

Churchill Bragaw Grimes. SOME ECOLOGICAL EFFECTS ON FISHES BY THE HOT WATER DISCHARGE OF A STEAM ELECTRIC GENERATING PLANT IN CRYSTAL RIVER, FLORIDA. (Under the direction of Joseph G. Boyette) Department of Biology, August 1971.

A field investigation was made throughout 1969 to determine the ecological effects of hot water discharge by a steam electric generating plant in Crystal River, Florida.

Trawl sampling disclosed that only shallow inshore areas near the discharge were thermally affected. Abundance of fishes at all shallow stations was greatest during spring and fall, but decreased in summer. In winter these stations were nearly barren. Comparison of data from affected stations and non-affected stations revealed greater abundance of fishes during late fall and early winter at affected stations but no large differences during other seasons. Shallow affected stations also possessed the greatest species abundance during late fall and early winter. Winter water temperatures, surface and bottom, at non-affected shallow stations were 14.3-14.6 C and 14.0-15.8 C as compared to 14.3-15.5 C and 14.3-16.5 C surface and bottom at shallow affected stations.

Statistical comparison of the annual growth of age 0 Bairdiella chrysura (Lacepede), Lagodon rhomboides (Linnaeus), and Orthopristis chrysopterus (Linnaeus) collected at affected and non-affected stations revealed no significant differences in growth increments within any of the three species. Standard length frequency plots of the same fishes revealed no differences in spawning time or age composition of the populations from affected vs. non-affected areas.

Results and comparison of seasonal and relative abundance of fishes from affected and non-affected stations indicated that no native species were being eliminated or greatly modified thus changing the abundance of different species and leading to possible undesirable replacement fauna.

The diversity index $(S-1)/\ln N$ was used to compare species diversity of fishes at stations of increasing distance from the point of discharge. Slight shifts in diversity toward the discharge in winter and away in summer were indicated.

SOME ECOLOGICAL EFFECTS ON FISHES BY THE HOT
WATER DISCHARGE OF A STEAM ELECTRIC GENERATING
PLANT IN CRYSTAL RIVER, FLORIDA

A Thesis

Presented to

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In Partial Fulfillment
of the Requirements for the Degree
Master of Arts in Biology

by

Churchill Bragaw Grimes

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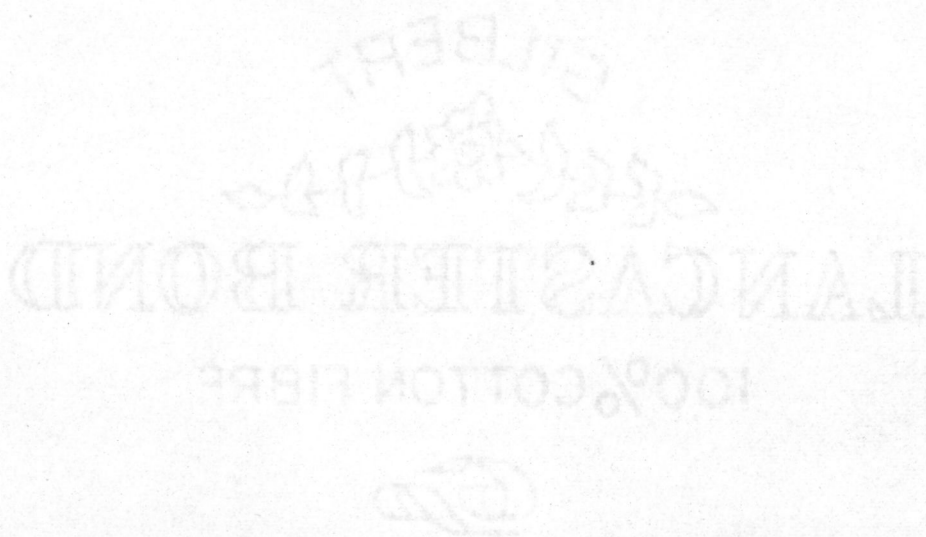
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INTRODUCTION

The potential dangers and problems of thermal pollution posed by the rapid expansion of the steam-electric industry have created an urgent need for increased knowledge concerning the effects of heated effluents on the aquatic ecosystem.

The steam-electric industry has the greatest non-consumptive industrial use for water as a heat transfer medium. Picton (1960) reported, on the basis of projected power needs for 1980, that one-fifth to one-sixth of the total freshwater runoff of the United States will be used as cooling water. More recently, Trembley (1965) predicted that the electricity needs of the United States will double every 6 to 10 years in some areas.

The recent trend toward construction of nuclear plants will result in greater amounts of waste heat produced per kilowatt hour, as nuclear plants are approximately 25% less efficient than conventional fossil-fueled plants. Increasing demands for cooling water are resulting in a larger percentage of steam electric stations being located on or near estuaries. According to Picton (1960), 32% will be on estuaries in 1980 as compared to 22% in 1950. Increases in generating-unit size will result in increases in steam pressure and temperature. In addition to thermal changes there will be a need for greater purity in boiler feed water which will require deionization units (Cadwallader, 1965).

These units and particularly internal surfaces of high pressure boilers must be kept meticulously clean. This will result in eventual discharge of a variety of cleaning agents ranging from detergents and hydrochloric acid to corrosion inhibitors (Mihursky and Kennedy, 1967).

Much of the recent research has been applied to the freshwater environment, and will be discussed only when applicable to the marine or estuarine environment. These have involved laboratory and field studies to better understand certain interactions in the marine or estuarine environment resulting from temperature change. The following lists some of the environmental modifications resulting from temperature change:

1. Increased temperature can kill an organism directly through denaturation of its proteins.
2. Because the metabolic rate of an organism increases rapidly with increases in temperature, survival of eggs, larvae, and adults of fishes and invertebrates may be decreased.
3. Increased temperature decreases the solubility of oxygen in water but increases its rate of consumption (metabolism) by aquatic organisms.
4. The flocculation of finely suspended particles in water increases with temperature thus increasing the direct removal of dissolved oxygen. Increased flocculation also reduces water clarity thus

retarding growth and photosynthesis in algae (a major source of atmospheric oxygen).

5. Salinity increases can occur with increasing temperature thus effecting survival of eggs and larvae.
6. Increased growth rates resulting from increased temperatures may not be maintained in later life and thus may lead to decreased longevity and final size.
7. Precocious maturity of fishes or invertebrates resulting from temperature increase can significantly change or interfere with reproductive cycles. Fecundity in some species is temperature dependent.
8. Water temperature may act as a selective factor altering the phenotypic distributions in offspring of parents subjected to thermal change.
9. Incidence of parasitism and its debilitating effects may vary with temperature.
10. Thermal effluents can result in vertical thermal stratification in receiving waters thus altering natural vertical movements of organisms.
11. In many organisms, adults may actively escape thermal effluent while the early stages may perish directly or become more vulnerable to predation.

12. Increased rates of chemical reaction in the environment could result in a wide range of already present wastes acting synergistically to increase existing toxic effects.
13. Effluents creating a thermal barrier in spawning and nursery areas may cause these areas to be avoided by fishes. Likewise, discharges in coastal areas could alter the migratory behavior of anadromous fishes.

Mihursky and Kennedy (1967), reporting on thermal studies of the heated discharge at the Chalk Point Steam electric station on the Patuxent River estuary in Maryland, indicated that under winter and summer power plant operating conditions lethal temperature levels would be reached for certain species of arthropods, pelecypods, and fish. The opossum shrimp, Neomysis americana, essential to the diet of juvenile striped bass, Roccus saxatilis, was found not to survive above 87.8 F, a surface temperature sometimes reached in the Patuxent River estuary. They concluded that, "Temperatures between 90 and 99.9 F, allowable under present land law, are going to suppress or eliminate certain species."

Mihursky and Cronin (1967) reported fish and crab kills around the outfall structure of the Chalk Point plant with 40 thousand blue crabs, Callinectes sapidus, being the largest kill recorded. Their laboratory and field studies indicated up to 95% mortality of entrained organisms pumped

through the power plant. Passage of water and subsequent heating caused a reported decrease in sea nettles around the plant. Fish catch data for the white perch, Roccus americanus, from deep-water trawling in the Patuxent River reflected an avoidance in summer and attraction in winter to maximally affected areas. These investigators found that certain estuarine forms (Mya sp., Neomysis sp., and Gemma sp.) would not survive in temperatures much above naturally occurring maxima.

Warinner and Brehmer (1966) published results of thermal addition research conducted at the Yorktown, Virginia steam electric station on the lower York River. They used the redundancy index developed by Margalef (1956) to express diversity of the benthic community at stations of increasing distances directly opposite the point of heated discharge. In winter a pattern of increasing community diversity at stations nearer the point of discharge was noted. Like diversity data for summer indicated a reversal of the winter situation. A station located 200 m opposite the point of discharge displayed the greatest seasonal variation in community diversity. The community diversity index as discussed by Jones (1961) was also applied to their benthic community data. This index indicated a pattern similar to that seen in the redundancy indices. Results from primary productivity studies by the Carbon-14 method indicated that when ambient river temperatures were between 15-20 C all

elevations in temperature of 5.6 C or more resulted in a significant depression in production. In winter, temperature changes normally experienced during passage through a power plant condenser enhanced primary production.

Allen, Boydston, and Garcia (1970) conducted a study of the distribution and behavior of marine fishes in the vicinity of the Pacific Gas and Electric Company's nuclear fueled generating station at Buhne Point, Humbolt Bay, Eureka, California. Fish were taken by hook and line at stations established near the discharge. Catch at each station was superimposed over a graph of water temperature at each station. Twelve species were captured in sufficient numbers to be classified as to temperature preference. They concluded that five species tended to congregate in warmer waters, four species showed a preference for colder waters, and three were taken in all temperature ranges.

Alabaster (1963) studied the effects of heated effluent discharge on fishes around seven power stations in Great Britain. The effluents caused temperature increases between 6.3 and 10.4 C and maximum temperatures up to 30 C. He found that heated effluents could be lethal to caged fishes in summer and most of these effluents tended to concentrate on the surface leaving cooler stratum below. He reported increased fish populations in waters below 26 C and decreased populations at 30 C and above. He concluded that the probability of fish kills was low in the area studied but

felt that kills could occur in areas where organic and thermal pollution might act synergistically. Jones (1964), another British researcher, believed that thermal addition would not cause significant fish kills. He stated that fish would completely disappear from thermal discharge areas in the summer but would congregate for extended periods in such areas in winter. Trembley (1960), in a four year study of a Delaware River power plant, found that most fish species were completely absent from the heated area in summer. Hoak (1961), also working on the Delaware River, found 40 C to be the minimum upper lethal temperature for most species. He stated that little propagation took place above 26 C even though numerical decreases did not occur until 36 C.

Mayer (1914), reported on thermal effects upon tropical marine animals. He reported average temperatures to be 29 C and that temperatures of 33-38 C caused high mortalities of mollusks, corals, and small fish. The thermal death points of eight representative marine organisms acclimated to 29 C were found to be 35, 36, 37.4, 38.5, 40, 42.3 and 46.3 C. He concluded that tropical marine animals lived within 5 C of their maximum activity and 10 to 15 C of their death temperature. Death from high temperatures he stated was caused by asphyxiation due to low oxygen.

Graham (1970) reported on temperature sensitivity of the fishes Clinocottus analis and Hypsoblennius gilberti

which occur together in an intertidal environment from central California to Baja, California. In winter he found that C. analis (of a predominately boreal family) acclimated to 11, 15, 17, and 23 C but had upper lethal temperatures of 27.0, 27.5, 27.8, and 27.8 C. In summer, using the same acclimation temperatures, upper lethal temperatures were 26.5, 27.5, 28.0, and 29.0 C. In winter H. gilberti (of a predominately tropical family) had upper lethal temperatures of 27.5, 29.5, 30.0, and 30.0 C when acclimated to the same temperatures while summer upper lethal temperatures were 28.0, 28.5, 29.0, and 30.0 C.

Allen and Strawn (1967) reported on the heat tolerance of channel catfish, Ictalurus punctatus, ranging in age from 6 days to 11½ months. The fish were from a common source but reared under different thermal conditions. They found that fish acclimated to 26.0, 30.0, and 34.0 C had upper lethal temperatures of 36.6, 37.2, and 37.8 C. They found differences in resistance times to be related to age but not size. Their results also indicated that channel catfish exposed to "semi-lethal" temperatures may die from the direct results of heat while slightly lower test temperatures cause death indirectly due to increased rate of metabolism resulting in starvation.

OBJECTIVES OF THE STUDY

The objectives of the Crystal River thermal addition study are as follows:

1. To determine the occurrence and abundance of certain nektonic and benthonic marine organisms in the vicinity of the Florida Power Corporation Crystal River steam electric station.
2. To monitor certain chemical and physical properties of the water in the vicinity of the plant.
3. To provide oyster samples for trace metals and pesticide residue analysis.

The objective of this thesis study is to assess the thermal effects upon the fishes in the vicinity of the Crystal River steam electric station.

HISTORY OF STUDY

The Crystal River project was formulated when the United States Fish and Wildlife Service (now the National Oceanographic and Atmospheric Administration) recommended to the Atomic Energy Commission that Florida Power Corporation (FPC) cooperate with the Florida Department of Natural Resources (FDNR) in developing ecological surveys, initiating these studies at least 2 years before reactor operation, and continuing them on a regular basis or until it has been conclusively demonstrated that no significant adverse conditions exist. Agreement was reached late in 1968

whereby the Marine Research Laboratory (of FDNR) would set up a field laboratory at the plant site and begin the study. FPC agreed to contribute \$25,000 per year for capital outlay expenditures, with other expenses (salaries, supplies, etc.) being paid by the Marine Research Laboratory. Physical implementation of the study at the FPC site began in January 1969.

PHYSICAL CHARACTERISTICS OF STUDY AREA

The plant site is located 112 km (70 miles) north of Tampa, Florida, 12 km (7.5 miles) northwest of Crystal River, Florida (lat. 23°57', lon. 82°45'). The terrain throughout the area is flat, relatively featureless, and bordered on the west by the Gulf of Mexico. The area west of the plant is typical of tidal marshes along the Gulf coast of the northern half of the Florida peninsula. Here, where tidal flooding occurs regularly, Juncus sp. is the dominant vegetation. Two canals have been dug through this marsh (Figure 1). The south canal, directed west southwest from the plant, serves as an intake canal for cooling water and as a deep water channel for coal and oil barges supplying the plant. The north canal, directed west from the plant, receives the heated effluent water.

The subtropical climate is characterized by diurnal wind shifts. Prevailing winds are northeasterly in the fall and winter and southwesterly in the spring and summer.

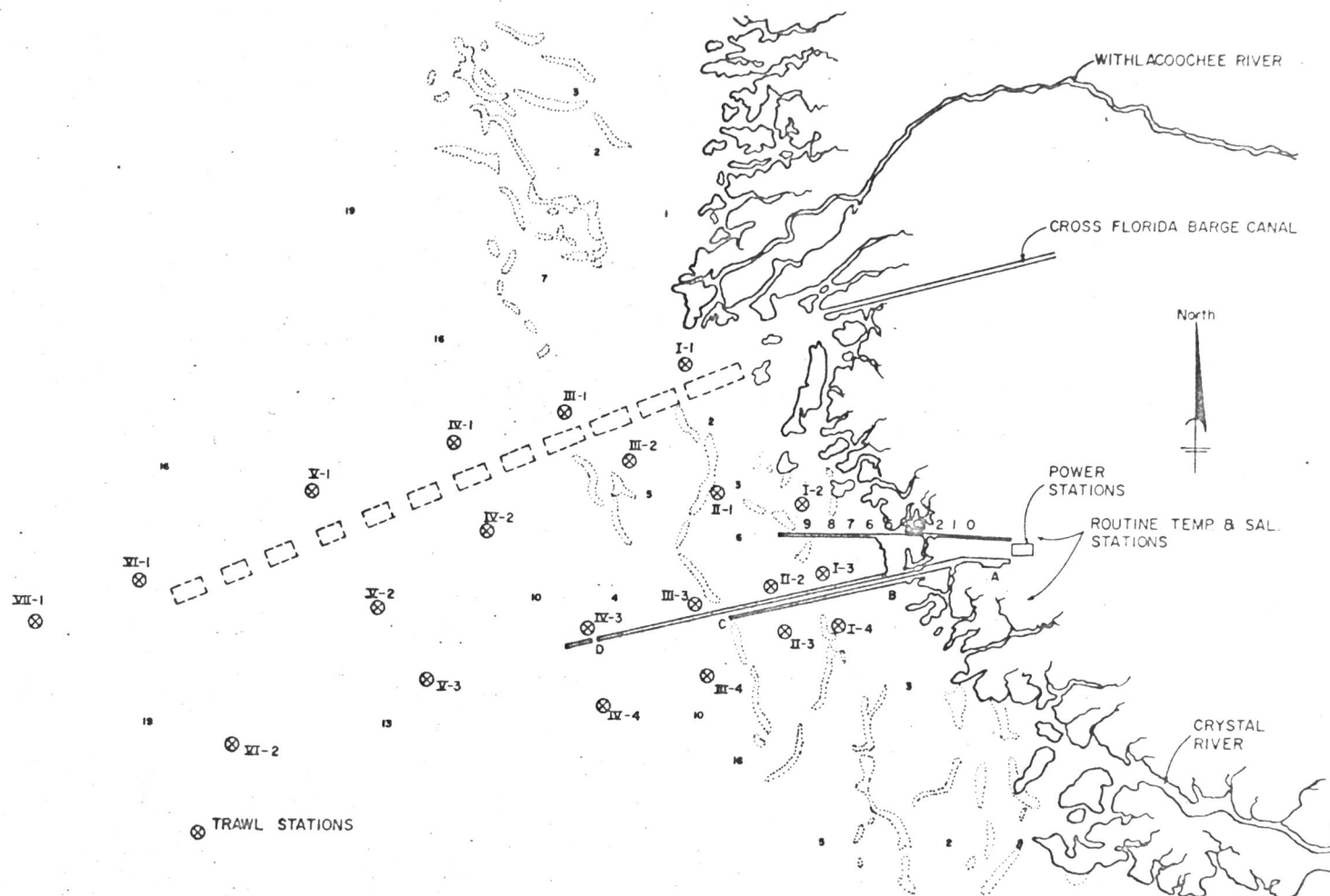


Figure 1. Map of study area indicating locations of trawl stations and temperature stations in discharge and intake canals.

Winds seldom persist from one direction for more than 24 hours. Winters are usually dry and summers wet, with more than 50% of the yearly average precipitation of 55 inches occurring between June and September.

Two rivers influencing the area are the Withlacoochee, which empties into the Gulf approximately 6.4 km (4 miles) northwest of the plant, and the Crystal, which enters approximately 4.8 km (3 miles) southeast. The former has an average flow of 817 thousand gal/min ($1820 \text{ ft}^3/\text{sec}$) and the latter 269 thousand gal/min ($600 \text{ ft}^3/\text{sec}$). The Cross Florida Barge Canal enters the Gulf approximately 5.8 km (3.6 miles) northwest of the plant.

The Gulf waters to the west of the plant are shallow, the bottom gradually sloping for a distance of 46.4 km (25.6 nautical miles) to the 5 fathom contour. The bottom composition varies from hard sand to rock covered with mud near the natural shoreline and silt in areas where dredging and draglining have occurred. Construction of the canals may have caused much of this siltation.

Description of Generating Facilities

The steam electric generating complex at Crystal River will eventually include three units, two fossil-fueled, the third (under construction) nuclear-fueled. Unit 1, in operation since July 1966, is oil fired (converted from coal in March 1970) with an 387 Mw generating capacity.

It is designed to have a maximum condenser temperature rise of 6.1 C (11 F) and a pumping rate of 340 thousand gal/min. Unit 2, in operation since November 1969, is coal fired, and has a generating capacity of 510 Mw with a maximum condenser temperature rise of 6.1 C (11 F) and a pumping rate of 340 thousand gal/min. Unit 3, of particular concern in our study, is scheduled to begin operation in late 1972, with a generating capacity of 825 Mw. Cooling water pumping rate will be 700 thousand gal/min with a maximum condenser temperature rise of 9.4 C (17 F).

METHODS AND MATERIALS

Temperature and salinity transects running 15 miles west out of the intake and discharge canals were run prior to establishing sampling procedures and stations. The latter part of January was spent in exploratory trawling to locate areas of differing ecological conditions. Twenty-one trawl stations were then established using these findings (Figure 1).

A 15 foot (measured from door to door) flat trynet with 1 inch stretched nylon mesh was used for sampling of trawl stations. During the first seven months of sampling, the trynet was towed by a 16 foot boat powered by a 50 hp outboard motor. Throughout the remaining five months, a 19 foot boat was used to fish at approximately 3-5 knots (2400 rpm from a 65 hp outboard). The duration of each tow was approximately five minutes. Water samples were obtained with a weighted, 1 liter, polyethylene bottle for determination of temperature, salinity, dissolved oxygen, dissolved carbon dioxide and pH.

A small dredge was used at several trawl stations during early stages of the study with little success. Few specimens were collected in the dredge and these were already represented in the trawl samples. Consequently, the dredge was discontinued as a monthly sampling tool.

Vertical traveling screens are used by FPC to prevent larger organisms and debris from being pulled into the

intake water pump wells. They provided a method for sampling macro-organisms present in the intake canal. The screens are rotated and the trapped organisms and debris flushed by a high pressure water jets into a sluiceway leading to a catchbasin. A 6 foot nylon bag net with 1 inch stretched mesh was placed at the end of the sluiceway for 24 hours once monthly. The sampling net was monitored periodically throughout the collecting period and species abundance and sizes recorded.

Specimen Handling and Preservation

The entire sample collected at each trawl station was preserved in approximately 10% seawater formalin and placed in large labeled polyethylene containers. The screenwash sample or a representative portion of it was handled similarly. All preserved specimens were fixed in (10%) formalin (solution) for at least 24 hours, then placed in containers of fresh water for 24 hours before sorting. Algae were placed in 10% formalin, invertebrates in 70% ethyl alcohol, and fishes in 40% isopropyl alcohol for storage and later examination. Standard measurements were made where appropriate. Algae were taken to the St. Petersburg Marine Laboratory for further examination and study.

RESULTS AND DISCUSSION

Data Handling

Seasonal trends of abundance and occurrence are based on fishes taken in monthly samples (Tables 2-6). These data are presented graphically in Figures 2-4. Accompanying physical data, chemical data, and field observations are included in Appendix II. Locations and depths of trawl stations are given in Appendix I. For analysis and presentation trawl data were divided into four groups:

- 1) Group A (control) included data from shallow stations (0.21-1.2 m) not affected by thermal effluent (Stations I-1, I-4, and II-3).
- 2) Group B (control) included data from intermediate-depth stations (1.2-2.4 m) not thermally affected (Stations III-1, III-4, IV-1, and IV-4).
- 3) Group C includes data from deep stations (3.04-9.1 m) not affected by thermal effluent (Stations V-1 V-2, V-3, VI-1, VI-2, and VII-1).
- 4) Group D (experimental) includes data from trawl stations affected by thermal discharge (Stations I-2, II-1, I-3, II-2, III-3, III-2, IV-3, and IV-2). These include shallow and intermediate stations listed in decreasing order of thermal influence received.

The categorization of trawl stations as affected or

non-affected was based upon three sources of information:

- 1) Temperature measurements at trawl stations during 1969 sampling.
- 2) Infra-red photography and mapping of the thermal plume in April and July 1969 by Cornell Aeronautical Laboratory, Inc.
- 3) Three dimensional thermal mapping by the Institute of Marine Science of the University of South Florida (Carter 1970).

The catch from two shallow Group D affected stations was compared with two Group A non-affected (Figure 2). Two intermediate Group D and two Group B stations were similarly combined and compared (Figure 3). Finally, two stations from Group C were merged for analysis but no comparison can be drawn as affected deep stations do not exist (Figure 4). The selection of stations from each group for combination was done on a basis of physical (hydrographic) similarity of stations.

Trawl Station Data

Stations in Group A, B, and C not affected by the heated effluent, served as controls. Close inspection of these data and comparison with Group D stations revealed certain trends.

shallow stations

Group A data indicates that the greatest number of

Table 1. Seasonal abundance of fishes at Group A trawl stations

1969	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Anchoa hepsetus								1				
A. mitchilli			4									
Synodus foetens		2						1	1	1	1	
Sygnathus sp.	2	4	1	1		5	3	2	1		2	
Hippocampus sp.	1		1		1							1
Centropristis striatus						1			1			
Eucinostomus gula								1		1	7	
Haemulon plumeri									1			
Orthopristis chrysopterus					1	4	4	8	6	2	8	40
Bairdiella chrysura			12	8	4	14		16	9	6	28	4
Cynoscion nebulosus				2		1	1					
Leostomus xanthurus			5	19	7	3	12	5				5
Sciaenops ocellata		1										
Calamus arctifrons						1	3	2		1		
Lagodon rhomboides		16	20	21	25	37	4	18	19	2	39	16
Lachnolaimus maximus									1			
Gobiosoma robustum			1	2			9		1			
Prionotus tribulus			1			1						
Paraclinus marmoratus				1			3					
Hypsoblennius ionthas									1	2		
Etropus crossotus							1					
Monacanthus ciliatus		1										
Lactophrys quadrocornis	1									1		
Sphaeroides nephelus									1			
Chilomycterus schoepfi										1	2	1
Opsanus beta						2	34	8	2		1	
Ogcocephalus nasutus			5	6	2	5		1	2	1		4

individuals were present during the spring and fall, those interim months when temperatures were not extreme in either direction (Figure 2). During these favorable periods temperatures ranged from approximately 17-25 C (62.6-77.0 F). Even though the number of individuals decreased during the summer, fishes did not completely vacate the shallows. Summer temperatures ranged from 28.2-29.5 C (83.0-85.1 F) on the surface and 28.1-29.5 C (82.6-85.1 F) on the bottom. However, a pattern of movement away from the shallows in winter seemed evident. The number of individuals present at Group A stations decreased markedly in December and remained low through February. During that time surface and bottom temperatures ranged from 14.3-14.6 C and 14.0-14.8 C. Dahlberg and Odum (1970) found numbers of species and individuals to be generally higher during spring, fall, and summer in Georgia estuarine fish populations, but no sharp winter decrease occurred. However, consideration was not given to numbers of individuals and species on the basis of collection depth. Reid (1954), studying the fishes of Cedar Keys, found the shallows mostly desolate in December, January, and February with the invertebrate fauna also meager, both in number and kind. He also reported great increases in abundance of fishes during spring. In summer, he observed a maximum increase in population density and species in shallow areas, with the approach of fall (September, October, and November) species diversity and

Table 2. Seasonal abundance of fishes at Group D (shallow) trawl stations

1969	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<i>Dasyatis sabina</i>										1		
<i>Anchoa hepsetus</i>						2			1			
<i>A. mitchilli</i>		5		1	2				1	2	1	
<i>Synodus foetens</i>					1	2	1		2			
<i>Parre marinus</i>								1				
<i>Galeichthys felis</i>				1	1	1		1			1	2
<i>Hippocampus</i> sp.	1	1		2								1
<i>Sygnathus</i> sp.	2							1		1	5	1
<i>Centropristis striatus</i>			1			1						
<i>Pomatomus saltatrix</i>				1								
<i>Selene vomer</i>								1				
<i>Eucinostomus argenteus</i>										4	3	12
<i>E. gula</i>									4	3	6	75
<i>Haemulon sciurus</i>				1			1		1			
<i>Orthopristis chrysopterus</i>			1	4	1	5	3	4	22	25	19	19
<i>Bairdiella chrysura</i>		2		22	3	32	4	13	19	72	27	12
<i>Cynoscion nebulosus</i>								1				
<i>Larimus fasciatus</i>											1	
<i>Leostomus xanthurus</i>				1	27	1	59	49	18	16	6	4
<i>Lagodon rhomboides</i>		1		25	13	23	18	24	53	60	14	42
<i>Chaetodipterus faber</i>					1	1				2		
<i>Gobiosoma robustum</i>					4			1				
<i>Prionotus scitulus</i>					2							
<i>P. tribulus</i>		1		1	1							
<i>Hypsoblennius ionthas</i>									1		1	
<i>Ancyloperetta quadrocillata</i>					1							
<i>Etropus crossotus</i>		1		1	1							1
<i>Paralichthys albigutta</i>		1										
<i>Trinectes maculatus</i>												1
<i>Alutera schoepfi</i>									1			

Table 2 (continued). Seasonal abundance of fishes at Group D (shallow) trawl stations

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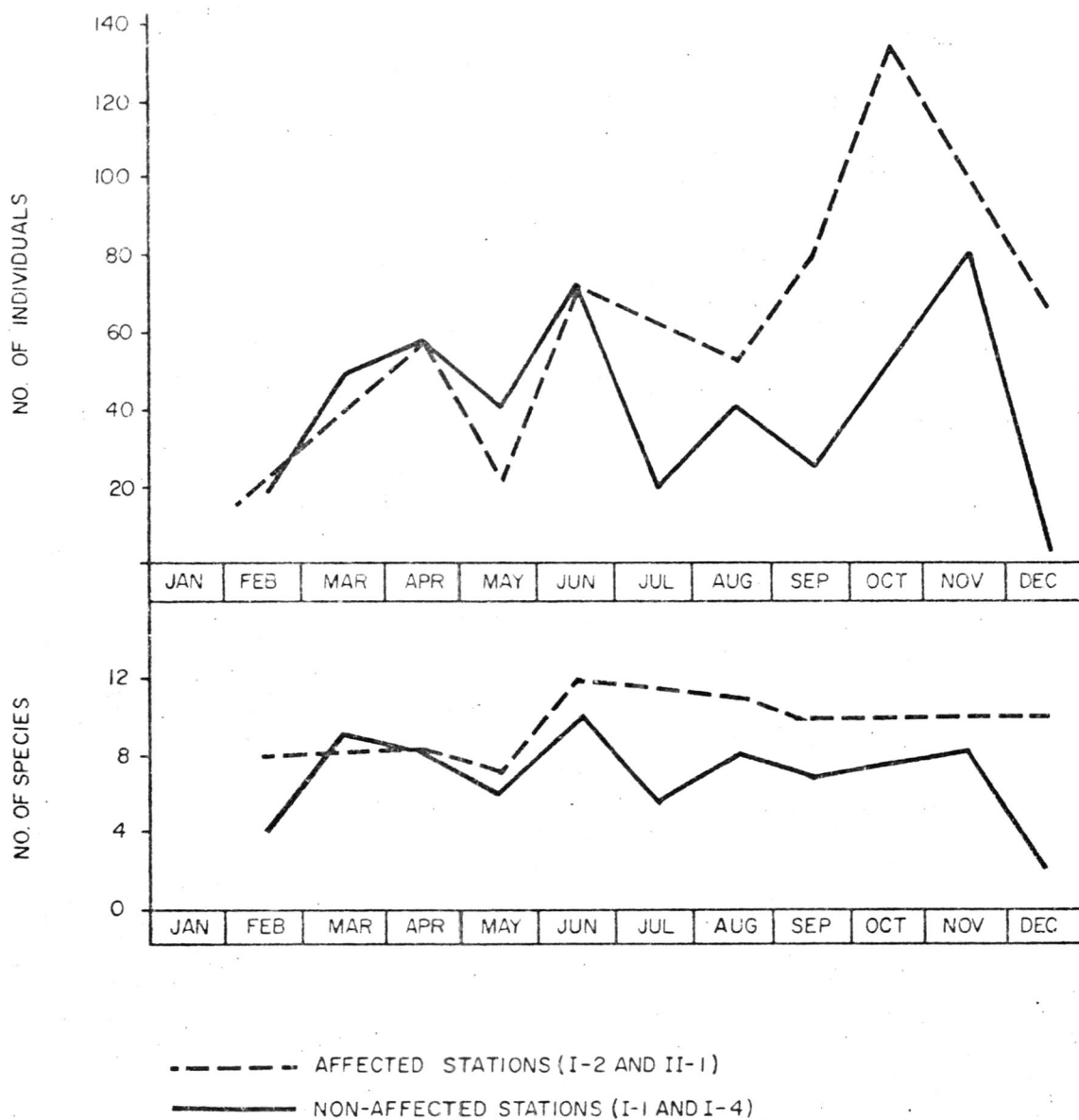


Figure 2. Seasonal abundance of fishes at shallow trawl stations - affected vs. non-affected.

abundance reached a peak.

At Group A stations, relatively uniform numbers of species were present during spring, summer, and fall but were greatly diminished in winter. No significant increase in species abundance occurred in fall when the greatest numbers of individuals were captured (Figure 2).

Group D (shallow) also exhibited the greatest number of individuals in spring and fall; however, significantly more individuals were captured in fall than in spring (Figure 2). These larger numbers were probably due to an increased presence of young of the year fishes. Reid (1954) stated that spring increases in abundance of fishes at Cedar Keys were probably due to winter spawned young. Moreover, fall abundance was greater at Group D (shallow) than Group A stations.

Winter water temperatures at Group D (shallow) stations were 14.3-15.8 C on the surface and 14.3-16.5 C on the bottom, representing temperature increases over Group A stations. Comparison of the number of individuals present in winter and late fall (Figure 2) reveals considerably more fish present at Group D (shallow) stations than at Group A stations. During the coldest part of winter, numbers fell off sharply in both groups. This implies that the thermal effluent provided more suitable conditions at shallow inshore areas during late fall and winter, thus increasing the abundance of fish in these affected areas.

Jones (1964), reporting on thermal effects around steam-electric stations in Great Britain, felt that fish would congregate in heated areas for extended periods during winter.

Summer temperatures at Group D (shallow) stations ranged from 28.1-30.5 C on the surface and 28.2-30.6 C on the bottom. These temperatures were slightly higher than those recorded at Group A stations (28.0-29.5 on the surface and 28.1-29.5 on the bottom). Abundance at these stations was similar during the summer of 1969.

Jones (1964) predicted that fish would completely disappear from thermal discharge areas in summer. Trembley (1960) reported that most fish species were completely absent from thermally polluted areas of the Delaware River in summer. These researchers were dealing with greater summer temperature maxima than those recorded for Crystal River, and were observing more northern fishes acclimated to lower temperatures thus having lower lethal temperatures.

Species abundance at Group D (shallow) stations remained relatively constant during 1969 except for a sharp winter decrease. Species abundance at Group A stations was moderately variable but was consistently exceeded by that of Group D (shallow) stations, probably a thermal effect. Figure 2 shows that more fish species remained inshore in thermally affected areas (Group D - shallow) in late fall and early winter. From September through December 1969, 10

fish species were captured at stations I-1 and I-4 and 21 at stations I-2 and II-1, indicating a richer, more diverse fish population at thermal stations during cooler weather.

intermediate-depth stations

These same contrasts were not so apparent between intermediate-depth trawl stations (Figure 3), but seasonal trends were approximately the same as at inshore stations (Group A). Although catches were larger at intermediate-depth trawl stations, there was no convincing evidence that differential abundance exist between control (Group B) and experimental (Group D) intermediate-depth stations.

Comparison of species abundance at control (Group B) and experimental (Group D) intermediate-depth stations indicates reasonably close agreement between these groups. The fall peak at experimental intermediate-depth (Group D) stations (Figure 3) probably represents natural variation.

Reid (1954) found the greatest population and species densities of fishes at Cedar Keys to be associated with a muddy, sand bottom and thick vegetation on deep flats. These conditions closely resemble those at intermediate-depth trawl stations of our study. The "bay stations" of Springer and Woodburn's (1960) ecological study of the fishes of Tampa Bay most closely correspond to shallow and intermediate-depth stations of our study. They found the greatest concentrations of fish fauna to be associated with

Table 3. Seasonal abundance of fishes at Group B trawl stations

1969	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<i>Dasyatus sabina</i>									1			
<i>Gymnura micrura</i>									1			
<i>Anchoa mitchilli</i>		1			48				4	1		
<i>Synodus foetens</i>					1	1						
<i>Galeichthys felis</i>					1	2	9	3	1			
<i>Urophycis floridanus</i>		1										
<i>Sygnathus</i> sp.								1	1			4
<i>Hippocampus</i> sp.		1	1			1	1					
<i>Centropristis striatus</i>				1	1		3	1				
<i>Diplectrum formosum</i>												1
<i>Mycteroperca bonaci</i>							1	1				
<i>Oligoplites saurus</i>						9						
<i>Selene vomer</i>											1	
<i>Eucinostomus argenteus</i>											1	
<i>Eucinostomus gula</i>									1			
<i>Haemulon plumeri</i>							1					
<i>Haemulon sciurus</i>										1		
<i>Orthopristis chrysopterus</i>			1	17	7	6	15	17	14	10	14	
<i>Bairdiella chrysura</i>			1	8	5	2	2	1	38		1	
<i>Cynoscion arenarius</i>									1			
<i>Leostomus xanthurus</i>			1		9	3	11	3			6	
<i>Menticirrhus americanus</i>								1			7	
<i>Calamus arctifrons</i>			1	4	7	4	16	1	15	4	3	2
<i>Diplodus holbrooki</i>							1		3	1		
<i>Lagodon rhomboides</i>		1	13	30	56	11	52	14	69	41	10	
<i>Chaetodipterus faber</i>			1					1	1	2	5	
<i>Lachnolaimus maximus</i>							1		1	2		
<i>Prionotus scitulus</i>	4	1				1	1				1	
<i>Prionotus tribulus</i>		1										
<i>Ancylopsetta quadrocellata</i>					1							

Table 3 (continued). Seasonal abundance of fishes at Group B trawl stations

[illegible]

Table 4. Seasonal abundance of fishes at Group D(intermediate-depth) trawl stations

1969	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<i>Dasyatis sabina</i>	1			1				1				
<i>Brevoortia patronis</i>					1							
<i>Anchoa hepsetus</i>					1				2			3
<i>Anchoa mitchilli</i>				2	1					11		
<i>Synodus foetens</i>				1				2		2		
<i>Galeichthys felis</i>			1	1	1	1		2	1			
<i>Hippocampus</i> sp.		4		1								
<i>Sygnathus</i> sp.	1						1		2			1
<i>Centropristis striatus</i>				2	1	2	1		1		2	
<i>Mycteroperca bonaci</i>							1					
<i>Selene vomer</i>							1					
<i>Eucinostomus argenteus</i>											1	
<i>Eucinostomus gula</i>											5	8
<i>Haemulon plumeri</i>											3	
<i>Haemulon sciurus</i>									1	4	7	
<i>Orthopristis chrysopterus</i>			1	9	28	16	9	25	25	27	18	22
<i>Bairdiella chrysura</i>			12	20	27	8	12	2	27	90	178	
<i>Cynoscion arenarius</i>				1								
<i>Cynoscion nebulosus</i>			1									
<i>Larimus fasciatus</i>										1		
<i>Leiostomus xanthurus</i>				3	2		1	38	2		3	4
<i>Menticirrhus americanus</i>					3							
<i>Calamus arctifrons</i>				1	3	2		2	2	3	3	
<i>Lagodon rhomboides</i>	1		7	49	41	26	60	77	71	38	27	21
<i>Chaetodipterus faber</i>			2		2	2				7	1	
<i>Lachnolaimus maximus</i>								2	7			
<i>Prionotus scitulus</i>		1										
<i>Prionotus tribulus</i>	1			1	1							
<i>Blennius</i> sp.						1						
<i>Hypsoblennius ionthas</i>		1										

Table 4 (continued). Seasonal abundance of fishes at Group D (intermediate-depth) trawl stations

[illegible]

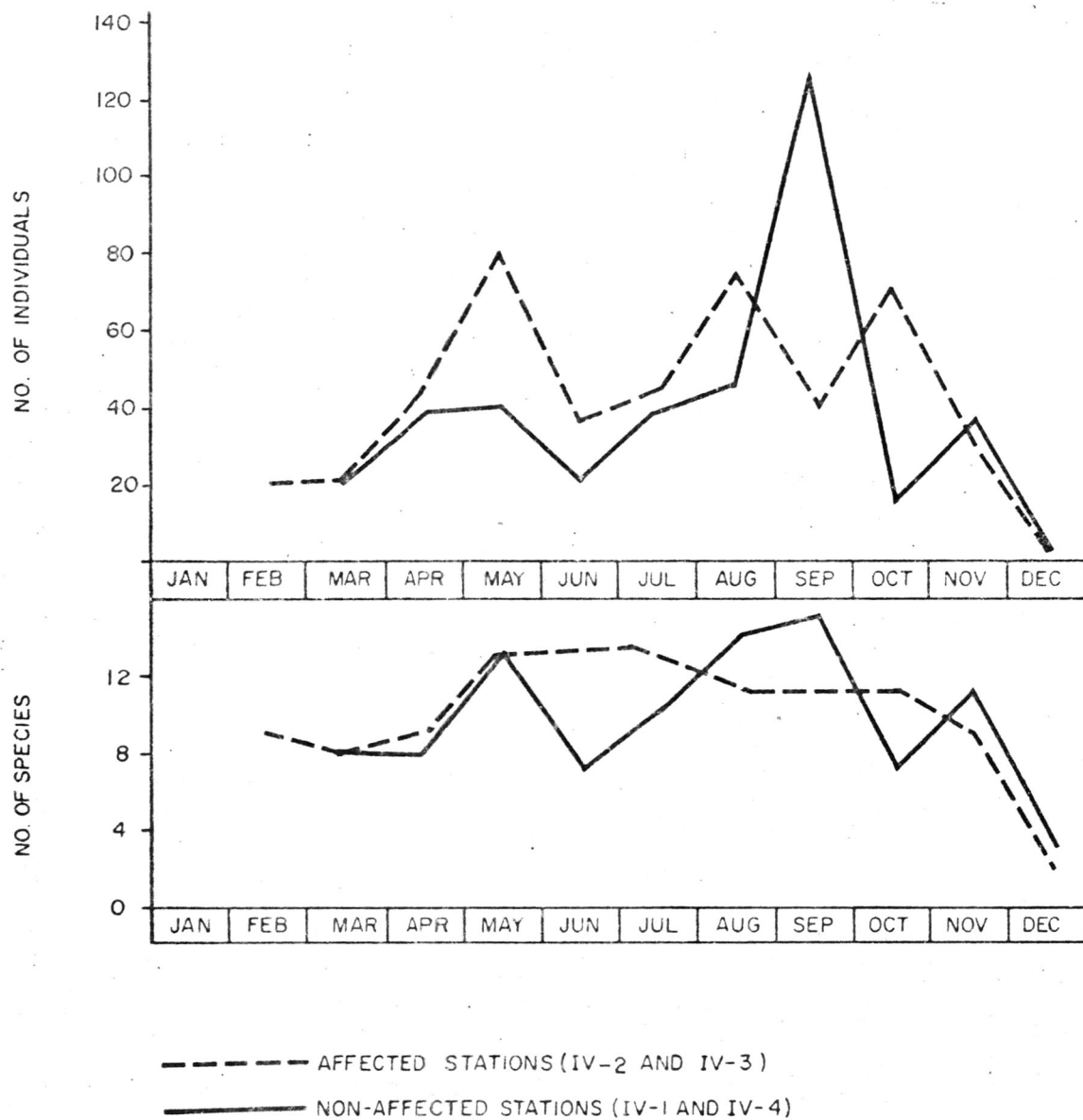


Figure 3. Seasonal abundance of fishes at intermediate depth trawl stations - affected vs. non-affected.

Table 5. Seasonal abundance of fishes at Group C trawl stations

1969	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Anchoa mitchilli							1					
Synodus foetens	1		1	1					1	1		
Galeichthys felis				1	1		15	1	1			
Sygnathus sp.								1				
Hippocampus sp.	3		1		1	4						1
Centropristis striatus						1	2					
Diplectrum formosum						1				2		
Eucinostomus argenteus											2	
E. gula										2	5	1
Haemulon plumeri								1			2	
H. sciurus					1		1			2		
Orthopristis chrysopterus			5	27	10	1	4	3	2	1	9	
Bairdiella chrysura		2	2	3							1	
Leostomus xanthurus					3		2					
Menticirrhus americanus							2					
Calamus arctifrons					7	1		3	3	2	1	
Lagodon rhomboides	2		8	18	4	5	4	1	5		4	
Chaetodipterus faber					6			2		3		
Lachnolaimus maximus								1				
Prionotus scitulus		1	1	3	3	1	1	1			1	
P. tribulus				1	1		1					
Blennius nicholsi				1								
Ancylosetta quadrocellata			1	1	1							
Etropus crossotus	2	1				1						
Symphurus plagiura							1				1	
Alutera schoepfi			1				1	1		1		
Monacanthus ciliatus	1					1	1	1		1		
Stephanolepis hispidus					1				3	2		
Lactophrys quadricornis	5			1	1		1	1	2	5	4	5
Sphaeroides nephelus											1	

Table 5 (continued). Seasonal abundance of fishes at Group C trawl stations

[illegible]

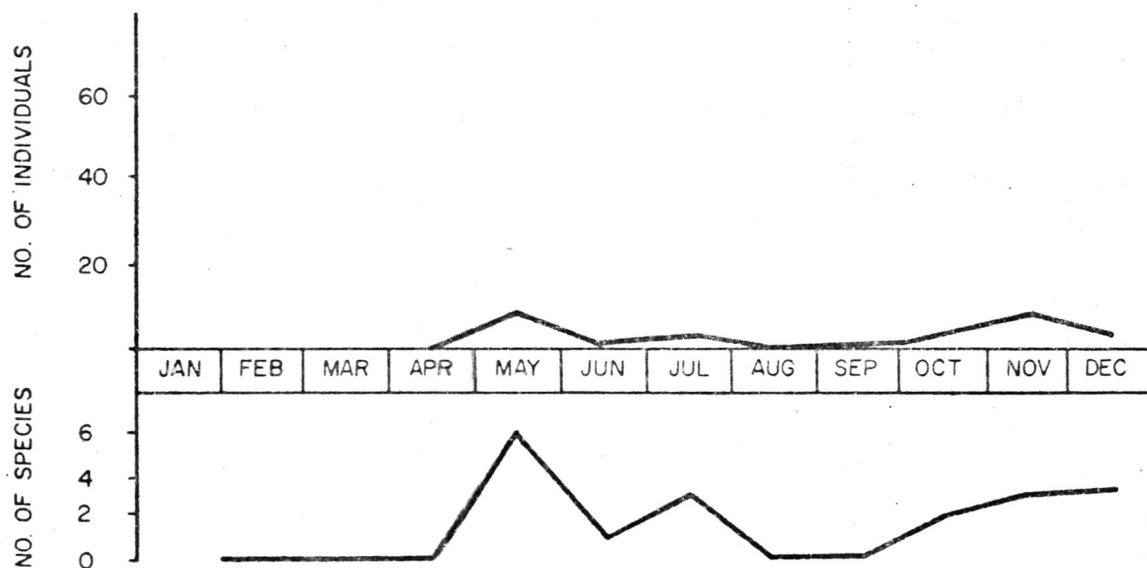


Figure 4. Seasonal abundance of fishes at deep trawl stations
(non-affected).

dense bottom vegetation and moderately high and stable salinities. They reported their fauna was closely allied to that of Reid at Cedar Key (1960).

deep stations

Figure 4 shows the fish catch at deep trawl stations (Group C). None were thermally affected.

Length Frequencies

After establishing that maximally affected trawl stations were located in the shallows, two other techniques of data analysis were employed. In Figures 5-11 standard length frequency and seasonal abundance are plotted for selected species of fish common to thermally affected stations (I-2 and II-1) and non-affected stations (I-1 and I-4).

Standard length frequencies for Bairdiella chrysura (Lacepede), Iagodon rhomboides (Linnaeus), and Orthopristis chrysopterus (Linnaeus) from affected and non-affected stations indicated no differences in spawning time or age composition. The affected and non-affected fishes are assumed to be of two distinct demes, their capture stations being physically separated by the spoil areas of the Cross Florida Barge Canal, and the intake canal (Figure 1). Standard length frequencies for Crystal River fishes are comparable to those presented by Springer and Woodburn (1960) from Tampa Bay and Reid (1954) at Cedar Keys.

Growth

Iles (1963) and Markowski (1965) reported increased growth rates of fish in cooling ponds of power stations. Although this clearly implies beneficial effects, it is a fairly general phenomenon that many marine and estuarine animals attain a larger final size in the colder parts of their distributional area. Kinne (1960), for example, reported high growth rates in Cyprinodon at high temperatures, but these were not maintained, and initially slow growing individuals at low temperatures reached a greater final length and age. Naylor (1965) stated, "In general one might presuppose that heated effluents would lead to increased growth rates and precocious maturity, resulting in a decrease in adult size and perhaps shortening the life cycle of at least some species."

The annual growth increments of first year fish of the three above named species from non-affected and affected areas were compared. The year class was determined from standard length frequency plots. In most instances young of the year individuals were well defined by their modal standard length progressions. Monthly mean standard lengths of these age 0 fishes compare favorably to those of Springer and Woodburn (1960) from Tampa Bay and Reid (1954) at Cedar Keys. For purposes of analysis annual growth was assumed to be linear.

The linear regression for each species (non-affected

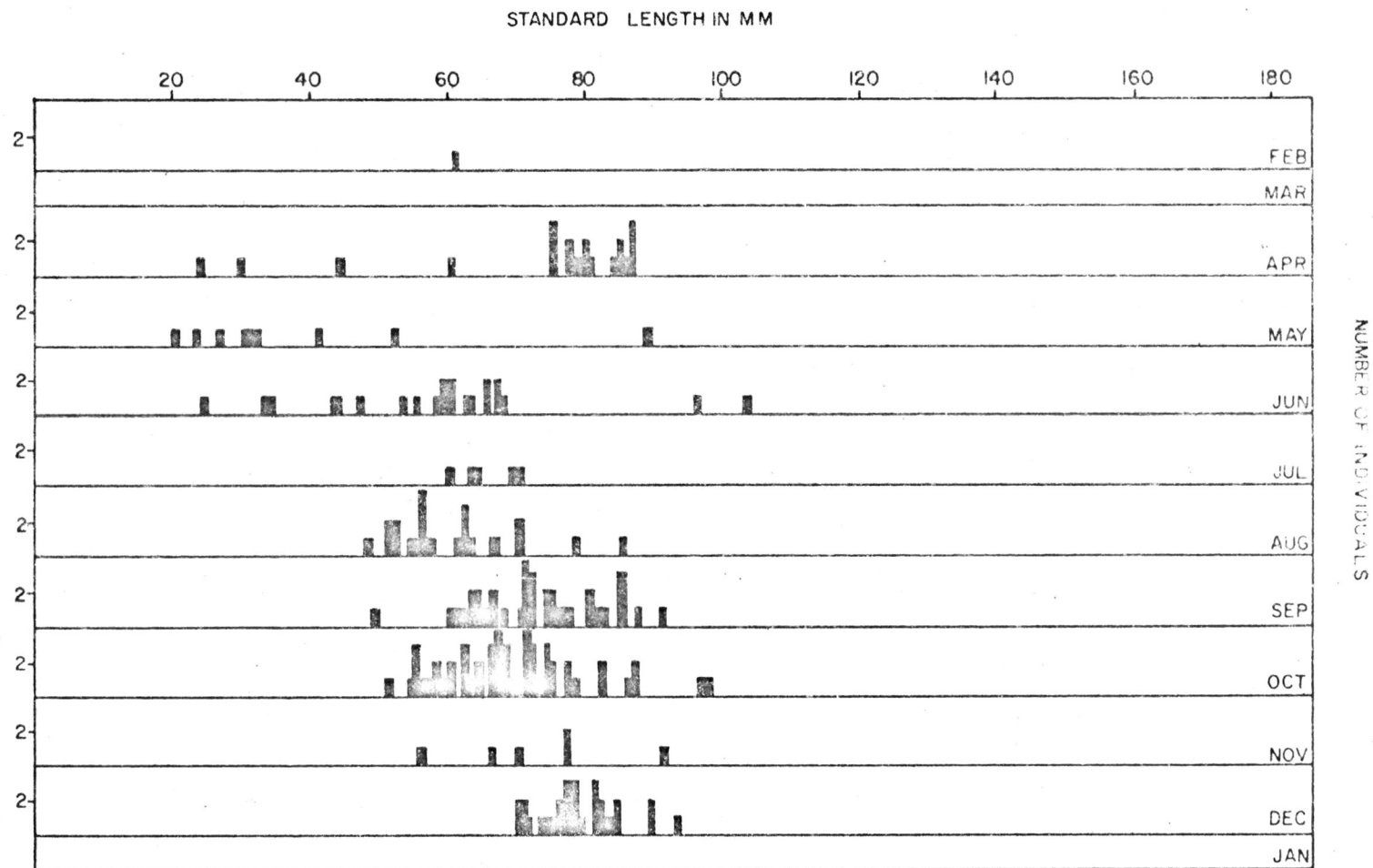


Figure 5. Standard length frequencies for Lagodon rhomboides at shallow thermally affected trawl stations (I-2 and II-1).

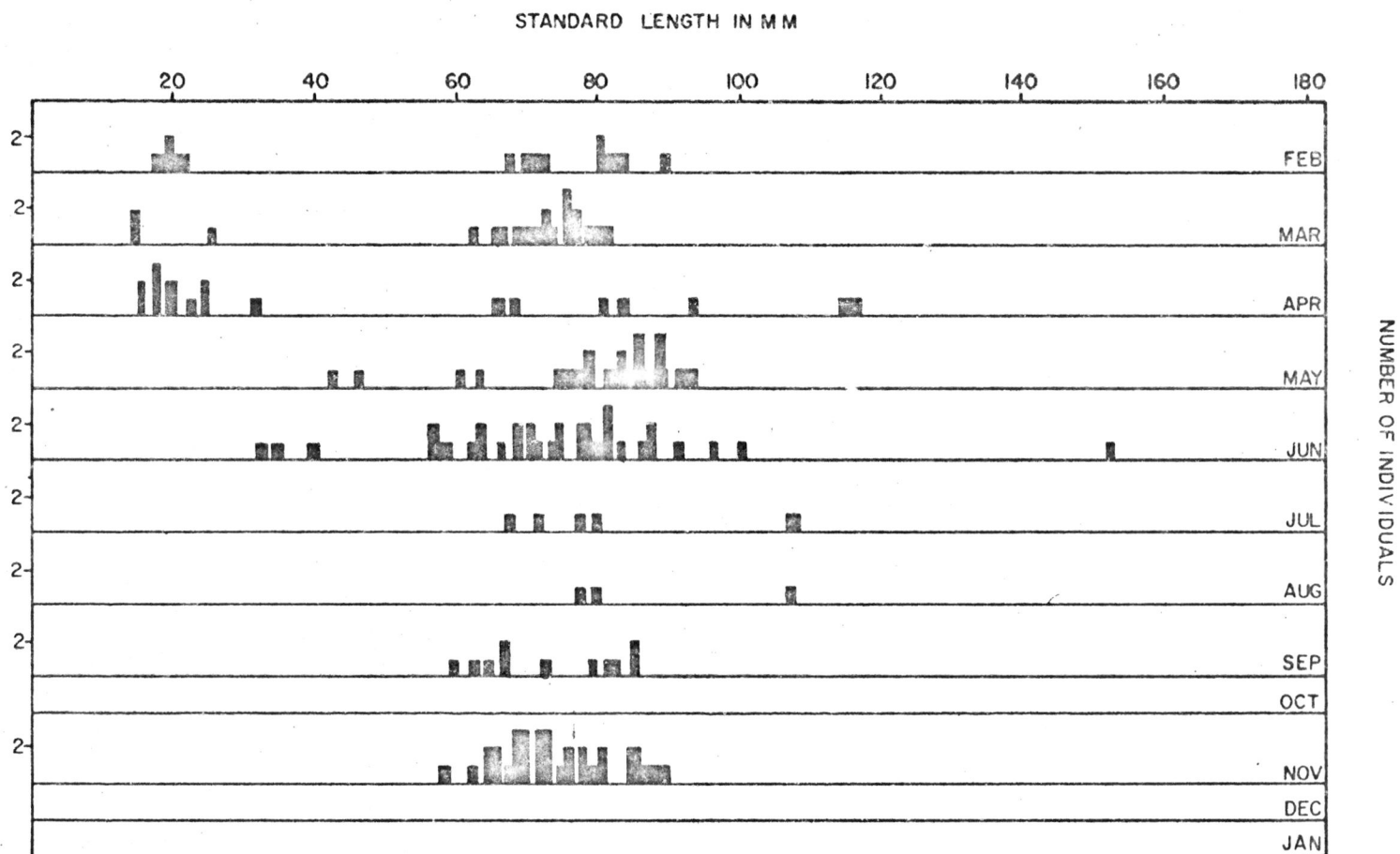


Figure 6. Standard length frequencies for Lagodon rhomboides at shallow non-affected trawl stations (I-1 and I-4).

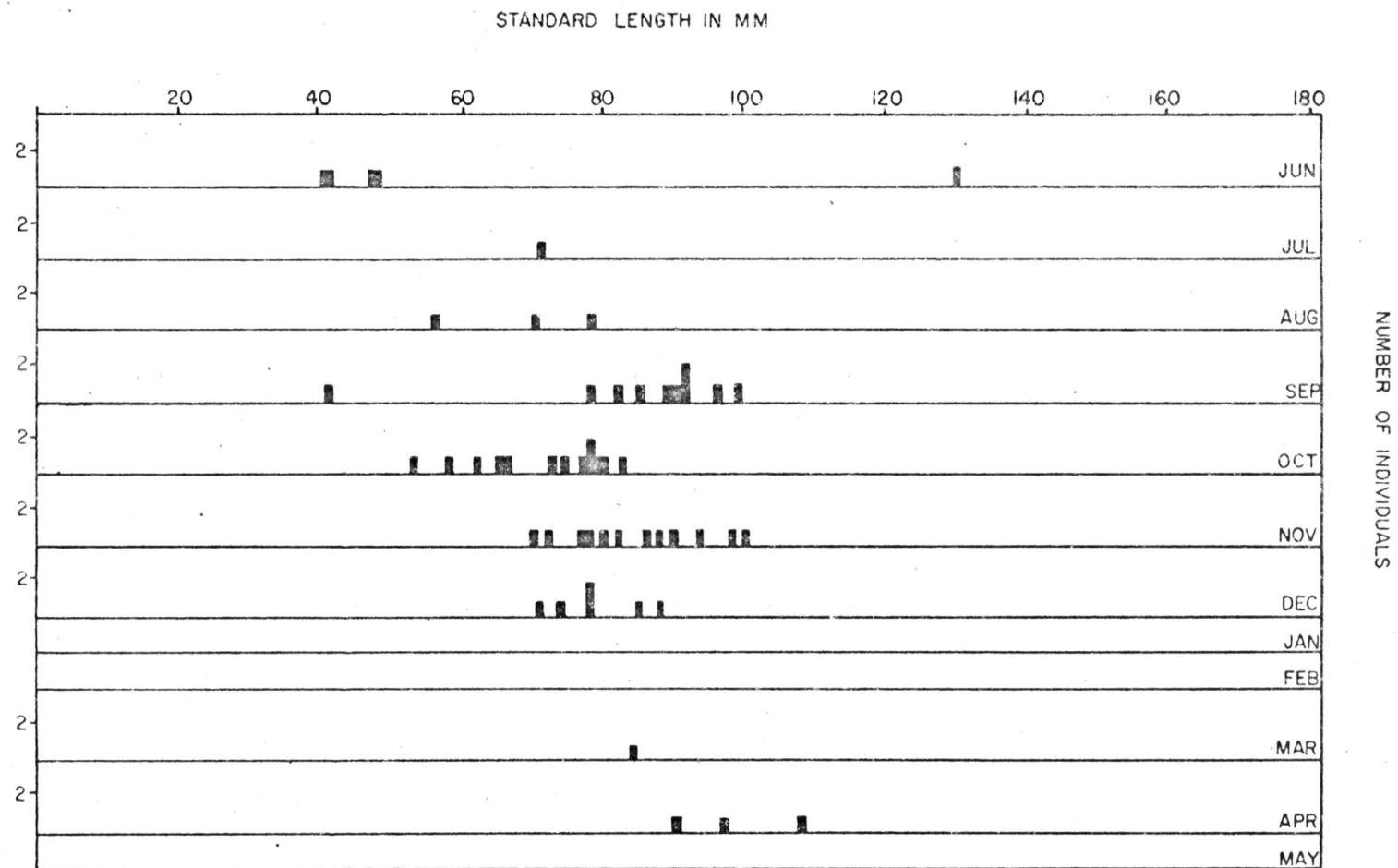


Figure 7. Standard length frequencies for Orthopristis chrysopterus at shallow thermally affected trawl stations (I-2 and II-1).

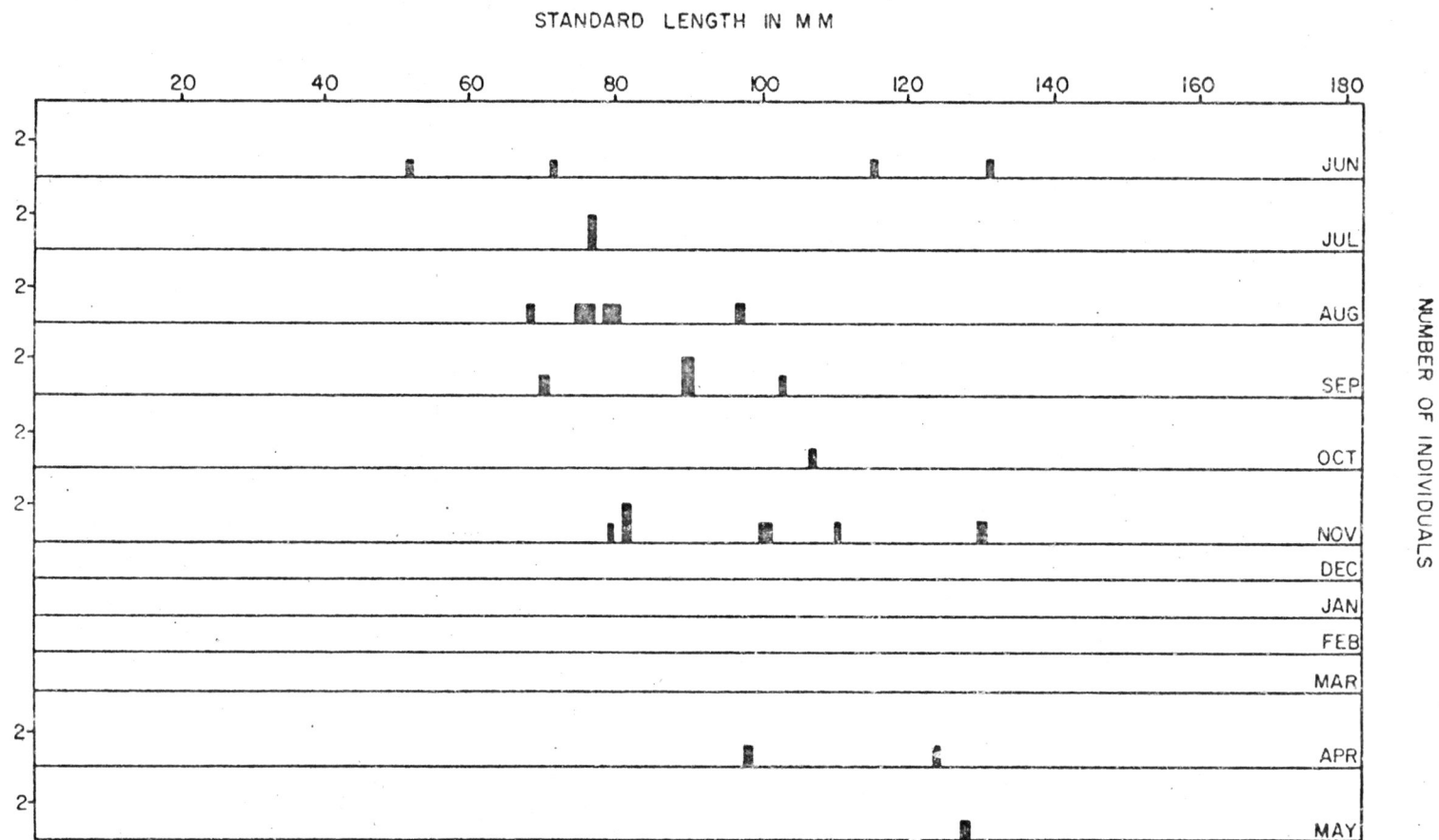


Figure 8. Standard length frequencies for Orthopristis chrysopterus at shallow non-affected trawl stations (I-1 and I-4).

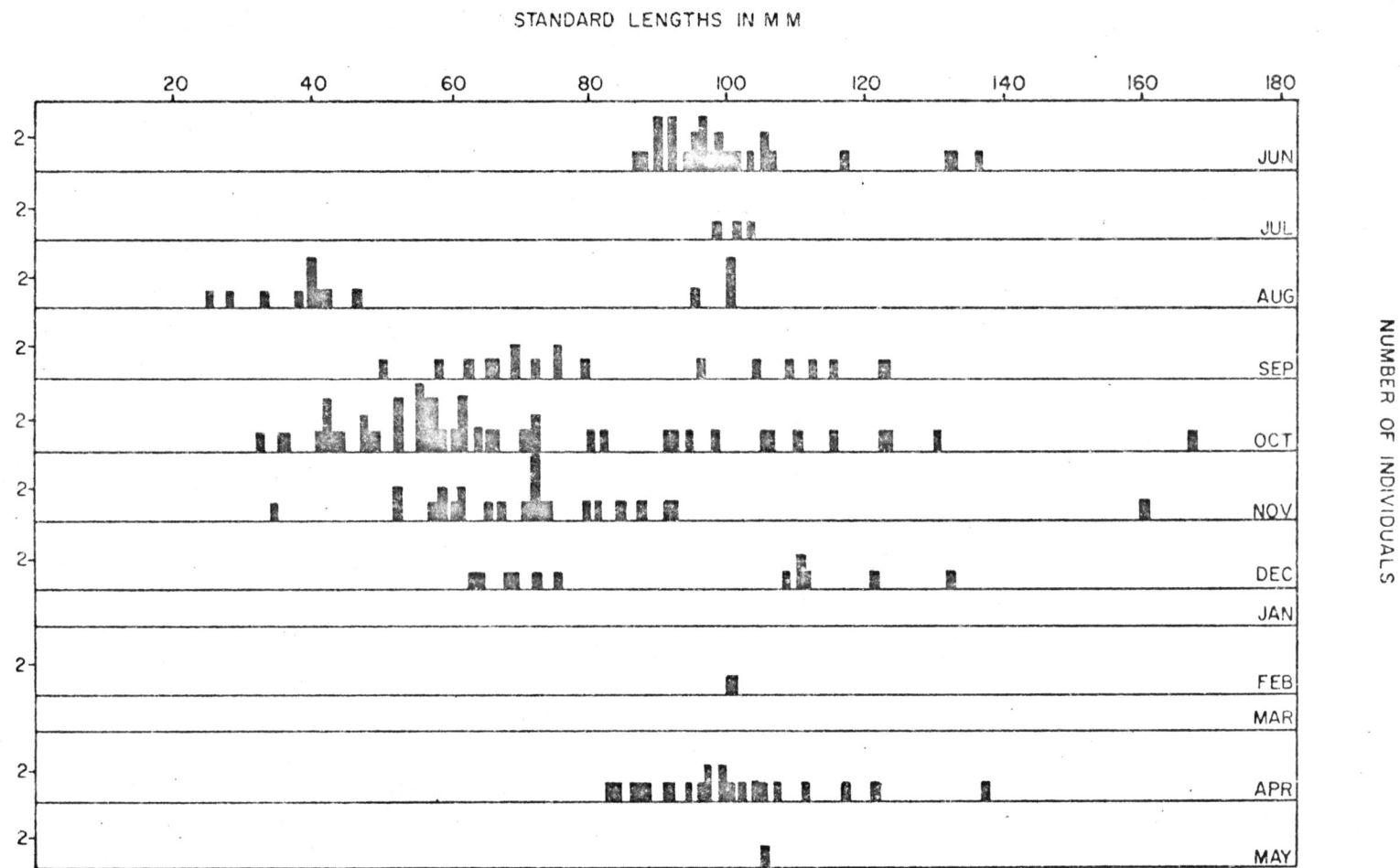


Figure 9. Standard length frequencies for Bairdiella chrysura at shallow thermally affected trawl stations (I-2 and II-1).

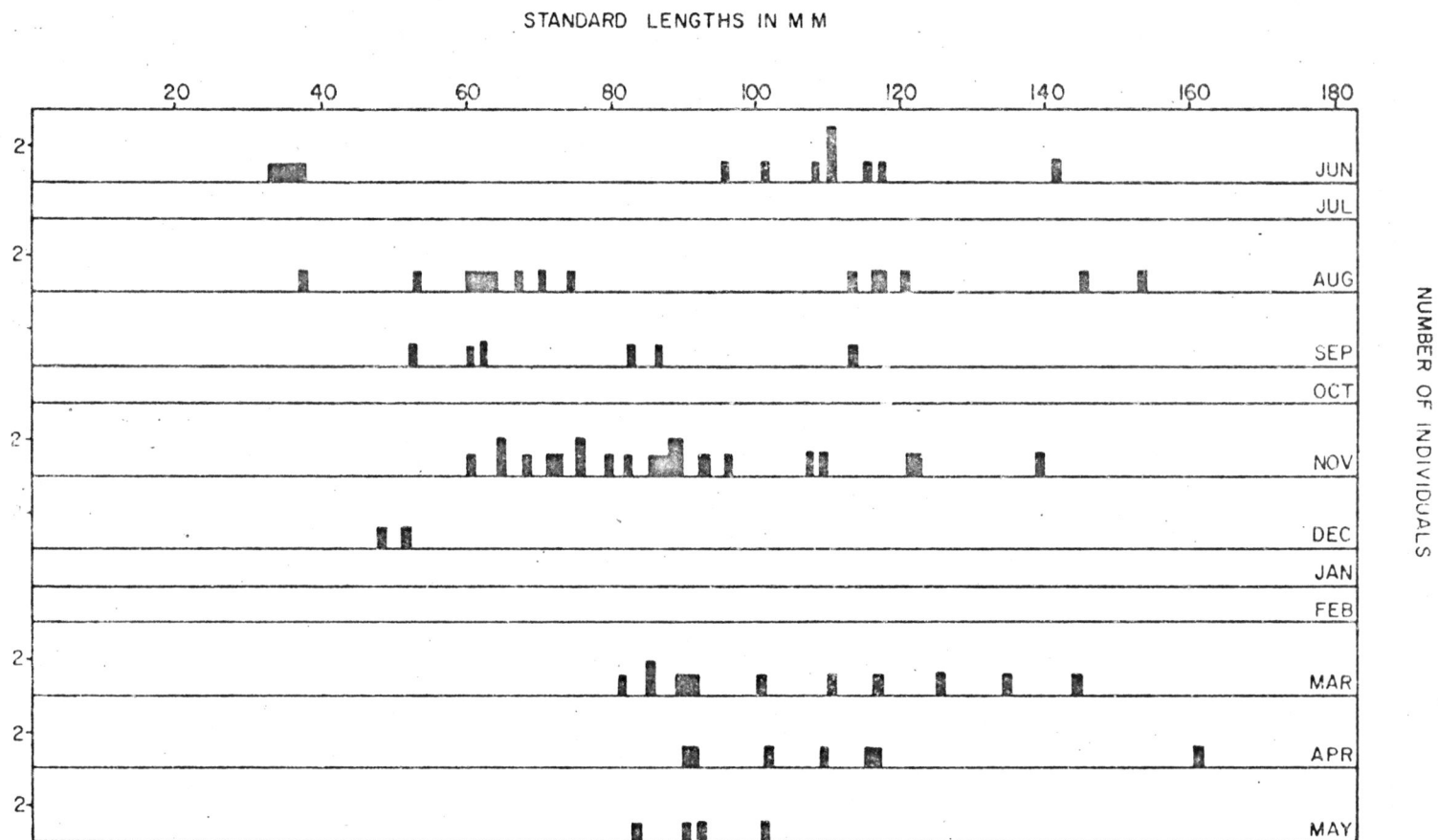
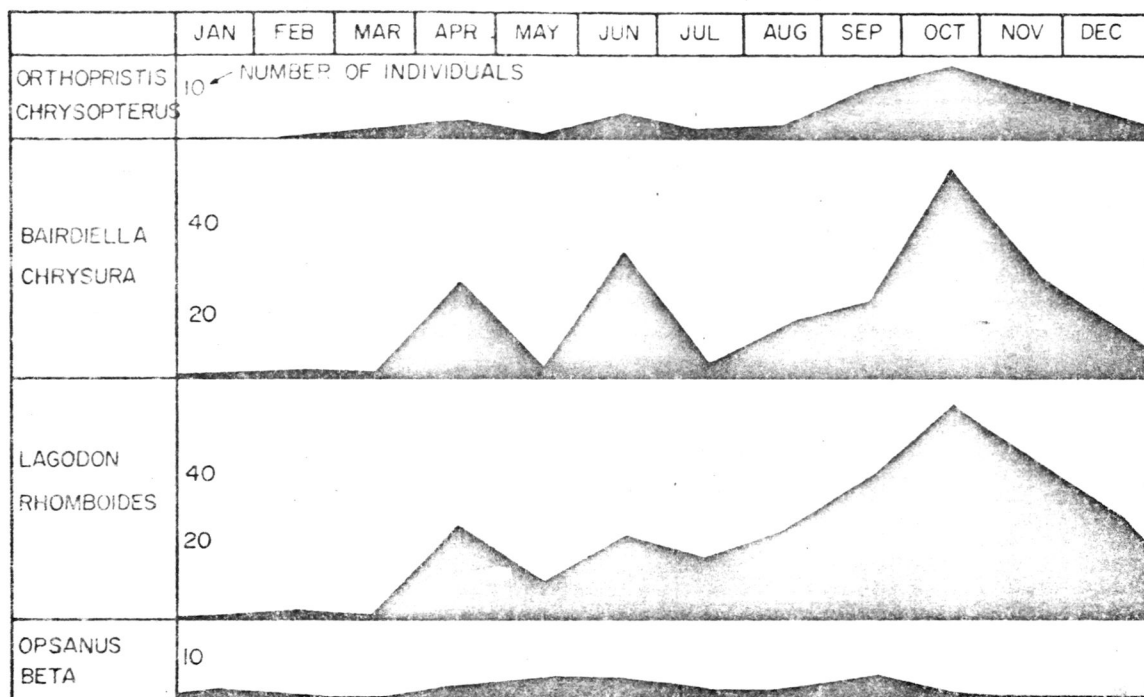


Figure 10. Standard length frequencies for Bairdiella chrysura at shallow non-affected trawl stations (I-1 and I-4).

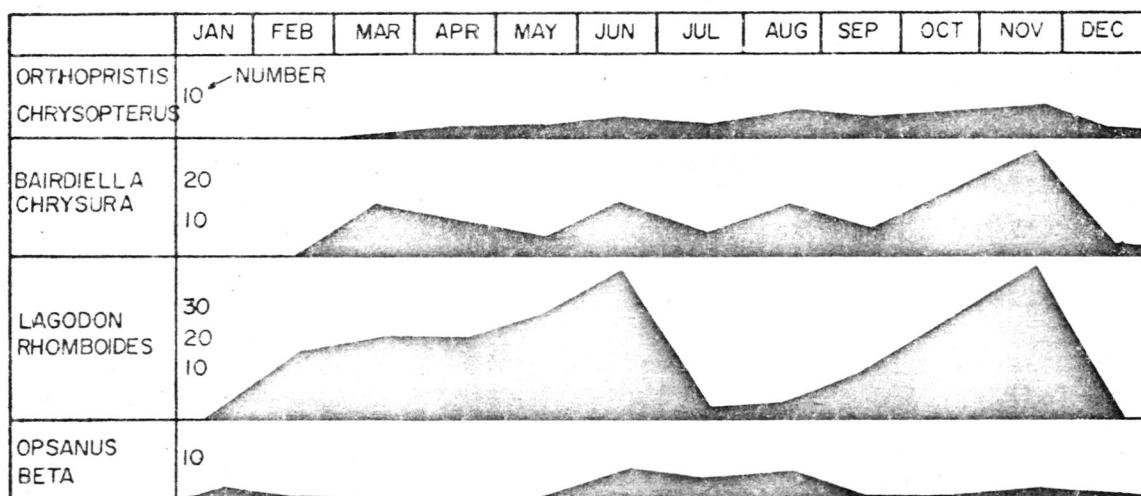
and affected) was calculated by the method of least squares. (B. chrysura: affected $Y=30.3 + 6.2X$, non-affected $Y=41.2 + 5.2X$; L. rhomboides: affected $Y=21.1 + 5.5X$, non-affected $Y=5.4 + 7.3X$; O. chrysopterus: affected $Y=55.9 + 3.6X$, non-affected $Y=57.8 + 5.2X$). A test for significance was applied to the two coefficients of regression of each species (affected vs. non-affected). No significant difference at the .05 level of probability was found within any of the three species (B. chrysura: $t=.0297$, $N=15$; L. rhomboides: $t=.061$, $N=16$; O. chrysopterus: $t=.0297$, $N=17$). Therefore, there was no significant difference in growth increments. It was further determined that the variance for affected and non-affected fishes did not differ significantly at the .05 level.

Seasonal and Relative Abundance

Wurtz and Dolan (1960) reported the elimination of thermally intolerant species below a power station in the Schuylkill River (Pennsylvania) and a compensatory increase in numbers of remaining tolerant species. Alabaster (1963) reported that coarse fish were attracted to heated water of about 26 C, but avoided temperatures above 30 C. Naylor (1965) discussed the danger of elimination of native species (especially) in the vicinity of outfalls in summer and considered the danger of the extension of breeding periods and alternation of abundance of species leading to changes in



A



B

Figure 11. Seasonal abundance of four fishes at shallow trawl stations
 A) affected stations, I-2 and II-1; B) non-affected stations,
 I-1 and I-4.

relative abundance of different species as a result of thermal addition, he pointed out the potential dangers of undesirable replacement fauna.

Figure 11 shows the seasonal abundance of O. chrysotermus, B. chrysura, L. rhomboides, and Opsanus beta (Goode and Bean) from shallow affected and non-affected trawl stations. The first three comprised 9, 31 and 32 per cent of the total 1969 fish sample at shallow affected stations (Group D), and 7, 18 and 44 per cent at non-affected shallow stations (Group A). Since these species comprised such large percentages of the total samples their seasonal abundance reflects the same trends as Figure 2. These fishes numbered 4.89, 18.05 and 45.9 per cent of Reid's (1954) total catch at Cedar Keys.

This data (Figure 11) closely agrees with the seasonal abundance data of Reid (1954) for these fishes at Cedar Keys. His data, however, shows greater abundance during certain periods, no doubt due to capture of large numbers of young of the year fishes in his seine samples. No seining was done at Crystal River in 1969.

Reid (1954) gives combined seasonal abundance from a variety of habitats. Since only shallow stations (affected and non-affected) catch data was used in the analysis, some differences may be expected between the two studies.

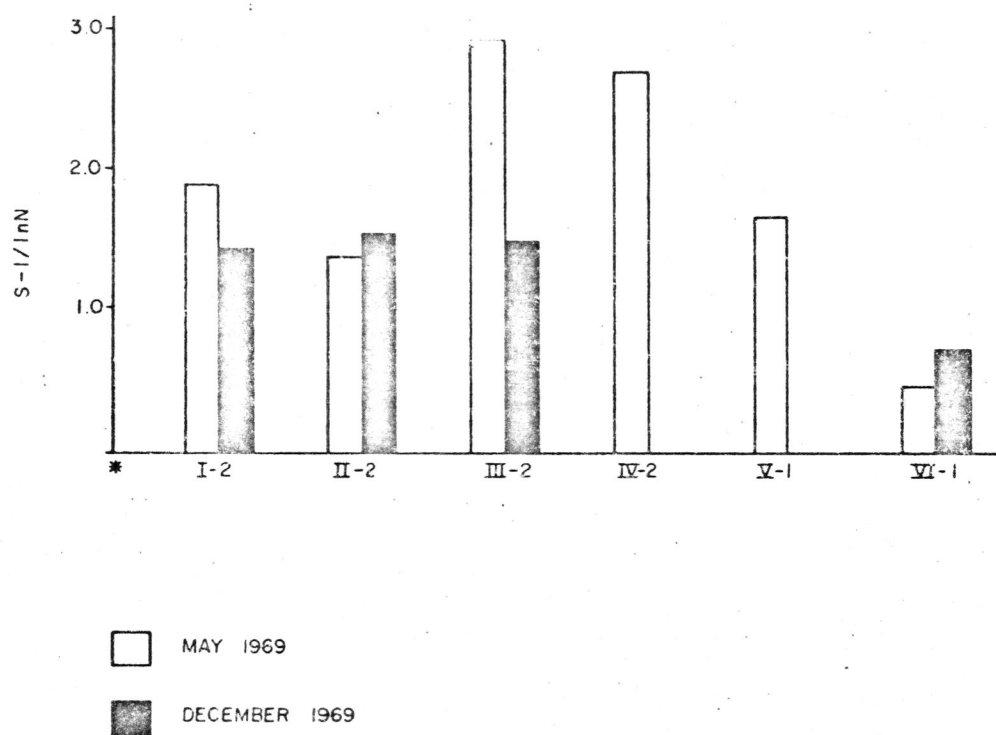
If we assume that Reids' (1954) data accurately reflects the faunal composition of the natural unaltered

population in the Crystal River area and his results are compared with those developed in the present study no evidence appears to indicate substantial changes in the relative abundance of different species in the area around the power plant.

Species Diversity

A diversity index was applied to the May and December 1969 fish catches from trawl stations I-3, II-1, III-2, IV-2, and VI-1. These stations are located on an east-west line beginning at the point of discharge (Figure 12). The diversity index used to derive the histogram shown in Figure 12 was discussed by Jones (1961) and Dahlberg and Odum (1970):

$\frac{(S-1)}{\ln N}$ Where S=number of species taken and $\ln N$ =natural logarithm of the number of individuals in the sample. Examination of the histogram reveals a slight shift in station diversity toward the discharge in winter and away in summer. The seasonal "shifting effect" is not nearly so pronounced as that described by Warinner and Brehmer (1966) in the York River. Their stations, however, were located much closer to the discharge. Figure 12 also indicates the greatest diversity, winter and summer, to have been at intermediate-depth stations in an area of extensive grass flats. These intermediate-depth stations received slight to no thermal influence.



* FROM LEFT TO RIGHT TRAWL STATIONS ARE LOCATED AT INCREASING DISTANCE FROM THE POINT OF DISCHARGE.

Figure 12. Species diversity of fishes at stations opposite discharge canal (S-1/lnN).

Screenwash Data

Figures 13 and 14 illustrate numbers of individuals and species in 1969 screenwash catches. This sample provided a method of determining seasonal occurrences of fishes in the intake canal. As generally indicated by other data, greatest numbers of species and individuals occurred in the spring and fall. The curves are probably exaggerated for cold periods as colder water temperatures cause fishes to be lethargic, therefore, much more susceptible to capture in intake cooling waters. Relative numbers of individuals captured at the screenwash are probably biased towards small or weak swimming fishes. Consequently, disproportionately high numbers of weak swimming, small species, and juveniles were present in the samples. Table 7, for example, reveals exceedingly high numbers of short-nose batfish, Ogcocephalus nasutus (Valenciennes).

Table 6. Seasonal abundance of fishes in screenwash samples

1969	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<i>Dasyatis sabina</i>			3		2							1
<i>Gymnura micrura</i>				1	9							
<i>Elops saurus</i>			1									
<i>Brevoortia patronus</i>		5	1	4					1			1
<i>Opisthonema oglinum</i>									3		2	
<i>Anchoa hepsetus</i>		6	78	15					3			
<i>Anchoa mitchilli</i>			260	2					9			
<i>Synodus foetens</i>									2			
<i>Bagre marinus</i>												9
<i>Galeichthys felis</i>											4	1574
<i>Gymnothorax nigromarginatus</i>		1										2
Ophichthidae		1		8						3		
<i>Strongylura marina</i>			2			5			5			
<i>Hemiramphus saltator</i>		1										3
<i>Hyporhamphus unifasciatus</i>			3									
<i>Hippocampus</i> sp.			7	2			1				1	2
<i>Syngnathus</i> sp.			3									
<i>Centropristis striatus</i>			2								PRES	
<i>Mycteroperca bonaci</i>			1									
<i>Pomatomus saltatrix</i>			1									
<i>Caranax hippos</i>												14
<i>Chloroscombrus chrysurus</i>											2	
<i>Oligoplites saurus</i>									1			
<i>Selene vomer</i>							5		3		9	
<i>Vomer setapinnis</i>											PRES	
<i>Eucinostomus argenteus</i>									11		PRES	22
<i>Eucinostomus gula</i>											1	107
<i>Haemulon plumeri</i>									2			
<i>Haemulon sciurus</i>									2			
<i>Orthopristis chrysopterus</i>		1	2	18			5		4			3

Table 6 (continued). Seasonal abundance of fishes in screenwash samples

1969	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<i>Bairdiella chrysura</i>		9	84	1		1			1	8	107+	377
<i>Cynoscion arenarius</i>									1			
<i>Cynoscion nebulosus</i>				4	17				3	1	1	1
<i>Sciaenops ocellata</i>		1		1								
<i>Archosargus probatocephalus</i>		1	1									
<i>Calamus arctifrons</i>						1					PRES	
<i>Lagodon rhomboides</i>		8	111		2	3			2	2		50
<i>Chaetodipterus faber</i>		3	6								1	6
<i>Scomberomorus maculatus</i>				1								
<i>Prionotus scitulus</i>			1		8							
<i>Prionotus tribulus</i>		14	36	4								
<i>Chasmodes saburrae</i>		1										
<i>Hypsoblennius ionthas</i>		8	19	4		3		1			PRES	
<i>Mugil cephalus</i>			3								PRES	1
<i>Membras martinica</i>		1		1					4			
<i>Menidia</i> sp.			2								3	6
<i>Ancylopsetta quadrocellata</i>		2	43	1								
<i>Etropus crossotus</i>			4									
<i>Etropus rimosus</i>		1										
<i>Paralichthys albigutta</i>				3								
<i>Trinectes maculatus</i>									3			3
<i>Symphurus plagiusa</i>		1		3								
<i>Alutera schoepfi</i>		4	4				2					
<i>Monocanthus</i> sp.			2	3			2	1		1	3	1
<i>Lactophrys quadricornis</i>		5	17					1			PRES	14
<i>Sphaeroides nephelus</i>		4	8	1					1		PRES	4
<i>Chilomycterus atinga</i>											5	
<i>Chilomycterus schoepfi</i>		10	11				5	2				
<i>Opsanus beta</i>		1	1	4						2	11	
<i>Porichthys porosissimus</i>				2								

Table 6 (continued). Seasonal abundance of fishes in screenwash samples

[illegible]

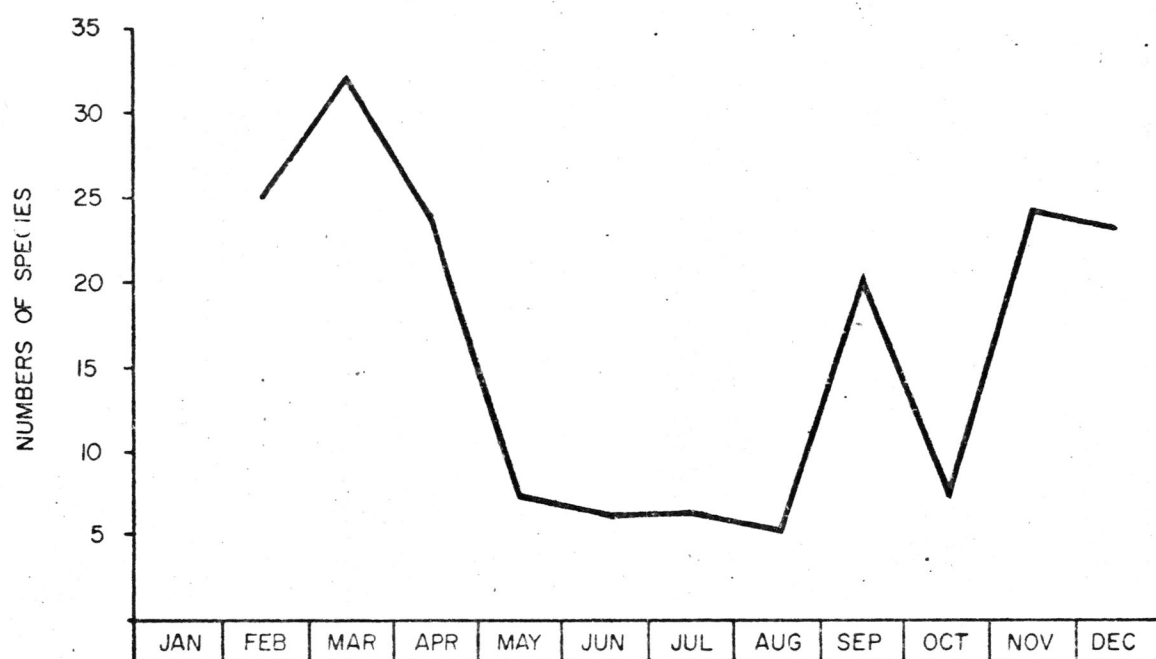


Figure 13. Seasonal species abundance of fishes in screenwash samples.

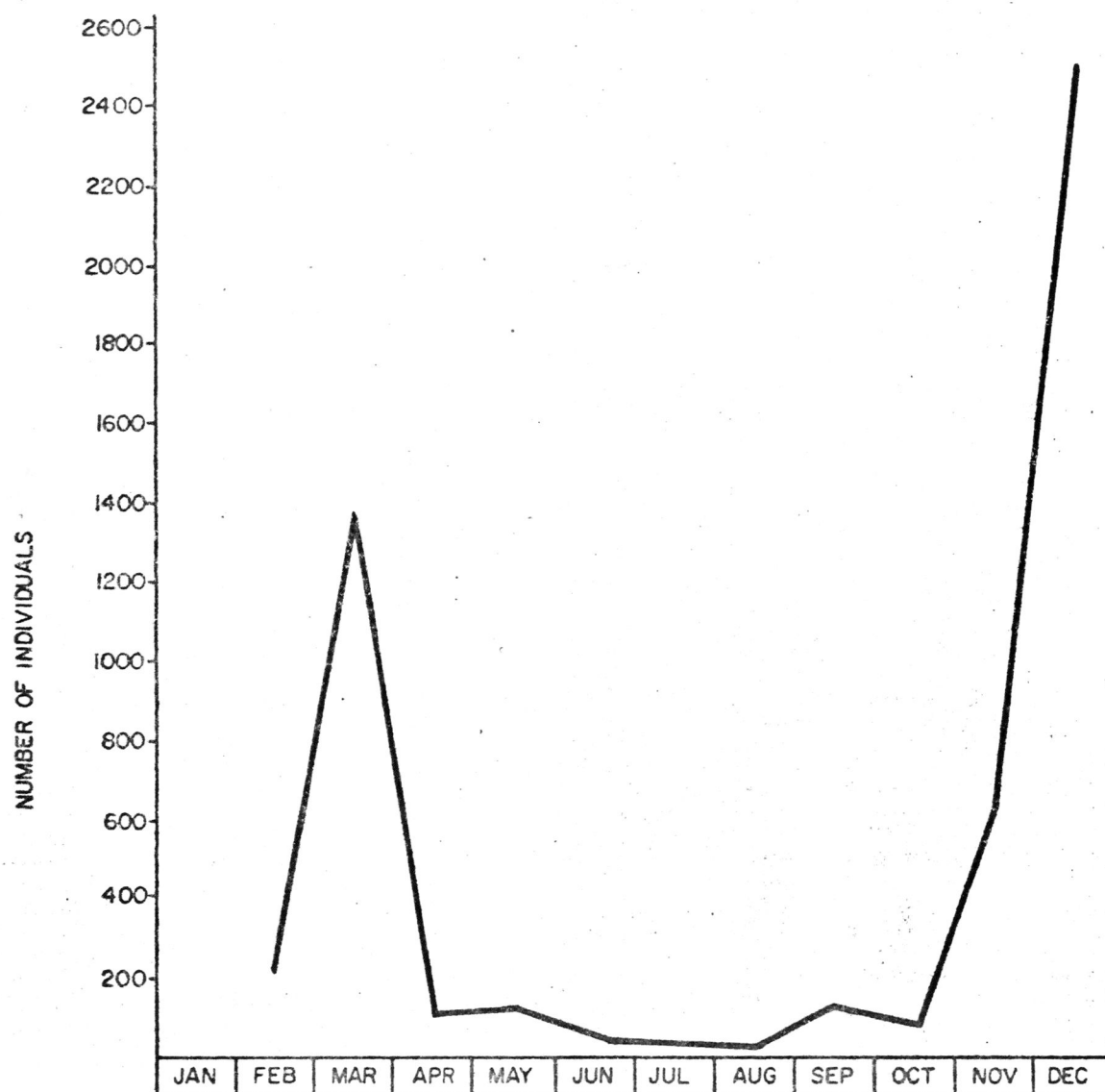


Figure 14. Seasonal abundance of fishes in screenwash samples.

SUMMARY AND CONCLUSIONS

Trawl data from 1969 indicated that the thermal discharge at Crystal River slightly affected the fishes of shallow inshore areas near the discharge.

Comparison of fish data from affected and non-affected areas showed that abundance of individuals was increased in affected areas during the spring, summer and particularly during fall. In winter, numbers of individuals decreased markedly in both affected and non-affected areas, but fishes remained at shallow thermally affected areas longer with the approach of winter.

Species abundance was greater and more constant in thermally affected shallow areas throughout 1969.

Sampling in intermediate-depth areas did not indicate any appreciable thermal effects upon the fishes of that area.

Comparison of standard-length frequency data of fishes from thermally affected and non-affected areas showed no difference in spawning time or age composition between the two demes. Statistical comparison of the annual growth of age 0 fishes of the same species from affected and non-affected areas showed that annual growth increments were not significantly different.

Seasonal abundance plots for selected fish species common to affected and non-affected areas supported the conclusion that seasonal abundance was increased in affected

areas during fall, spring, and summer. The data showed that these fishes remained in shallow areas longer with approaching winter and gave no indication that heated discharge had eliminated native species nor resulted in any change in relative abundance of species present.

Diversity indices indicated a slight shift in species diversity away from the outfall in summer and toward the outfall in winter. In both seasons, however, the greatest species diversity occurred in intermediate-depth areas.

Sampling at the intake screenwash was helpful in establishing the general seasonal occurrence of fishes in the area. However, these catches were not considered a valid reflection of relative abundance.

Data reported here was collected throughout 1969 when a single generating unit was in operation. It is possible that some or all of the benign effects reported herein will be substantially changed as units two and three become operational.

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Appendix I. Location and depth of trawl stations

Station	Latitude	Longitude	Depth		Nautical miles discharge to series
			mean low water ft	meter	
I-1	28 59'24"N	82 45'54"W	1	.305	1.9-due W
I-2	28 57'48"N	82 44'24"W	2	.610	
I-3	28 57'18"N	82 44'06"W	1	.305	
I-4	28 56'30"N	82 43'48"W	3	.914	
II-1	28 57'54"N	82 45'18"W	5	1.524	2.6-due W
II-2	28 57'12"N	82 44'42"W	4	1.219	
II-3	28 56'24"N	82 44'30"W	4	1.219	
III-1	28 58'54"N	82 47'06"W	5	1.524	3.3-due W
III-2	28 58'12"N	82 46'18"W	5	1.524	
III-3	28 56'54"N	82 45'48"W	6	1.829	
III-4	28 56'06"N	82 45'18"W	5	1.524	
IV-1	28 58'30"N	82 48'18"W	6	1.829	4.6-due W
IV-2	28 58'00"N	82 47'48"W	7	2.134	
IV-3	28 56'42"N	82 46'48"W	7	2.134	
IV-4	28 56'06"N	82 46'42"W	8	2.438	
V-1	28 57'54"N	82 49'42"W	12	3.658	6.2-266 WSW
V-2	28 57'00"N	82 49'06"W	11	3.353	
V-3	28 56'24"N	82 48'30"W	10	3.048	
VI-1	28 56'42"N	82 53'12"W	20	6.036	9.1-261 WSW
VI-2	28 55'18"N	82 51'06"W	18	5.486	
VII-1	28 55'42"N	82 55'24"W	30	9.144	12.0-261 WSW

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station I-1

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C		air	salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot		sur	bot			sur	bot	sur	bot
24 Feb	0959-1004	14.5	14.0	----	07.1	21.7	clear WNW 15-18	0100-,1800+	-	-	--	--
26 Mar	1245-1247	19.0	18.5	13.2	02.2	15.4	p cldy WNW 15-25	0230-,1900+	9	8	20	30
15 Apr	1204-1209	23.0	23.0	22.1	25.3	25.8	cldy ESE 08-10	0630-,1230+	8	8	25	25
08 May	0911-0914	24.7	24.7	22.9	17.6	18.7	clear SE ---	0200-,0930+	6	6	35	25
05 Jun	1013-1016	28.2	28.5	28.1	18.7	20.3	p cldy WSW 02-06	0800+,1300-	6	6	30	35
14 Jul	0914-0916	28.8	29.3	28.0	10.4	16.1	cldy NW 02-04	0200-,1500+	9	6	15	15
08 Aug	0933-0935	28.4	29.2	28.0	18.5	26.2	clear NE 04-06	0600-,1100+	6	6	15	15
10 Sep	1036-1038	27.9	27.9	27.5	04.6	12.0	clear W 10-12	0830-,1400+	6	6	20	20
09 Oct	1013-1023	25.5	25.8	25.7	11.7	16.9	p cldy ENE 04-06	0800-,1300+	8	6	25	15
10 Nov	1117-1119	19.9	19.5	20.0	07.8	16.2	clear -- ---	0900-,1400+	7	7	20	15
17 Dec	1031-1034	14.3	14.1	14.5	14.7	17.7	clear NE 06-08	0900+,1500-	7	8	20	25

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station I-2

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature °C			salinity		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
17 Feb	1340-1350	14.3	14.3	09.3	18.3	18.3	clear NW 10-15	1000-,1600+	9	-	40	--
26 Mar	---	19.2	19.4	11.8	19.2	19.8	p cldy WNW 15-25	0230-,1900+	8	8	30	30
18 Apr	1125-1135	25.5	25.5	24.0	25.1	21.8	p cldy S 12-15	0800-,1500+	7	-	35	--
12 May	1411-1416	25.9	25.9	----	19.8	22.0	clear ENE 08	1300+,1900-	7	8	40	30
09 Jun	0919-0924	29.2	30.0	26.5	26.4	28.0	clear NE 00-02	0400-,1100+	6	6	30	30
17 Jul	1439-1444	30.5	30.6	30.0	25.0	25.1	p cldy W 04-06	1000-,1500+	6	6	15	15
07 Aug	1036-1041	30.1	29.0	28.2	27.0	27.5	cldy NE 01-02	1000+,1800-	4	6	15	15
10 Sep	1456-1501	30.3	29.8	27.5	23.6	27.5	clear W 06-08	1400+,2100-	7	6	15	15
10 Oct	1412-1417	26.9	26.8	22.2	26.7	26.7	p cldy NE 04-06	0900-,1500+	6	5	15	15
06 Nov	1345-1350	18.0	18.0	15.5	21.3	21.3	clear W 06-08	1200+,1800-	5	7	20	25
04 Dec	0938-0941	14.7	16.5	11.2	17.4	22.6	clear W 06-08	0530-,1200+	9	8	15	15

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station I-3

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature °C		air	salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot		sur	bot			sur	bot	sur	bot
---	---	----	----	----	----	----	---	----	-	-	--	--
24 Feb	1400-1405	15.0	15.0	----	21.3	21.3	clear WNW 15-18	0100-,1800+	-	-	--	--
---	---	----	----	----	----	----	---	----	-	-	--	--
15 Apr	1258-1301	23.1	23.0	22.1	24.2	25.3	cldy ENE 08-10	1230+,1900-	7	8	25	25
12 May	1307-1310	24.2	24.2	----	21.4	21.4	clear ENE 08	1300+,1900-	7	7	30	25
09 Jun	0952-0955	28.4	28.5	26.5	26.4	26.4	clear NE 00-02	0400-,1100+	5	5	30	25
17 Jul	1522-1525	29.9	30.4	30.0	24.0	24.2	p cldy W 04-06	1500+,2300-	7	6	20	15
07 Aug	1117-1120	28.1	28.2	28.2	27.0	27.2	cldy NE 01-02	1000+,1800-	6	5	15	15
09 Sep	1101-1104	28.2	28.2	29.3	26.9	26.9	cldy WSW 12-15	0700-,1310+	-	-	10	10
10 Oct	1258-1301	26.0	26.3	22.2	26.7	26.7	p cldy NE 04-06	0900-,1500+	6	5	20	10
12 Nov	1509-1512	22.0	21.5	24.0	26.2	25.1	clear WSW 04-06	0900-,1600+	8	8	25	15
08 Dec	1130-1333	15.6	15.3	18.5	21.8	22.9	cldy NNE 06-08	0800-,1400+	8	8	15	15

*wind velocity estimated in knots
a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station I-4

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C		air	salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot		sur	bot			sur	bot	sur	bot
---	---	----	----	----	----	----	---	---	-	-	--	--
05 Feb	1255-1257	----	----	----	21.5	----	clear SW 04-08	1100-,1700+	-	-	--	--
27 Mar	1443-1453	16.9	16.9	----	19.8	19.8	clear NNW 03-06	0400-,1300+	8	9	35	30
11 Apr	1025-1027	24.0	23.9	23.8	20.9	20.9	p cldy WNW 03-04	0400-,1100+	7	7	35	40
06 May	1353-1356	25.0	25.0	23.0	23.1	23.1	clear E 05-07	1100-,1800+	7	7	25	30
03 Jun	1308-1310	29.1	29.0	27.5	25.3	26.4	clear ENE 02-04	1100-,1800+	6	6	40	35
15 Jul	1318-1321	29.5	29.5	27.8	25.1	25.2	cldy SE 01-03	1000-,1600+	7	7	30	25
07 Aug	1159-1202	28.0	28.1	28.2	16.1	22.1	cldy NE 01-02	1000+,1800-	6	6	20	15
08 Sep	1013-1016	27.9	27.8	25.0	30.0	30.0	p cldy NW 08-10	0700-,1230+	6	6	20	20
07 Oct	1103-1106	25.7	25.6	22.8	30.5	29.5	cldy ENE 06-08	0530-,1200+	6	5	20	20
18 Nov	1020-1023	16.8	16.7	21.4	28.0	29.1	clear SSE 08-10	0900+,1500-	7	8	15	15
15 Dec	1147-1150	16.1	14.8	17.0	21.8	21.8	clear WSW 08-10	0630+,1300-	8	8	20	20

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station II-1

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
26 Jan	1040-1045	14.6	----	09.3	22.0	----	clear NE 04-06	0300-,2000+	-	-	--	--
25 Feb	1305-1310	15.2	16.3	----	17.5	20.2	clear W 10-12	0300-,2000+	9	-	45	--
26 Mar	1145-1147	17.5	18.5	13.2	08.8	17.6	p cldy WNW 15-25	2300-,1900+	8	9	20	25
18 Apr	1058-1100	25.0	25.0	24.0	26.2	26.2	p cldy S 12-15	0800-,1500+	6	-	45	--
09 May	0921-0924	26.0	25.8	24.1	24.2	24.2	cldy S 08-10	0330-,1500+	6	6	30	20
09 Jun	1102-1105	29.2	29.2	26.5	26.4	26.9	clear NE 00-02	1100+,1800-	6	6	30	25
17 Jul	1120-1123	28.2	28.7	26.0	21.8	25.0	cldy SE 06-08	1000-,1500+	6	5	20	15
05 Aug	1341-1344	28.7	28.6	30.3	26.2	26.2	p cldy S 08-10	0700+,1500-	5	6	25	25
09 Sep	1501-1504	29.6	29.4	29.3	23.6	24.8	cldy WSW 12-15	1310+,2030-	-	-	25	25
10 Oct	1333-1336	26.7	26.2	22.2	24.0	27.2	p cldy NE 04-06	0900-,1500+	6	6	15	20
10 Nov	1420-1425	20.3	19.9	20.0	22.6	23.0	clear -- -----	1400+,1930-	7	8	25	20
04 Dec	1041-1046	15.5	16.0	11.2	17.4	20.7	clear N 06-08	0530-,1200+	7	7	25	25

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station II-2

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
07 Feb	0940-0950	14.5	14.4	17.1	26.7	27.2	cldy+f --- -----	0530+,1100-	-	-	---	---
26 Mar	1038-1047	18.1	17.7	13.2	18.1	19.8	p cldy WNW 15-25	0230-,1900+	7	8	25	30
16 Apr	1021-1031	23.1	23.0	23.5	24.2	26.4	cldy ESE 06-08	0700-,1200+	7	-	25	---
12 May	1337-1342	25.0	24.8	----	19.8	20.9	clear ENE 08	1300+,1900-	7	7	25	25
09 Jun	1031-1036	29.0	29.5	26.5	26.4	27.5	clear NE 00-02	0400-,1100+	6	6	25	30
17 Jul	0907-0912	28.9	28.9	26.0	25.1	25.2	cldy SE 06-08	0500+,1000-	6	8	10	10
05 Aug	0943-0947	27.6	27.6	30.3	26.7	26.8	p cldy S 08-10	0700+,1500-	-	6	25	20
09 Sep	1016-1021	29.0	28.8	29.3	25.9	25.9	cldy WNW 12-15	0700-,1310+	-	-	10	10
06 Oct	1428-1433	26.9	27.2	30.4	25.1	25.1	p cldy ENE 12-15	1100+,1745-	5	6	15	20
10 Nov	1534-1539	20.0	18.7	20.0	23.9	23.5	clear --- -----	1400+,1930-	8	8	10	15
08 Dec	1423-1428	15.8	15.6	18.5	22.9	24.2	cldy NNE 06-08	1400+,1900-	8	8	15	15

* wind velocity estimated in knots

a + high, - low

f = fog

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station II-3

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS			CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a		D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot				sur	bot	sur	bot
05 Feb	1115-1120	----	----	----	----	----	clear WSW 04-08	1100-,1700+		-	-	--	--
27 Mar	1400-1410	16.6	16.6	----	22.0	22.0	clear NNW 03-06	0400-,1300+		8	6	40	35
11 Apr	1105-1110	23.7	23.8	23.8	23.1	23.1	p cldy WNW 03-04	1100+,1600-		7	7	30	30
06 May	1324-1327	25.0	24.8	23.0	23.1	24.2	clear E 05-07	1110-,1800+		7	7	45	30
03 Jun	1218-1221	28.7	28.6	27.5	26.9	27.5	clear ENE 02-04	1100-,1800+		6	7	35	35
15 Jul	1223-1226	29.3	29.7	27.8	25.0	27.0	cldy SE 01-03	1000-,1600+		5	5	15	35
07 Aug	1252-1255	28.2	28.5	28.2	18.6	23.1	cldy NE 01-02	1000+,1800-		6	5	25	25
08 Sep	1059-1102	28.2	28.2	25.0	31.2	31.2	p cldy NW 08-10	0700-,1230+		6	6	15	15
07 Oct	1210-1213	25.8	25.8	22.8	29.1	29.1	cldy ENE 06-08	1200+,1900-		6	5	20	15
18 Nov	1125-1128	17.0	16.8	21.4	28.0	28.0	clear SSE 08-10	0900+,1500-		7	8	15	15
16 Dec	1126-1129	14.6	14.5	14.0	19.6	22.6	cldy --- -----	0845+,1400-		9	8	20	15

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station III-1

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
24 Feb	1118-1123	14.2	13.6	----	18.6	18.6	clear WNW 15-18	0100-,1800+	-	-	--	--
26 Mar	1340-1350	18.3	18.2	11.8	15.4	16.5	p cldy WNW 15-25	0230-,1900+	9	9	25	25
15 Apr	1106-1116	22.9	22.9	22.1	23.1	23.6	cldy ESE 08-10	0630-,1230+	7	7	35	35
08 May	0952-0957	24.8	24.7	22.9	23.1	23.1	clear SE -----	0930+,1500-	7	7	30	25
05 Jun	1122-1127	28.9	28.9	28.1	17.6	23.1	p cldy WSW 02-06	0800+,1300-	6	6	40	35
14 Jul	0958-1003	29.6	29.8	28.0	12.5	18.4	cldy NW 02-04	0200-,1500+	6	7	15	15
08 Aug	1008-1013	28.9	29.0	28.0	22.8	27.0	clear NE 04-06	0600-,1100+	6	6	15	20
10 Sep	1131-1136	29.0	28.2	27.5	13.6	20.2	clear W 06-08	0830-,1400+	6	6	10	15
09 Oct	1048-1053	26.0	25.9	25.7	20.2	24.0	p cldy ENE 04-06	0800-,1300+	6	6	20	15
10 Nov	1213-1218	20.5	18.8	20.0	22.6	23.0	clear --- -----	0900-,1400+	7	6	25	20
17 Dec	1149-1154	14.6	14.2	14.5	18.5	25.1	clear NE 06-08	0900+,1500-	7	7	15	20

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station III-2

DATE		TIME		PHYSICAL DATA						GENERAL FIELD OBSERVATIONS				CHEMICAL DATA				
				temperature C			salinity o/oo							D. O. (ppm)		CO ₂ (ppm)		
				sur	bot	air	sur	bot	weather*				tide ^a		sur	bot	sur	bot
26 Jan	1100-1105	14.0	14.4	09.3	20.9	23.6	clear	NE	04-06	0300-,2000+				-	-	--	--	
25 Feb	1445-1450	14.8	14.8	14.0	19.7	23.0	clear	W	10-12	0300-,2000+				-	-	--	--	
28 Mar	0917-0927	15.6	16.1	13.4	08.2	15.9	---	---	-----	0500-,1230+				8	8	25	30	
18 Apr	1009-1014	24.8	24.8	24.0	27.3	27.3	p cldy	S	12-15	0800-,1500+				-	-	--	--	
09 May	0845-0848	25.5	25.5	24.1	24.7	25.3	cldy,r	S	08-10	0330-,1500+				6	6	30	30	
06 Jun	0754-0757	27.9	27.9	21.7	24.2	25.3	cldy	ENE	04-06	0800+,1400-				6	6	20	25	
17 Jul	1040-1043	28.1	28.5	26.0	20.8	25.0	cldy	SE	06-08	1000-,1500+				5	5	15	15	
05 Aug	1308-1311	28.8	28.2	30.3	25.1	26.6	p cldy	S	08-10	0700+,1500-				5	6	25	20	
09 Sep	1417-1420	29.1	28.8	29.3	25.3	24.8	cldy	WSW	12-15	1310+,2030-				-	-	10	10	
10 Oct	1143-1146	26.0	26.3	22.2	21.9	25.1	p cldy	NE	04-06	0900+,1500-				5	6	20	15	
26 Nov	1204-1209	17.1	16.9	20.0	21.8	22.1	clear	NE	10-12	1030-,1600+				8	8	15	15	
16 Dec	1524-1529	16.4	15.4	18.5	21.3	21.3	cldy	---	-----	1400-,2000+				10	10	20	20	

* wind velocity estimated in knots

a + high, - low

r = rain

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station III-3

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
07 Feb	1015-1020	16.2	15.8	----	24.8	25.3	cldy, f ---	0530+, 1100-	-	-	--	--
27 Mar	1011-1021	15.8	15.8	----	12.1	12.6	clear NNE 03-06	0400-, 1300+	8	8	25	25
16 Apr	1113-1123	23.1	23.1	23.5	26.4	26.4	cldy ESE 06-08	0700-, 1200+	7	7	30	35
06 May	0956-1006	23.7	23.7	23.0	22.0	22.5	clear E 05-07	0645+, 1110-	7	7	35	35
06 Jun	1039-1049	28.9	28.7	21.7	26.9	27.5	cldy ENE 04-06	0800+, 1400-	6	6	30	30
17 Jul	0950-0955	28.6	28.3	26.0	25.2	25.1	cldy SE 06-08	0500+, 1000-	5	5	15	10
05 Aug	1022-1027	27.9	27.8	30.3	27.9	27.8	p cldy S 08-10	0700+, 1500-	5	6	25	25
09 Sep	1327-1332	29.0	28.8	29.3	25.2	26.3	cldy WSW 12-15	1310+, 2030-	-	-	15	15
10 Oct	1059-1104	25.8	25.8	22.2	27.2	27.0	p cldy NE 04-06	0900-, 1500+	6	5	25	20
12 Nov	1305-1315	22.0	21.5	24.0	27.2	27.2	clear WSW 04-06	0900-, 1600+	7	7	25	25
08 Dec	1532-1537	15.5	15.3	18.5	22.9	24.8	cldy NNE 06-08	1400+, 1900-	8	8	15	15

* wind velocity estimated in knots

a + high, - low

f = fog

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station III-4

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
05 Feb	1130-1135	----	----	----	----	----	clear SW 04-08	1100-,1700+	-	-	--	--
27 Mar	1314-1324	17.4	17.0	----	22.0	23.1	clear NNW 03-06	0400-,1300+	8	8	30	35
11 Apr	1155-1205	23.5	23.4	23.8	24.7	24.7	p cldy WNW 03-04	1100+,1600-	7	7	35	35
06 May	1245-1255	24.8	24.5	23.0	25.3	25.3	clear E 05-07	1110-,1800+	7	7	35	25
03 Jun	1058-1108	28.2	28.2	27.5	28.0	28.6	clear ENE 02-04	0600+,1100-	6	6	30	30
15 Jul	1100-1110	29.6	29.7	27.8	25.0	28.4	cldy SE 01-03	1000-,1600+	6	6	05	15
07 Aug	1327-1332	28.8	28.7	28.2	22.9	27.2	cldy NE 01-02	1000+,1800-	6	6	15	20
08 Sep	1234-1239	28.7	28.6	25.0	30.5	31.1	p cldy NW 08-10	1230+,2000-	6	5	05	05
07 Oct	1014-1019	25.5	25.4	22.8	29.3	29.3	cldy ENE 06-08	0530-,1200+	5	5	25	15
18 Nov	1218-1223	17.1	17.1	21.4	31.2	31.2	clear SSE 08-10	0900+,1500-	6	7	15	20
15 Dec	1503-1508	15.1	14.8	17.0	24.0	19.6	clear --- -----	1300-,1900+	6	7	20	15

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station IV-1

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
26 Jan	1205-1220	14.3	14.4	09.3	21.4	26.9	clear NE 04-06	0300-,2000+	-	-	--	--
24 Feb	1242-1247	13.8	13.6	----	23.0	28.4	clear WNW 15-18	0100-,1800+	-	-	--	--
29 Mar	0814-0824	16.5	16.5	17.7	15.9	22.0	-----	0530-,1300+	8	8	40	35
15 Apr	1031-1036	22.9	22.9	22.1	26.9	27.5	cldy ESE 08-10	0630-,1230+	7	7	25	30
08 May	1038-1048	25.0	24.9	22.9	27.5	28.6	clear SW -----	0930+,1500-	7	7	35	25
05 Jun	1221-1231	29.8	29.0	28.1	23.1	27.5	p cldy WSW 02-06	0800+,1300-	6	6	40	35
14 Jul	1037-1047	30.7	30.2	28.0	25.9	25.6	cldy NW 02-04	0200-,1500+	6	5	30	25
08 Aug	1044-1049	28.9	29.1	28.0	28.3	30.5	clear NE 04-06	0600-,1100+	5	6	15	20
10 Sep	1255-1305	29.1	28.7	27.5	28.5	28.8	clear W 06-08	0830-,1400+	7	6	05	15
09 Oct	1125-1135	26.0	25.9	25.7	25.1	38.5	p cldy ENE 04-06	0800-,1300+	5	6	20	20
13 Nov	1316-1321	20.3	20.2	20.5	26.2	25.6	clear W 04-06	1000-,1600+	8	8	20	15
17 Dec	1307-1312	14.9	14.4	14.5	19.9	22.9	clear NE 06-08	0900+,1500-	8	8	15	15

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station IV-2

DATE	TIME	PHYSICAL DATA						GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo			weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot				sur	bot	sur	bot
20 Feb	1420-1425	13.4	12.3	14.4	23.5	28.0	p cldy W	12-15	1030-,1700+	-	-	--	--
28 Mar	1014-1019	16.0	16.5	13.4	16.5	22.0	-----	----	0500-,1230+	8	8	25	30
16 Apr	1323-1333	24.0	23.7	23.5	27.5	28.6	cldy	ESE 06-08	1200+,1900-	7	8	30	35
08 May	1120-1130	25.0	24.9	22.9	28.6	28.6	clear	SE -----	0930+,1500-	7	7	40	30
06 Jun	0832-0842	28.0	28.0	21.7	24.2	25.3	cldy	ENE 04-06	0800+,1400-	6	6	30	25
16 Jul	1235-1240	28.9	28.9	27.3	26.7	27.9	cldy	SSE 04-06	1000-,1500+	6	5	10	15
05 Aug	1231-1236	28.2	28.1	30.3	29.3	29.3	p cldy S	03-10	0700+,1500-	6	7	15	10
10 Sep	1337-1342	29.2	28.7	27.5	27.2	27.2	clear	W 06-08	0830-,1400+	6	6	15	10
09 Oct	1222-1232	26.3	25.5	25.7	28.9	29.7	p cldy	ENE 04-06	0800-,1300+	6	5	15	15
13 Nov	1137-1142	20.8	20.0	20.5	25.2	27.2	clear	W 04-06	1000-,1600+	8	8	25	25
16 Dec	1423-1428	16.2	14.5	18.5	25.1	16.3	cldy	--- -----	1400-,2000+	9	8	15	20

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station IV-3

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
25 Feb	-----	14.8	14.5	14.0	23.0	24.0	clear W 10-12	0300-,2000+	-	-	--	--
27 Mar	1103-1113	16.0	16.3	----	14.3	17.6	clear NNW 03-06	0400-,1300+	8	8	30	30
16 Apr	1235-1245	23.7	23.5	23.5	28.0	28.6	cldy ESE 06-08	1200+,1900-	7	8	30	20
06 May	1056-1106	24.0	24.0	23.0	23.1	25.3	clear E 05-07	0645+,1110-	7	7	35	25
06 Jun	0957-1007	28.5	28.3	21.7	27.5	30.2	cldy ENE 04-06	0800+,1400-	6	6	25	30
16 Jul	1129-1139	29.1	29.0	27.3	27.8	28.1	cldy SSE 04-06	1000-,1500+	6	7	20	15
05 Aug	1131-1136	28.0	28.0	30.3	28.6	28.4	p cldy S 08-10	0700+,1500-	5	6	20	25
10 Sep	1410-1415	29.7	28.7	27.5	27.0	27.7	clear W 06-08	1400+,2100-	5	5	20	15
10 Oct	1002-1012	25.6	25.8	22.2	27.3	28.3	p cldy NE 04-06	0900-,1500+	6	5	20	25
13 Nov	1043-1048	20.3	20.0	20.5	26.0	28.9	clear W 04-06	1000-,1600+	7	8	15	20
16 Dec	1326-1331	17.0	14.5	14.0	19.3	23.4	cldy --- -----	0845+,1400-	10	9	20	15

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station IV-4

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
25 Jan	-----	----	----	----	----	----	-----	---	---	---	---	---
27 Mar	1151-1201	17.0	16.9	----	19.8	22.0	clear NNW 03-06	0400-,1300+	8	8	35	30
11 Apr	1316-1326	24.0	23.5	23.8	27.5	27.5	p cldy WNW 03-04	1100+,1600-	8	8	35	35
06 May	1135-1145	24.1	24.1	23.0	27.5	27.5	clear E 05-07	1110-,1800+	7	8	25	25
03 Jun	1004-1009	28.0	28.0	27.5	30.2	30.2	clear ENE 02-04	0600+,1100-	6	6	35	35
15 Jul	1016-1021	30.0	29.8	27.8	28.5	29.0	cldy SE 01-03	1000-,1600+	4	6	15	10
07 Aug	1403-1408	28.9	28.6	28.2	24.2	27.5	cldy NE 01-02	1000+,1800-	6	6	15	20
08 Sep	1315-1320	28.8	28.6	25.0	29.7	29.9	p cldy NW 08-10	1230+,2000-	5	6	20	10
07 Oct	0923-0928	25.6	25.6	22.8	31.2	31.3	cldy ENE 06-08	0530-,1200+	5	7	20	15
18 Nov	1336-1341	17.3	17.2	21.4	29.1	30.2	clear SSE 08-10	0900+,1500-	7	6	15	15
15 Dec	1423-1427	15.5	14.8	17.0	25.0	25.0	clear WSW 08-10	1300-,1900+	8	7	25	25

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station V-1

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
29 Mar	0913-0923	16.9	16.9	17.7	19.8	24.2	-----	0530-,1300+	8	8	25	30
15 Apr	0921-0931	22.7	22.8	22.1	27.5	27.5	cldy ESE 08-10	0630-,1230+	7	7	45	35
08 May	1226-1236	25.0	25.0	22.9	29.7	29.7	clear SE -----	0930+,1500-	7	7	30	35
05 Jun	1309-1314	30.2	28.9	28.1	26.4	28.6	p cldy WSW 02-06	1300-,1700+	6	6	35	35
14 Jul	1122-1127	30.5	30.5	28.0	27.5	27.7	cldy NW 02-04	0200-,1500+	7	7	10	15
08 Aug	1115-1120	29.2	29.2	28.0	29.4	31.9	clear NE 04-06	1100+,1800-	5	6	10	10
04 Sep	1055-1100	28.1	28.6	26.7	27.0	31.4	clear E 04-06	0800+,1530-	7	6	15	15
08 Oct	0924-0929	25.4	25.6	21.8	28.8	31.5	----- ENE -----	0700-,1300+	5	6	20	15
25 Nov	0957-1002	15.7	15.7	18.5	21.8	25.1	-----	0800-,1530+	7	8	15	20
17 Dec	1345-1350	14.9	14.4	14.5	22.9	28.1	clear NE 06-08	0900+,1500-	6	7	20	20

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station V-2

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C		air	salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot		sur	bot			sur	bot	sur	bot
29 Mar	0959-1009	17.3	17.2	17.7	22.0	25.3	-----	0530-,1300+	8	6	25	30
16 Apr	1323-1333	23.9	23.5	23.5	29.7	25.7	cldy ESE 06-08	1200+,1900-	6	7	35	40
08 May	1315-1320	25.0	25.0	22.9	29.7	29.7	clear SE -----	0930+,1500-	6	7	30	35
05 Jun	1342-1352	30.3	29.1	28.1	27.5	30.2	p cldy WSW 02-06	1300-,1700+	7	6	35	35
16 Jul	1008-1013	29.4	29.0	27.3	28.9	28.9	cldy SSE 04-06	1000-,1500+	6	6	15	30
08 Aug	1222-1225	30.1	29.3	28.0	28.9	34.2	clear NE 04-06	1100+,1800-	5	5	10	20
08 Sep	1450-1500	29.3	29.0	25.0	30.4	30.8	p cldy NW 08-10	1230+,2000-	5	6	10	10
09 Oct	1306-1316	26.5	26.3	25.7	30.4	30.7	p cldy ENE 04-06	1300+,2100-	6	5	20	15
26 Nov	1123-1128	16.6	16.6	20.0	26.7	26.7	clear NE 10-12	1030-,1600+	8	8	15	20
17 Dec	1430-1435	15.2	14.6	14.5	22.9	27.5	clear NE 06-08	0900+,1500-	6	6	15	25

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station VI-1

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS			CHEMICAL DATA				
		temperature C			salinity c/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)			
		sur	bot	air	sur	bot			sur	bot	sur	bot		
20 Feb	1300-1305	13.3	12.6	14.4	29.7	31.4	p cldy W	12-15	1030-,1700+	-	-	--	--	
10 Apr	1023-1033	21.7	21.8	21.5	29.7	30.8	p cldy ESE	08-10	1000+,1400-	8	8	25	25	
01 May	1032-1037	24.0	23.5	21.3	26.9	27.5	0 cldy E	06-08	1410+,2100-	7	7	30	30	
02 Jun	1151-1156	28.4	28.1	36.1	30.2	32.4	clear	WNW	03-05	1000-,1345+	7	7	35	30
10 Jul	1025-1030	31.4	31.3	----	33.8	33.2	cldy	S	10-12	0545-,1200+	6	6	10	15
19 Aug	0931-0936	29.1	29.0	26.5	33.0	33.0	clear	SSE	06-08	0700+,1300-	6	6	25	20
04 Sep	1137-1142	28.8	28.8	26.7	30.8	32.3	p cldy E	04-06	0800+,1530-	6	5	10	15	
08 Oct	1017-1022	25.8	26.0	21.8	32.4	33.8	-----	ENE	-----	0700-,1300+	4	6	15	20
25 Nov	1118-1121	15.5	16.0	18.5	28.3	28.3	-----	---	-----	0800-,1530+	8	8	20	15
18 Dec	1125-1130	14.3	14.2	14.0	28.3	28.6	clear	NE	10-12	1100+,1600-	6	9	15	20

* wind velocity estimated in knots
a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station VI-2

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
10 Apr	1322-1332	23.8	22.8	21.5	30.8	30.8	p cldy ESE 08-10	1000+,1400-	7	8	35	40
01 May	1237-1242	23.9	23.7	21.3	29.7	29.7	p cldy E 10-12	1410+,2100-	7	7	35	35
02 Jun	1336-1341	28.9	28.5	36.1	30.8	33.0	clear WNW 03-05	1000-,1345+	6	7	40	35
11 Jul	1038-1043	31.5	31.0	29.5	33.8	33.8	p cldy W 04-06	0700-,1200+	4	6	15	20
19 Aug	1058-1103	29.1	29.0	26.5	31.6	31.6	clear SSE 06-08	0700+,1300-	6	6	20	20
04 Sep	1410-1413	29.8	28.7	26.7	31.9	31.9	p cldy E 04-06	0800+,1500-	5	5	15	15
08 Oct	1245-1248	26.1	26.0	21.8	33.9	33.9	----- ENE -----	0700-,1300+	5	5	20	15
25 Nov	1408-1411	16.0	16.2	18.5	29.3	29.3	----- ---- -----	0800-,1530+	10	9	20	15
18 Dec	1335-1338	14.1	14.5	16.5	27.2	28.9	clear NE 10-12	1100+,1600-	9	9	20	20

* wind velocity estimated in knots

a + high, - low

Appendix II. Additional pertinent data for 1969 trawl samples

Trawl station VII-1

DATE	TIME	PHYSICAL DATA					GENERAL FIELD OBSERVATIONS		CHEMICAL DATA			
		temperature C			salinity o/oo		weather*	tide ^a	D. O. (ppm)		CO ₂ (ppm)	
		sur	bot	air	sur	bot			sur	bot	sur	bot
10 Apr	1145-1155	22.5	21.8	21.5	----	----	p cldy ENE 08-10	1000+,1400-	8	8	25	30
01 May	1130-1135	23.5	23.5	21.3	30.8	30.8	p cldy E 06-08	1410+,2100-	7	7	35	35
02 Jun	1237-1247	28.2	28.0	36.1	33.0	34.1	clear WNW 03-05	1000-,1345+	6	7	30	30
11 Jul	0932-0942	31.4	31.5	29.5	33.8	34.3	p cldy W 04-06	0700-,1200+	5	6	15	15
19 Aug	1012-1022	29.2	29.0	26.5	32.4	32.4	clear SSE 06-08	0700+,1300-	5	5	10	15
04 Sep	1253-1303	29.3	28.7	26.7	31.6	34.9	p cldy E 04-06	0800+,1500-	5	5	15	15
08 Oct	1109-1119	26.1	26.1	21.8	34.9	34.5	----- ENE -----	0700-,1300+	5	6	25	15
25 Nov	1257-1302	16.0	16.5	18.5	32.7	32.7	----- --- -----	0800-,1530+	10	9	20	10
18 Dec	1240-1245	14.5	14.2	15.5	30.0	30.5	clear NE 10-12	1100+,1600-	9	9	20	20

* wind velocity estimated in knots

a + high, - low

Appendix III. Intake/discharge temperature data, unit 1

1969		condenser inlet		condenser outlet		circulated water temperature rise	
		mean	range	mean	range	mean	range
January	C	16.11	15.06-19.00	21.39	18.95- 23.06	5.17	3.55- 6.11
	F	61.00	59.10-66.20	70.50	66.10- 74.50	9.30	6.40-11.00
February	C	15.20	13.00-18.67	20.78	18.95- 24.22	5.56	3.83- 6.83
	F	59.40	55.40-65.60	69.40	66.10- 75.60	10.00	6.90-12.30
March	C	14.84	11.56-20.06	19.50	14.78- 24.61	5.06	2.72- 6.77
	F	58.10	52.80-68.10	67.10	58.60- 76.30	9.10	4.90-12.20
April	C	24.06	22.33-25.50	26.78	22.67- 31.39	2.61	0.60- 6.01
	F	75.30	72.20-77.90	80.20	72.80- 88.50	4.70	0.00-10.70
May	C	26.33	23.06-28.00	31.22	28.67- 34.62	5.39	4.33- 6.28
	F	79.40	73.50-82.40	88.20	83.60- 93.60	9.70	7.80-11.30
June	C	29.78	28.00-31.78	35.11	32.33- 38.11	5.17	3.06- 6.67
	F	85.60	82.40-89.20	95.20	90.20-100.60	9.30	5.50-12.00
July	C	30.06	28.06-34.48	34.78	30.84- 38.00	4.66	0.00- 6.56
	F	86.10	82.50-94.10	94.60	87.50-100.40	8.60	*0.00-11.80
August	C	29.11	27.22-31.11	34.17	30.67- 37.33	3.83	1.73- 6.39
	F	84.40	81.00-88.00	93.50	87.20- 99.40	6.90	3.10-11.50
September	C	27.83	25.38-31.17	33.17	27.89- 35.84	4.06	2.61- 6.33
	F	82.10	77.50-88.10	91.70	82.20- 96.40	7.30	4.70-11.40
October	C	24.79	21.60-26.73	28.11	24.61- 32.22	3.00	0.06- 5.56
	F	76.80	70.90-80.10	82.60	76.30- 90.00	5.40	0.10-10.00
November	C	19.33	15.00-23.22	22.95	17.17- 26.95	3.50	2.33- 5.56
	F	66.90	59.00-73.80	73.30	62.90- 80.50	6.30	4.20-10.00
December	C	18.94	12.84-14.79	17.33	15.45- 19.94	3.44	2.67- 5.11
	F	57.10	55.10-58.80	63.20	59.80- 67.90	6.20	4.70- 9.20

* Unit 1 was not in operation for 5 days during this month.