1
	D.O.		5.5	2.0		5.0	2.0
24 - 25 Sept.	Temp.*	28.1	29.8	26.8	30.9	32.7	27.6
	Sal.		19.3	17.7		21.7	20.1
	D.O.		4.5	3.0		4.5	3.5
30 Sept. - 1 Oct.	Temp.*	27.7	29.7	26.8	28.9	31.3	27.7
	Sal.		19.5	17.7		20.2	18.9
	D.O.		4.0	3.5		4.5	3.5
8 - 9 Oct.	Temp.*	29.4	30.5	27.2	31.1	32.9	27.6
	Sal.		17.7	15.7		18.5	17.3
	D.O.		5.5	3.5		4.5	3.0
23 - 24 Oct.	Temp.*	25.4	26.3	25.0	25.4	26.6	24.8
	Sal.		18.1	13.3		17.3	14.1
	D.O.		4.5	2.0		4.5	2.5

## Appendix I. Continued

Sampling Dates		Station 1			Station 16		
		Mean	Max.	Min.	Mean	Max.	Min.
30 - 31 Oct.	Temp.*	22.3	23.1	21.1	22.2	23.3	20.1
	Sal.		17.3	15.3		17.3	16.9
	D.O.		6.5	5.0		6.0	2.5
7 - 8 Nov.	Temp.*	23.4	25.3	21.8	25.0	26.2	23.3
	Sal.		19.3	18.1		19.7	19.3
	D.O.		5.5	4.0		5.5	4.0
16 - 17 Nov.	Temp.*	22.9	23.2	22.1	24.1	24.7	23.1
	Sal.		19.9	16.1		20.2	19.5
	D.O.		5.0	2.0		5.5	3.0
22 - 23 Nov.	Temp.*	17.6	18.2	16.2	18.9	21.6	16.8
	Sal.		19.3	17.7		20.9	19.3
	D.O.		5.0	3.5		6.0	4.0
28 - 29 Nov.	Temp.*	22.2	23.2	21.9	24.1	25.2	23.3
	Sal.		20.2	20.1		20.2	20.1
	D.O.		6.5	4.5		6.0	3.5
6 - 7 Dec.	Temp.*	17.6	19.2	16.0	19.2	23.7	17.9
	Sal.		23.3	22.5		25.0	24.1
	D.O.		-	-		5.5	2.5
15 - 16 Dec.	Temp.	15.3	17.1	13.3	16.3	17.6	13.2
	Sal.		24.3	23.7		25.5	25.3
	D.O.		5.5	3.0		5.0	-
21 - 22 Dec.	Temp.	22.8	23.5	21.7	24.6	26.3	23.9
	Sal.		25.9	25.2		26.7	26.1
	D.O.		4.5	2.5		5.0	3.0
28 - 29 Dec.	Temp.	22.7*	23.1*	22.2*	23.1	24.3	18.6
	Sal.		27.5	27.1		28.1	28.1
	D.O.		5.5	2.0		5.5	2.0
1969							
5 - 6 Jan.	Temp.	17.9	18.2	17.2	18.7	19.0	18.3
	Sal.		26.9	25.7		27.3	26.1
	D.O.		6.0	3.0		6.5	3.0
13 - 14 Jan.	Temp.	18.5	19.3	17.8	18.9*	19.3*	18.2*
	Sal.		23.3	22.9		25.5	24.3
	D.O.		5.0	2.0		5.5	2.5

## Appendix I. Continued

Sampling Dates		Station 1			Station 16		
		Mean	Max.	Min.	Mean.	Max.	Min.
19 - 20 Jan.	Temp.	21.1	22.3	20.2	23.2	24.3	19.6
	Sal.		24.3	17.7		24.9	11.1
	D.O.		5.0	2.0		5.5	1.5
27 - 28 Jan.	Temp.	21.5	22.6	20.0	22.8	23.5	20.8
	Sal.		23.3	22.7		25.7	25.3
	D.O.		4.5	4.0		5.5	3.5
3 - 4 Feb.	Temp.	21.7	23.9	19.5	24.2	27.3	23.6
	Sal.		27.0	24.1		28.1	26.5
	D.O.		4.5	2.5		6.5	3.0
11 - 12 Feb.	Temp.	21.0	22.9	19.6	22.0	23.1	21.3
	Sal.		29.1	28.1		29.9	29.3
	D.O.		5.5	2.5		7.0	3.5
18 - 19 Feb.	Temp.	17.3	19.1	14.4	18.1	22.9	15.8
	Sal.		27.3	25.7		28.5	28.1
	D.O.		4.5	3.0		4.5	3.5
25 - 26 Feb.	Temp.	17.7*	19.7*	16.8*	18.8	20.6	17.5
	Sal.		28.9	28.1		29.2	28.7
	D.O.		6.0	5.0		5.5	2.5
6 - 7 Mar.	Temp.	19.6	21.4	18.9	21.0	24.1	19.7
	Sal.		30.5	29.0		30.5	29.5
	D.O.		5.0	2.6		7.1	2.7
13 - 14 Mar.	Temp.	15.4	16.0	14.7	16.7	18.5	14.1
	Sal.		30.1	29.3		31.3	31.3
	D.O.		5.5	3.0		6.0	3.0
19 - 20 Mar.	Temp.	23.3	26.0	20.4	24.8	29.2	23.1
	Sal.		31.7	30.9		32.9	32.3
	D.O.		6.0	2.0		7.5	4.5
27 - 28 Mar.	Temp.	19.0	19.5	16.3	20.7	23.1	18.9
	Sal.		28.9	25.0		28.1	26.5
	D.O.		5.5	3.0		4.5	1.5
4 - 5 Apr.	Temp.	25.2	28.8	23.4	25.6*	26.4*	24.2*
	Sal.		23.3	22.1		25.8	24.9
	D.O.		5.5	3.0		6.5	3.5
11 - 12 Apr.	Temp.	25.8	26.8	25.1	27.0	29.3	26.6
	Sal.		29.7	23.3		28.5	27.3
	D.O.		8.6	3.4		5.5	2.3



## Appendix I. Continued

Sampling Dates		Station 1			Station 16		
		Mean	Max.	Min.	Mean	Max.	Min.
18 - 19 Apr.	Temp.	28.9	30.4	26.1	30.8	33.1	26.3
	Sal.		30.5	29.7		30.9	30.6
	D.O.		6.5	2.5		6.0	3.0
26 - 27 Apr.	Temp.	24.6	25.5	23.2	26.0	26.7	23.4
	Sal.		31.5	29.7		34.1	32.2
	D.O.		7.0	2.5		6.0	3.0
4 - 5 May	Temp.	25.9	28.9	24.7	27.5	30.4	24.7
	Sal.		28.1	26.5		30.1	29.1
	D.O.		5.5	5.0		6.5	4.0
10 - 11 May	Temp.	26.1	27.8	25.6	28.1	29.4	25.6
	Sal.		30.7	30.7		33.7	30.9
	D.O.		6.5	3.0		6.5	3.5
18 - 19 May	Temp.	27.7	29.6	25.9	30.0	31.7	25.7
	Sal.		31.7	30.1		32.5	30.9
	D.O.		5.5	4.0		5.5	3.5
26 - 27 May	Temp.	28.1	29.2	27.2	29.0	30.3	28.0
	Sal.		18.9	18.9		22.5	22.1
	D.O.		7.0	4.0		6.5	4.0
2 - 3 June	Temp.	30.2	31.4	27.1	31.9	33.8	26.9
	Sal.		20.9	19.3		22.9	20.1
	D.O.		5.0	2.5		6.0	3.0
8 - 9 June	Temp.	26.8	27.1	25.7	27.0	27.9	26.4
	Sal.		22.5	18.7		19.7	18.5
	D.O.		6.0	3.5		5.0	3.5
16 - 17 June	Temp.	30.4	32.5	27.9	31.5	34.1	27.3
	Sal.		22.5	16.9		20.9	19.3
	D.O.		4.5	1.5		5.5	2.5
24 - 25 June	Temp.	32.9	33.7	29.9	33.5*	35.2*	30.0*
	Sal.		16.1	13.0		17.7	15.6
	D.O.		4.5	1.5		5.5	1.0
1 - 2 July	Temp.	31.3	32.1	27.4	32.1	35.3	26.9
	Sal.		16.1	12.9		15.7	13.0
	D.O.		4.5	1.5		5.0	2.0
7 - 8 July	Temp.	31.5	32.9	29.3	33.2*	34.0*	29.1*
	Sal.		20.5	18.9		21.0	19.9
	D.O.		6.5	3.0		7.0	2.5

## Appendix I. Continued

Sampling Dates		Station 1			Station 16		
		Mean	Max.	Min.	Mean	Max.	Min.
16 - 17 July	Temp.	33.0	34.5	28.5	34.7	37.1	28.0
	Sal.		26.9	24.9		27.6	26.5
	D.O.		4.6	2.4		4.3	2.0
24 - 25 July	Temp.	31.9	33.2	30.8	32.6	34.7	30.9
	Sal.		25.9	25.2		26.9	25.9
	D.O.		8.5	2.5		7.0	3.0
30 - 31 July	Temp.	30.0	32.2	27.3	33.1	35.3	27.9
	Sal.		27.3	25.7		27.5	27.0
	D.O.		6.5	3.0		7.0	2.5
6 - 7 Aug.	Temp.	31.4	32.7	29.5	32.8	34.5	30.4
	Sal.		28.0	27.3		29.7	28.3
	D.O.		4.0	3.0		6.0	3.5
15 - 16 Aug.	Temp.	31.3	32.1	28.0	33.1	34.4	27.7
	Sal.		30.1	24.1		27.7	25.9
	D.O.		4.4	3.0		5.4	2.1
22 - 23 Aug.	Temp.	32.6	33.5	30.6	33.1	35.1	31.8
	Sal.		29.1	28.9		30.5	29.1
	D.O.		6.5	3.0		8.0	2.5
29 - 30 Aug.	Temp.	29.0	30.1	26.9	31.7	32.2	26.8
	Sal.		23.7	21.1		26.9	24.1
	D.O.		7.0	3.0		7.5	3.5
5 - 6 Sept.	Temp.	27.2	28.3	27.0	28.6	29.5	28.1
	Sal.		20.1	17.7		26.0	22.5
	D.O.		3.5	2.0		6.0	2.5
14 - 15 Sept.	Temp.	26.3	27.4	25.7	27.9	29.0	25.8
	Sal.		20.1	13.3		20.9	19.3
	D.O.		5.5	3.0		6.5	3.5
20 - 21 Sept.	Temp.	29.2	30.2	28.7	30.1	31.6	28.7
	Sal.		20.5	19.3		18.5	15.7
	D.O.		7.0	4.5		6.0	3.0
27 - 28 Sept.	Temp.	28.8	29.7	27.2	31.4	31.7	27.0
	Sal.		22.5	20.9		24.1	21.7
	D.O.		4.5	3.9		4.0	2.5
5 - 6 Oct.	Temp.	28.6	29.8	27.4	29.7	31.7	27.2
	Sal.		24.9	22.7		25.9	24.9
	D.O.		7.0	-		7.0	3.0

## Appendix I. Continued

Sampling Dates		Station 1			Station 16		
		Mean	Max.	Min.	Mean	Max.	Min.
13 - 14 Oct.	Temp.	27.0	28.2	25.5	29.0	30.8	25.4
	Sal.		17.7	17.3		19.3	19.3
	D.O.		7.5	3.5		6.5	4.0
20 - 21 Oct.	Temp.	27.3	28.2	26.6	28.5	29.7	27.5
	Sal.		24.9	22.9		22.7	22.5
	D.O.		7.0	3.0		6.5	3.5
27 - 28 Oct.	Temp.	26.1	26.8	25.4	27.4	29.1	26.1
	Sal.		13.1	10.3		18.5	17.7
	D.O.		5.3	2.7		4.9	2.7
4 - 5 Nov.	Temp.	26.0	26.9	20.8	26.5	28.0	22.6
	Sal.		15.3	12.5		18.5	16.1
	D.O.		4.5	2.0		6.5	2.5
11 - 12 Nov.	Temp.	21.9	23.3	19.7	23.1	25.7	19.8
	Sal.		19.7	18.5		19.3	19.3
	D.O.		5.5	2.5		6.5	2.5
18 - 19 Nov.	Temp.	23.0	24.9	21.3	24.0	24.9	22.6
	Sal.		17.7	17.3		18.5	18.5
	D.O.		6.0	3.0		6.5	3.5
25 - 26 Nov.	Temp.	22.2	23.8	20.8	23.9	25.9	20.5
	Sal.		14.5	13.7		16.5	16.1
	D.O.		6.0	2.0		7.0	2.0
3 - 4 Dec.	Temp.	18.9	19.7	18.1	20.3	21.0	19.1
	Sal.		20.9	19.3		20.9	20.1
	D.O.		7.0	4.8		7.0	4.2
11 - 12 Dec.	Temp.	22.4	23.4	19.0	24.1	25.1	17.9
	Sal.		19.7	16.1		20.3	19.3
	D.O.		7.0	4.0		5.5	4.0
17 - 18 Dec.	Temp.	19.3	20.0	18.0	20.8	21.1	18.4
	Sal.		20.9	20.5		21.7	20.9
	D.O.		5.5	3.5		6.0	4.0
26 - 27 Dec.	Temp.	18.5	22.0	14.6	20.2	25.0	16.8
	Sal.		22.5	22.1		24.1	23.5
	D.O.		5.0	4.0		5.0	3.5

## Appendix I. Continued

Sampling Dates		Station 1			Station 16		
		Mean	Max.	Min.	Mean	Max.	Min.
1970							
3 - 4 Jan.	Temp.	22.2	23.4	21.4	23.1	24.7	21.0
	Sal.		22.5	22.5		24.9	23.7
	D.O.		6.0	3.6		5.9	3.6
Mean Differences	Temp.	0.0			+ 1.6		
	Sal.	0.0			+ 1.2		

\*Indicates temperatures listed are the result of 3 or 4 separate measurements with a mercury thermometer calibrated in 0.1°C.

Appendix II. Monthly mean water temperatures at twelve stations at Turkey Point. Four readings comprise each mean except where indicated. (Temperature in °C)

Date	Station											
	1	2	3	4	6	8	10	12	14	15	16	19
February	19.4	21.0	19.4	24.8	23.7	23.5	23.1	22.8	22.5	23.0	22.9	21.8
March	20.3	21.9	21.1	26.7	26.2	26.2	25.9	25.5	23.8	26.2	22.8	23.9
April	27.4	27.2	26.7	32.6	32.1	31.8	31.5	32.2	32.0	31.9	32.8	29.8
May	29.6	28.4	28.1	34.5	33.5	33.3	32.5	32.6	32.3	32.5	32.7	32.0
June*	31.2	30.5	30.2	35.9	34.4	34.7	33.9	33.7	33.4	33.9	33.2	32.1
July	31.3	31.9	31.7	36.0	35.4	35.2	34.6	33.4	33.1	34.0	31.5	30.6
August*	32.8	32.9	31.8	38.1	37.4	37.0	36.4	36.0	35.1	36.3	34.4	35.9
September	30.3	30.5	29.6	36.8	35.5	34.6	34.0	33.1	32.3	33.9	31.6	32.3
October	28.2	28.5	27.9	35.0	34.2	34.2	33.1	32.0	30.2	33.3	29.8	30.8
November	24.7	25.1	23.9	30.2	29.2	28.8	28.0	27.5	26.6	28.3	26.1	27.1
December	21.6	22.6	21.0	27.4	26.7	26.7	26.1	25.6	24.3	26.2	23.6	24.7
January*	19.6	21.3	19.1	25.7	25.1	25.0	24.8	24.9	22.8	25.3	22.0	23.9

\*Five readings comprise each mean

Appendix III. Monthly mean salinity values at twelve stations at Turkey Point. Four readings comprise each mean except where indicated. (Values are in ppt)

Date	Station											
	1	2	3	4	6	8	10	12	14	15	16	19
February	28.1	27.8	28.8	29.0	29.0	29.0	28.9	29.0	28.8	29.0	28.9	27.0
March	26.8	30.2	30.5	30.7	30.8	31.1	31.0	30.2	31.2	30.8	31.2	26.8
April	26.6	27.6	27.5	28.3	28.5	28.7	28.4	28.4	28.6	28.3	29.5	23.7
May	27.0	27.6	28.0	28.4	29.0	29.0	29.0	29.4	29.2	29.3	29.6	19.9
June*	17.5	18.6	18.0	19.4	17.2	18.1	17.1	18.3	19.5	19.9	19.5	5.6
July	22.2	23.1	24.9	25.4	25.0	24.8	23.1	23.7	24.6	25.2	24.5	5.3
August*	26.7	27.8	26.7	27.3	27.3	27.6	27.7	27.9	27.8	28.0	28.2	27.7
September	20.6	22.1	23.4	24.3	23.3	23.4	20.8	20.6	22.1	22.9	22.4	12.2
October	19.9	21.3	20.6	21.4	21.4	21.3	21.1	21.1	21.2	22.0	21.2	15.6
November	15.7	18.4	16.3	17.5	16.3	16.6	15.3	16.3	17.7	17.1	18.1	16.2
December	20.1	20.6	21.2	21.7	21.6	21.7	21.7	21.4	21.3	21.8	21.1	19.2
January*	23.1	24.6	23.7	24.2	24.3	24.3	24.3	24.6	24.6	24.6	24.7	22.5
Mean	22.9	24.1	24.1	24.8	24.5	24.6	24.0	24.2	24.7	24.9	24.9	18.5

\*Five readings comprise each mean

Appendix IV. Monthly mean dissolved oxygen concentrations at twelve stations at Turkey Point. Four readings comprise each mean except where indicated. (Values are in ml/l [ppm]).

Date	Station											
	1	2	3	4	6	8	10	12	14	15	16	19
February	5.61	4.61	5.65	5.60	5.41	5.25	5.18	5.46	5.67	5.49	5.61	4.71
March	4.80	4.69	-	5.11	4.78	4.77	5.16	5.62	5.44	5.11	5.41	4.54
April	4.42	4.65	5.18	4.78	4.53	4.12	4.32	4.93	5.38	4.91	5.23	3.92
May	4.50	4.51	5.01	4.87	4.29	4.28	4.47	5.09	5.23	5.20	5.42	4.30
June*	4.42	4.44	5.10	4.95	4.41	4.31	4.28	5.10	4.77	5.10	5.32	4.22
July	3.61	3.81	4.09	4.26	3.98	3.93	3.83	3.53	3.73	3.74	3.83	2.18
August*	5.92	4.60	5.32	4.94	4.47	4.24	3.85	4.31	5.46	4.10	6.41	3.76
September	4.45	4.32	5.41	4.87	4.37	4.16	4.04	3.85	4.40	3.96	5.23	3.94
October	5.41	4.50	5.32	4.97	4.56	4.88	4.27	4.66	5.85	4.30	5.93	4.51
November	6.05	5.21	6.80	6.24	5.64	5.59	5.46	5.85	6.16	6.05	6.63	5.16
December	6.01	5.87	6.11	5.95	5.53	5.37	5.25	5.65	6.11	5.65	6.20	5.18
January*	5.92	5.13	5.94	5.86	5.58	5.49	5.33	5.69	5.72	5.63	5.91	4.75
Mean	5.09	4.69	5.45	5.20	4.80	4.70	4.62	4.98	5.33	4.93	5.60	4.26

\*Five readings comprise means

Appendix V. Monthly mean percent of oxygen saturation at twelve stations at Turkey Point.  
Four readings comprise each mean.

Date	Station											
	1	2	3	4	6	8	10	12	14	15	16	19
February	114	113	111	113	107	104	104	107	110	123	111	90
March	89	91	99	107	96	100	107	116	117	106	103	90
April	91	97	107	110	101	97	97	123	123	111	121	86
May	99	96	107	116	101	100	97	119	121	120	126	99
June*	94	94	107	116	97	97	94	113	106	116	119	86
July	79	84	90	97	94	93	89	81	86	87	87	43
August	139	107	120	124	111	104	94	106	131	100	153	91
September	114	93	117	119	103	97	91	87	97	93	116	83
October	110	93	109	114	104	113	94	101	124	97	126	94
November	114	100	126	130	114	113	109	116	121	121	130	101
December	109	109	111	120	110	107	104	111	117	111	117	100
January*	106	97	104	117	110	107	104	111	109	111	111	91
Mean	105	98	109	115	104	102	99	108	114	108	118	88

\*Five readings comprise each mean



Appendix VI. Monthly mean inorganic phosphate levels at twelve stations at Turkey Point.  
 Four readings comprise each mean except where indicated. (Values are in  $\mu\text{gA}/\text{l}$ )

Date	Station											
	1	2	3	4	6	8	10	12	14	15	16	19
February	.05	.06	.09	.08	.07	.10	.10	.10	.05	.09	.09	.10
March	.17	.09	.13	.10	.24	.10	.11	.14	.12	.11	.13	.11
April	.10	.10	.08	.08	.07	.07	.07	.08	.07	.08	.06	.06
May	.10	.08	.08	.10	.08	.08	.09	.11	.06	.07	.07	.07
June*	.13	.14	.08	.10	.11	.13	.10	.18	.10	.10	.11	.13
July	.19	.28	.15	.18	.14	.17	.14	.16	.11	.10	.11	.12
August*	.13	.11	.10	.09	.12	.11	.11	.10	.11	.11	.11	.11
September	.11	.13	.15	.12	.07	.14	.14	.12	.16	.08	.19	.18
October	.20	.12	.15	.16	.19	.14	.14	.15	.15	.20	.16	.16
November	.14	.17	.12	.11	.16	.18	.10	.16	.14	.14	.13	.14
December	.10	.12	.09	.10	.09	.09	.10	.12	.08	.09	.07	.08
January*	.09	.10	.09	.11	.07	.08	.13	.09	.07	.06	.06	.09
Mean	.13	.13	.11	.11	.12	.12	.11	.12	.10	.10	.11	.11

\*Five readings comprise each mean