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SEASONAL NEARSHORE DISTRIBUTIONS OF FISHES IN A PIEDMONT SECTION OF THE JAMES RIVER, VIRGINIA

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Abstract

The seasonal nearshore distributions of 17 species of fishes were determined in natural and artificially heated areas in a 9.6 km stretch of the Piedmont section of the James River, Virginia from July, 1973 to June, 1974. Analyses of the seasonal distributions were based on abundance and percent frequency of occurrence data. The maximum abundance and percent occurrence of ten of the 17 species of fishes in natural temperature areas occurred in early autumn. Deviations from this pattern included *Notropis analostanus*, equally abundant throughout the year, and *Lepisosteus osseus*, *Notropis amoenus*, *Notropis ardens*, *Notropis rubellus*, *Catostomus commersoni* and *Lepomis macrochirus*, which were taken most often in periods other than early autumn. In the heated effluent, seven species of fishes attained maximum abundance in late autumn. Exceptions were *L. macrochirus*, equally abundant throughout the year, and *L. osseus*, *Cyprinus carpio*, *N. rubellus* and *Hypentelium nigricans*, which were more abundant in the spring. Except for *L. macrochirus*, all fishes were absent or scarce in the heated effluent when temperatures exceeded 30 C in the summer and early autumn. In the winter abundance values of fishes in the heated effluent were usually comparable to those of ambient temperature locations.

Introduction

Fishes are adapted to various ecological conditions in lotic waters. Seasonal alterations of these conditions may result in fishes occupying different habitats at different periods of the year. Temperature, recognized as one of the more important environmental factors for fishes, limits both the broad geographical distributions and local distributions of fishes within a single river (Hynes, 1970). In temperate climates most fishes are naturally subjected to a wide variety of temperatures ranging from near freezing in winter to about 28 C in summer (Hynes, 1970). Investigations by Trautman (1957) and Benda and Gammon (1968) indicate that fishes move to and from shallow shore areas in relation to temperature changes during the year. Warmer weather attracts fishes to banks for reproduction and feeding activities (Breder and Rosen, 1966). Munther (1970) studied the movement of smallmouth bass in the Middle Snake River, Idaho and found that the greatest number of bass at shore areas occurred at warmer temperatures in the spring and summer and could be found in the deeper parts of the river when temperatures declined in late autumn and winter. Although overwintering in deeper water is less common in fishes inhabiting rivers than those populating reservoirs, it is probable that most riverine fishes move out from the banks in winter to avoid the fluctuating temperatures at shallow shore regions (Nikolsky, 1963).

Recent studies on the release of heated effluents produced by electric power facilities and other industries into rivers have indicated changes in the distributions of fishes in relation to thermally enriched areas. Fishes tend to be most abundant in that part of the habitat having temperatures within or near a species specific preferred range (Neill and Magnuson, 1972). Investigations by Trembley (1960) on the effects of heated effluents on the distributions of fishes in the Delaware River, Pennsylvania and similar studies by Gammon (1973) in the Wabash River, Indiana, have indicated a general movement of fishes away from heated areas in summer during periods of maximum temperatures and an attraction to the thermal effluents during other parts of the year.

Natural temperature fluctuations in the Piedmont section of the James River are consistent with those of other temperate zone rivers. The only artificial thermal alteration in the environment is a heated effluent from a power station which has minimal effects on the river. This section of the James River has been studied less and is the least understood of the river's physiographic provinces.

The relatively difficult collecting conditions presented by the river in the Piedmont and the assumption by naturalists that this region did not offer the variety of organisms found in the Mountain and Coastal Plain Provinces has been responsible in part for the scarcity of ecological information concerning organisms from this section of the river (Raney, 1950). Until recently, the only known published study that involved several species of fishes is that of Flemer and Woolcott (1966) who studied the distribution and food habits of fishes in Tuckahoe Creek, the last major tributary of the James River above the Fall Line. The most comprehensive study of the river itself in the Piedmont was made by Woolcott (1974) who studied the effects of a heated discharge from the Bremo Power Station on the lotic ecosystem during a three-year period. Included in this report is a section by Woolcott who assessed the influence of the heated water on species composition, abundance and biomass of fish populations and gave a general description of seasonal movements of selected species in relation to the heated water. In conjunction with this study, three additional papers deal specifically with fish communities and populations in this section of the river. Woolcott et al. (1973) reported the effects of a flood associated with tropical storm Agnes on fish populations in the Piedmont. In 1974, White applied diversity indices to express community structure of fishes in relation to fluctuating temperatures in natural and heated areas. Saecker (1975) analyzed the seasonal age class structure of Lepomis auritus (redbreast sunfish) from the same area.

Unpolluted by present standards, the Piedmont section of the James River may become more urbanized through development of industrial sites and recreational facilities in the future (Holm, 1968). Knowledge of the seasonal distributions of fishes in the Piedmont is important in the establishment of baseline information in order to assess the effects of development of industries. In addition, it will serve as a foundation for management of forage and game fishes.

In an attempt to evaluate the present status of the fish community in the Piedmont section of the James River, the primary objective of this study was to characterize the natural seasonal nearshore distributions of individual species of fishes and secondly, to determine the effects of the heated discharge from the Bremo Power Station on natural distributions.

Study Area

Only those characteristics of the river that are pertinent to this investigation are described because the study area was thoroughly described by Kirk (1974).

The research area was a 9.6 km stretch of the James River in the center of the Piedmont Province near Bremo Bluff, Virginia (Fig. 1). The river averages approximately 230 m wide here and has a flat bed of rock with scattered boulders and rubble areas. Mud, sand and debris characterize the shore and rarely extend an appreciable distance outward from the bank. River velocity along the shore is moderate to fast except where debris, overhanging logs or islands create areas of backwater. Banks on the north side of the river are steeper than those on the south.

The river gradient is about 0.6 m/km (3 ft/mi) through the study area from an elevation of 77.22 m at Scottsville, Virginia (20 km above Bremo Bluff) to 49.23 m at Cartersville, Virginia (30.4 km below Bremo Bluff).

Generally river discharge was lowest (48 m^3/sec) in the autumn, increased through the winter to a peak of about 480 m^3/sec in the spring and declined thereafter. Substrate composition along the banks varied with river discharge. Slow moving pools (15 cm/sec) and riffle areas, with the bottom composed mainly of rubble mixed with sand, were associated with low water levels (110 m^3/sec). Numerous boulders and beds of <u>Justica americana</u> Vahl (water willow) were found in both pool and riffle habitats during low flow. In contrast, during periods of high flow (river discharge over 280 m^3/sec), sloping banks were inundated and the substrate consisted of mud and debris. At intermediate water levels (120-280 m^3/sec), when the majority of collections were made, habitats consisted of pools and riffles with a bottom composition of rubble, sand, mud and debris.

The Virginia Electric and Power Company operates a 210 MW fossil fueled, swing load power station (peak load at 1600 hours) adjacent to the north bank of the river at Bremo Bluff (Fig. 1). Depending on station operation and river flow, 2-13% of the river water was used for once through cooling purposes. The heated discharge (Δt of 4-13 C) was released back into the river where it maintained its identity as a narrow plume (approximately 23 m wide) along the north bank from the discharge tunnel to a point 8 km downstream. Antifouling agents, which could have affected the habitat of fishes on the north side of the river, were not used in the cooling tubes of the power station.

The overall water quality in the study area was favorable for the maintenance of a diverse ichthyofauna. The water was clear except after periods of heavy rain when turbidity increased. Dissolved oxygen (range 6.0-13.8 mg/l), pH (range 6.6-8.0), total inorganic nitrogen (range 0.3-2.4 mg/l) and total phosphate (range 0.04-0.35 mg/l) were well within the limits for clean water according to the American Public Health Association (1961).

The benthic macroinvertebrate community offered an abundant food supply throughout the study area except in the thermal plume immediately below the discharge tunnel. Dominant invertebrate forms were trichopteran (caddis fly) and dipteran (midge) larvae, and ephemeropteran (mayfly), odonate (dragonfly and damselfly) and plecopteran (stonefly) naiads.

The dominant terrestrial vegetation that lined the banks on both sides of the river was *Celtis occidentalis* L. (hackberry), *Platanus occidentalis* L. (sycamore), *Acer rubrum* L. (red maple) and *Rhus radicans* L. (poison ivy). Trees along the bank shaded the south side of the river, frequently causing the ambient temperature on the south side to be as much as 2 C lower than that on the north side, independent of plume temperatures. In the autumn and winter leaf fall enters the river and results in a substantial amount of decayed organic matter. This is subsequently utilized as food by macroinvertebrates.

Methods and Materials

Five transects (A-G), one above, one at and three below the point of heated discharge were established. Collecting stations located on both sides of the river at each transect were paired with regard to most environmental factors except those directly associated with the heated effluent (Fig. 1). Paired stations are designated by n and s (e.g. An and As) which denote the north and south sides of the river, respectively. Transect A was established 1.2 km above the power station discharge and transect B at the point of discharge of the heated effluent. Transects C, D and G were established 0.8, 1.6 and 8.0 km below the outfall, respectively. North side stations B-G were subjected to the direct influence of the heated discharge.

Fishes were collected from shore areas during daylight hours by electrofishing (220 volts; 1-3 amperes, DC) from a 4.8 m boat. The anode was an electrode dipnet (5 mm^2 mesh) manipulated at the bow; four cathodes (each 1 m long) hung from the sides of the boat. A second dipnet, without electrical current, was used to assist in collecting stunned fishes. The boat was maneuvered upstream in order to maintain a constant sampling speed. Each station was sampled for 20 minutes which allowed 130-180 m of shoreline to be sampled. Proximity from the shore varied from 0.6 m to 9.0 m depending on river height and shoreline obstructions. Most samples were taken at river discharges of 156 m^3/sec to 227 m^3/sec; no collections were made when the river flow exceeded 340 m^3/sec.

Fishes were collected monthly during the first year (August, 1971 - June, 1972); thereafter, samples were taken three times every two months in the second year (July, 1972 - June, 1973) and the third year (July, 1973 - May, 1974).

Small specimens were put in one-half gallon plastic jars and preserved with 10% formalin; larger fishes were injected with 10% formalin. All specimens were returned to the laboratory where abundance and percent occurrence were determined for each species. All specimens were measured to the nearest whole millimeter. Standard length (mm) is reported for all species except Lepisosteus osseus and Anguilla rostrata, where total length (mm) was measured.

Temperature was measured 0.1 cm below the water surface with a centigrade mercury thermometer and on occasions, with a Yellow-Springs Oxygen Meter (Model 51A) equipped with a YSI 5400 Series O_2/Temperature electrode. River discharge data (cfs) were obtained from the United States Weather Service at Byrd International Airport, Richmond, Virginia and converted into metric units (m^3/sec).

Because of the difference in magnitude of temperatures within a given calendar season (e.g. autumn; 6-22 C), it was necessary to divide the year into thermal seasons to analyze the data (Table 1). For a given temperature period, collections from all southside stations were combined. On the north side, collections from those stations having a Δt equal to or greater than 4 C were combined. This 4 C increment approximated the maximum allowable temperature of 3 C for the heated effluent from the Bremo Power Station as established by the Virginia State Water Control Board (1974). Five temperature periods are recognized in the first year and six in each of the second and third years (Table 1).

Two parameters, abundance and percent occurrence, were analysed for all three years and used to characterize the spatial and temporal distributions. Although 50 species were collected, insufficient sample size precluded a thorough analysis of abundance and percent occurrence data for 33 of them. For those with sufficient numbers, abundance and occurrence data from the third year are used to depict distributions provided they do not deviate from those of previous years. Data from the first two years are used only when they are more complete or differ significantly from those of the third year.

For a given period, the means of the parameters for each species from the ambient side of the river were compared with those from the heated effluent with a paired t-test (Steel and Torrie, 1960). Duncan's New Multiple Range Test (Steel and Torrie, 1960), as modified by Kramer (1956), was used to test temporal differences among mean numbers and percent occurrences of fish per species. Relationships between occurrence and abundance per species were measured by correlation coefficients and tested with a t-test. Significance was established at the 0.95 confidence level. All computations were made on Wang Models 500 and 600 Series computers (Wang, 1971; 1972).

References to lotic waters in this paper follows the nomenclature of Jenkins et al. (1971): i.e. rivers are greater than 61 m (200 ft) in average width; streams average between 9-61 m in width; creeks up to 9 m in width.

Results and Discussion

Fifty species of fishes were collected during this three-year study, but only 17 species occurred in numbers of individuals sufficiently large to analyze their seasonal nearshore distributions (Table 2). The findings, with a comparative discussion of the results of studies in other aquatic environments, are presented in the following species distributional analyses.

Lepisosteidae

Lepisosteus osseus (Linnaeus), longnose gar

Two hundred seventeen longnose gar (72-1019 mm) were collected, 75% of which occurred in the third year. Included in the total count were 11 melanistic specimens (Minson, 1975; Woolcott and Kirk, 1976).

Abundance was directly correlated with percent occurrence on the southside of the river throughout the year and never exceeded one gar per period (Table 3; Fig. 2). Numbers of gar ($\overline{X} = 0.7$) were significantly greater when temperatures ranged from 6-12 C (October - November) than those in most other periods (0-0.13) [exceptions, $\overline{X}$ 0.5, 19-23 C (May - June) and $\overline{X}$ 0.53, 24-26 C (July - August) (Table 4; Fig. 2)].

Abundance was directly correlated with percent occurrence in the thermal plume throughout the year (Table 3). Numbers of gar ($\bar{X}$ = 1.5 - 2.1) were significantly greater when temperatures ranged from 15-22 C (October - November), 17-20 C (April-May) and 25-29 C (May-June) than those (0.1-0.3) in other periods (Table 5; Fig. 2). In general, the greatest abundance of this species at nearshore areas in the heated effluent occurred in the spring and late autumn (Fig. 2). Numbers of gar were significantly greater in the plume than those on the southside of the river in the October-November period (15-22 C, Δt 9-11) and the two spring periods: April-May (17-20 C, Δt 6) and May-June (25-29 C, Δt 6) (Fig. 2).

The longnose gar is a sluggish solitary species for most of the year (Suttkus, 1963). Suttkus (1963) reported that large numbers of individuals which congregate in the shoal areas suitable for spawning disperse soon after breeding. Netsch and Witt (1962) indicated that spawning in Missouri takes place entirely in shallow areas along the shore during a brief period from mid-May through June. In the present investigation, numbers of gar at shore areas on the southside of the river increased with rising temperatures in the spring, but were never as abundant in a particular area as they were in the heated effluent on the northside. The greatest abundance of this species at nearshore ambient temperature areas occurred in the autumn when food organisms were plentiful (ictalurids and cyprinids were the dominant food items in stomachs; Woolcott, 1974). The lowest abundance of this species at nearshore areas was found during the winter months and concurs with the report of Suttkus (1963), who indicated that this species moves to deep water in winter.

Gammon (1973) reported that *L. osseus* was attracted to, and concentrated in, certain segments of a heated effluent in the Wabash River, Indiana during the summer and proposed an optimum temperature range of 33-35 C. Correspondingly, Neill and Magnuson (1972) found this species in a heated effluent in Lake Monona, Wisconsin at temperatures around 34 C in August and September. In contrast, during spring and autumn when temperranged from 17-29 C and 15-22 C, respectively, gar in the thermal plume were significantly more numerous than on the southside of the river. Concentrations of longnose gar were never observed at nearshore areas in the James River when heated effluent temperatures exceeded 30 C.

Cyprinidae

Cyprinus carpio (Linnaeus), carp

Eighty-three carp (318-745 mm) were collected during the study, 88% of which occurred at nearshore areas in the heated effluent.

Mean abundance and percent occurrence of carp at nearshore areas on the southside of the river were consistently low throughout the year and averaged less than one carp per period (Fig. 3).

In the plume the number of carp ($\overline{X}$ = 2.1) was significantly greater at temperatures ranging from 13-20 C (March-April) than those in all other periods (Table 5; Fig. 3). No carp occurred in the heated effluent when plume temperatures ranged from 29-37 C (July-August) and 25-27 C (September) (Fig. 3).

The infrequent occurrence of carp on the southside of the river precluded an analysis of seasonal movements to and from shore areas.

The great influx of carp in the heated plume in early spring is probably associated with spawning activities, as most carp (41) captured were either ripe or gravid. Carlander (1969), cited Sigler (1958), stated that spawning starts when water temperatures ranged from 14.5-17 C; but most activity occurred from 18.5-20 C. Similarly, Nikolskii (1961) indicated that carp begin to spawn in late spring and early summer when water temperatures reach 16.1-22.8 C. Temperatures in the plume were well within that range in March and early April and may have afforded an area conducive to premature spawning because ambient temperatures in the James River in the Piedmont Province do not reach these ranges until May (Table 1).

Neill and Magnuson (1972) found that carp concentrated in a heated effluent in Lake Monona, Wisconsin during the summer when temperatures exceeded 30 C. Correspondingly, Trembley (1960) found an abundance of carp in a heated effluent in the Delaware River when temperatures ranged from 33.4-35.5 C. Contradictory in part, Gammon (1973) reported that carp moved into a heated effluent in the Wabash River at 30-32 C, but moved out at higher temperatures. Ferguson (1958), cited Pitt et al. (1956) who reported that in laboratory studies carp preferred a temperature of 32 C. In contrast to the results of these studies, and more in accord with the findings of Dendy (1945) who stated that carp are widely scattered in a reservoir and probably tolerate a wide range of temperatures, all but two carp in the present investigation (which were captured at 31-32 C) were taken at temperatures less than 27 C.

Nocomis raneyi (Lachner and Jenkins), bull chub

About 60% of the 189 bull chubs (18-222 mm) were collected at nearshore areas on the southside of the river in the third year. Abundance was directly correlated with percent occurrence of bull chubs on this side of the river (Table 3). Numbers of fish ($\overline{X}$ = 2.3-3.9) were significantly greater when temperatures ranged from 24-26 C (July-August) and 19-20 C (September) than those in other periods (Table 4; Fig. 4). In general, greatest abundance occurred during the warmer months of the year.

Five individuals were captured in the heated effluent at minimum and maximum temperatures of 16 C (Δt 4) in November and 33 C (Δt 9) in August, respectively.

The distribution of the bull chub in mountain streams is well documented by Lachner and Jenkins (1971). However, they point out that even though this is a highly plastic form, able to adapt to habitats in typical piedmont rivers, little information is available regarding its distribution and relative abundance in the larger rivers. The results of the present investigation indicate that bull chubs were present at nearshore areas on the southside of the river mainly from July through September. About 50% of these occurred at nearshore areas where there was a well-established growth of _J. americana_ (waterwillow). This observation supports the statement by Lachner and Jenkins (1971) who reported that the largest bull chub populations are at or near beds of waterwillow. After September abundance and percent occurrence of bull chubs at nearshore areas declined drastically and remained low throughout the winter. A related species, _Nocomis micropogon_ (river chub), is reported by Miller (1964) to winter offshore in deeper water.

This is the first investigation in which bull chubs were studied in relation to a heated effluent and the results indicated that it avoided the higher temperatures of the thermal plume throughout the year.

Notropis amoenus (Abbott), comely shiner

In the first year, 45 of the 65 specimens were collected in two samples, 33 individuals at 24 C in August and 12 at 14 C in April and therefore analysis was not possible. Correspondingly, 70% of the fish in the second year occurred in two collections (75 specimens at 7 C in December and 20 at 6 C in January). In the third year, 35 comely shiners (1-2 individuals per collection) were collected at various times and locations; however, the majority (82%) occurred on the southside of the river.

Although abundance was variable, percent occurrence of the comely shiner at shore areas on the southside of the river in the second and third years showed an increase in late autumn when temperatures ranged from 6-12 C (Figs. 5 and 6). Only three of the 38 individuals, which were collected at nearshore areas in the thermal plume during the three years, occurred at or above 30 C.

The infrequent occurrence of the comely shiner at nearshore areas is corroborated by the cursory observations of Snelson (1968) who indicated that it is a midwater species which swims about actively in school-like aggregations and prefers areas where the water is at least 0.6 m deep.

The scarcity of the comely shiner in the heated effluent in this study agrees with the observation by Trembley (1960), who said that it was rare in a heated effluent in the Delaware River.

Notropis analostanus (Girard), satinfin shiner

A total of 7983 satinfin shiners (11-75 mm) were collected during the three-year investigation and accounted for almost 50%

of the 16,700 fishes caught. It was consistently the most frequently collected form on the southside of the river as evidenced by the fact that percent occurrence averaged 84% and ranged from 50-100%.

There were no significant differences among the mean numbers (5.4-17.8) or percent occurrence (88-100) of fish at nearshore areas on the southside of the river throughout the year (Tables 4 and 6; Figs. 8 and 9). The only deviation from this pattern occurred in the first year where percent occurence (90) was significantly greater when the temperature was 24 C (August-September) than that (55%) when temperatures ranged from 19-25 C (May-June) (Fig. 7). Large schools of N. analostanus which contributed to the extreme variation in the number of fish captured at nearshore areas in the thermal plume within a given temperature period precluded analysis of abundance data.

Occurrence data were less variable and indicated that percent occurrence (80-100) at nearshore areas when temperatures in the plume ranged from 9-29 C (October-June) were significantly greater than those (25-33%) at temperatures ranging from 33-37 C (July-August) and 25-27 C (September)(Fig. 8). Data from the first year substantiate these findings as the percent occurrence (25) when temperatures ranged from 33-34 C (August-September) was significantly lower than those (84-100%) from October through June (Fig. 7).

Notropis analostanus was present in large numbers at nearshore areas on the southside of the river throughout the year (Figs. 8 and 9). Apparently, the overwhelming abundance of this species is typical wherever it occurs in rivers. Trembley (1960) indicated that it was found in large numbers at most of his collecting stations in the Delaware River. A related species, Notropis spilopterus (spotfin shiner), was reported by Stauffer et al. (1974) to be the dominant species in their collections in the New River, and also by Starrett (1951) in the Des Moines River in Iowa.

Except when thermal plume temperatures exceeded 30 C, the heated effluent had no affect on the abundance or percent occurrence of the satinfin shiner (Fig. 8). In contrast, Trembley (1960) found that the satinfin shiner was abundant in a heated effluent throughout the year at temperatures up to 37 C. Stauffer et al. (1974) found that the spotfin shiner showed a similar response to heated effluents because the fish were present in significant numbers at temperatures up to 35 C.

Notropis ardens (Cope), rosefin shiner

One thousand one hundred twenty-six rosefin shiners (21-68 mm) were collected, 79% of which occurred in the second year. Mean percent occurrences of rosefin shiners at nearshore areas on the southside of the river in the second year were directly correlated with those in the third year. Percent occurrence (80) of fish was significantly greater when temperatures ranged from 11-12 C (March - April) than those 10-20%) at 16-26 C (May - September) but not from those in other periods (Fig. 10). Mean percent occurrences and abundances of fish on the southside of the river in the third year were usually greater than those in the plume, but only in September was there a statistical difference between sides (Figs. 11 and 12).

In the plume, mean abundance was directly correlated with percent occurrence in the third year (Table 3; Figs. 11 and 12). Mean numbers (0.85-1.4) of fish collected when temperatures ranged from 6-12 C (October - November) and 19-23 C (May-June) were significantly greater than those (0-0.4) taken in the other periods (Table 5; Fig. 12). No specimens were captured at nearshore areas in the heated effluent when temperatures ranged from 29-37 C (July - September) (Figs. 11 and 12).

Trautman (1957) indicated that the rosefin shiner spawns in fast currents or shallow pools in the spring and remains in these areas throughout the warmer periods of the year. Results of the present study showed that this species occurred frequently and was present in large numbers at nearshore areas on the southside of the river in the early spring. However, both parameters declined from late spring through late summer (August) Figs. 11 and 12). Thereafter, occurrence increased as temperatures declined in late autumn and winter (Figs. 11 and 12).

This is the first investigation in which the rosefin shiner was collected in numbers sufficiently large in order to analyse its movements in relation to a heated effluent. The results indicated that it avoided the heated effluent in September (27 C) as percent occurrence values during this period were significantly less than that on the southside of the river (19 C) (Figs. 11 and 12). The abundance and percent occurrence values recorded in late autumn probably reflect movement of this form back to the plume area after avoiding the higher temperatures in early autumn. It does not necessarily indicate a preference for the warmer water as comparable values were recorded at ambient temperature locations.

Notropis hudsonius (Clinton), spottail shiner

The spottail shiner was the second most abundant species collected during the three-year investigation. Over 85% of the 2436 individuals (8-89 mm) were captured in the third year. It was usually collected in schools ranging from 22-350 individuals per school in the autumn and spring. The number ($\overline{X}$ = 90.7) of fish at nearshore areas on the southside of the river when temperatures ranged from 19-20 C (September) was significantly greater than those (0.04-23.1) in other periods (Table 4; Fig. 13). Correspondingly, numbers ($\overline{X}$ = 19.3-23.1) recorded when temperatures ranged from 6-12 C (October-November) and 24-26 C (July-August) were significantly greater than those (0.04-5.27) in other periods (Table 4; Fig. 13).

Numbers ($\overline{X}$ = 90.7) of fish collected at nearshore areas on the southside of the river in September (19-20 C) were significantly greater than those (0) on the opposite side of the river in the heated effluent where plume temperatures ranged from 25-27 C (Fig. 13).

In the thermal plume the number ($\overline{X}$ = 20.0) of fish captured when temperatures ranged from 15-22 C (October - November) was significantly greater than those (0-4.7) in all other periods (Table 5; Fig. 13). No spottail shiners were collected at nearshore areas in the heated effluent when plume temperatures ranged from 25-37 C (July-September) (Fig. 13).

Spottail shiners were abundant at nearshore areas on the southside of the river from July through September (Fig. 13). Fish (1932) and Breder and Rosen (1966) indicated that spottail shiners spawn in closely packed groups along the banks and shores of rivers from June through July. Carlander (1969), cited Griswald (1963), found that spottail shiners spawn a second time in August. The greatest abundance of this species at nearshore areas on the southside of the river coincided with the time of year when food (primarily dipteran and trichopteran larvae; Woolcott, 1974) was plentiful.

The largest number of spottail shiners at nearshore areas in the heated effluent occurred when temperatures ranged from 15-22 C (October - November) (Fig. 13). This increase probably represents a re-invasion of the nearshore areas in the autumn following an avoidance of the higher temperatures (25-37 C) in the heated effluent from July through September. It does not necessarily indicate a preference for the warmer temperatures as comparable numbers of individuals occurred on the southside of the river during the same period. Compared to the results of other studies, it is difficult to say what the thermal responsiveness of the spottail shiner is because of the wide range of temperatures that it is reported to tolerate. Meldrim and Gift (1971) found in laboratory studies that spottail shiners preferred temperatures around 14 C. In their study in the New River Stauffer et al. (1974) found that fewer spottail shiners were in a heated effluent than in reference areas and, whether in or out of the plume, most (92%) were captured when temperatures ranged from 20-27 C. Trembley (1960), however, found large schools of spottail shiners in a heated effluent in the Delaware River during the summer at temperatures up to 35 C.

Notropis rubellus (Agassiz), rosyface shiner

Three hundred eighty-two rosyface shiners (24-64 mm) were collected during the investigation, 50% of which occurred in the third year. There were no differences among the mean numbers or percent occurrence of fish collected per period at nearshore areas on the southside of the river throughout the year (Tables 4 and 6; Figs. 14 and 15). Percent occurrence of the rosyface shiner on the southside of the river was low throughout the year and averaged less than 13 percent per period (Fig. 15).

Over 60 percent of the 185 fish collected in the third year occurred at nearshore areas in the heated effluent. Abundance was directly correlated with per cent occurrence throughout the year in the plume (Table 3). Mean numbers (1.7-2.0) of rosyface shiners at nearshore areas in the heated effluent were significantly greater when temperatures ranged from 9-13 C (December-March) and 17-20 C (April-early May) than those (0-0.08) in other periods (Table 5; Fig. 14). No fish were collected at nearshore areas in the plume when temperatures ranged from 25-37 C (late May-September) (Table 5; Fig. 14). Mean numbers collected in the plume when temperatures ranged from 9-13 C were significantly greater than those on the southside of the river from December through March (3-6 C) (Fig. 14).

The constant occurrence of rosyface shiners at nearshore areas on the southside of the river suggested that they have a distribution pattern similar to _N. analostanus_, although their abundance is far less than that of the satinfin shiner. Pfeiffer (1955) stated that the rosyface shiner spawns in the spring and summer at temperatures from 24-29 C over substrates composed of gravel and bedrock in shallow riffle areas, but no increase in the occurrence of this species was noted during this period over comparable substrates in the James River. Although Trautman (1957) reported that the rosyface shiner moved offshore in the autumn and wintered in deeper water, there was no evidence of this in the present investigation.

The rosyface shiner showed a definite preference for nearshore areas in the heated effluent in the winter when plume temperatures ranged from 9-13 C (Fig. 14). They avoided nearshore areas in the artificially heated water when plume temperatures ranged from 25-37 C (late May-September) (Fig. 14). This is in accord with the findings of Stauffer et al. (1974) who indicated that the numbers of rosyface shiners decreased linearly as temperatures increased from 20-26.7 C and then abruptly decreased in abundance when temperatures exceeded 27 C.

Catostomidae

Catostomus commersoni (Lacépède), white sucker

One hundred eighteen white suckers (16-416 mm) were collected, 50% of which occurred in the third year; about 70% of these were taken from the southside of the river. Abundance was directly correlated with percent occurrence throughout the third year (Table 3; Figs. 16 and 17). Numbers ($\overline{X} = 0.6$) of fish were significantly greater when temperatures ranged from 19-23 C (May-June) than those ($\overline{X} = 0.07$-0.2) at 19-26 C (July-September) and 3-6 C (December-March) but not from those ($\overline{X} = 0.27$-0.33) in other periods (Table 4; Fig. 16).

In the plume, where only large specimens ranging from 215-398 mm in length were collected, abundance was directly correlated with percent occurrence (Table 3). Numbers ($\bar{X}$ = 0.66) of fish captured at temperatures ranging from 9-13 C (December-March) were significantly greater than those ($\bar{X}$ = 0) taken in all temperature periods except early spring (April-May, 17-20 C) when the mean was 0.5 (Table 5; Fig. 16). No specimens were collected in the heated effluent from late May through November (Fig. 16).

The increase in numbers of white suckers in the spring (19-23 C) on the southside of the river probably reflects a movement toward shore areas after wintering offshore in deeper waters similar to spring nearshore movements described by Trautman (1957) for the species in Ohio. He said that this species moves from deep water in late winter when temperatures reach 4.4 C and aggregate for spawning in shallow water when temperatures ranging from 10-20 C occur in March through June. However, the increase in numbers in the James River probably underestimates the abundance of white suckers along the shore as collections were made during daylight hours and most spawning activity takes place at night according to Raney and Webster (1942).

After the spring increase, fish dispersed from shore areas as was evidenced by the smaller numbers present in the summer and autumn collections.

Although the white sucker occurred more frequently in the plume in winter (9-13 C) and early spring (17-20 C) when the Δ t ranged from 6-7 C this does not mean necessarily that they were attracted to the heated area as comparable numbers of fish were taken on the southside of the river during the same period. These ranges of temperatures are consistent with the preferred range of temperatures (11.8-20.6 C) for the white sucker as proposed by Cooper and Fuller (1945) and Martin and Baldwin (1958) in Ferguson (1958). Trembley (1960) found an abundance of white suckers in similar heated effluent temperatures in late winter and early spring. In deference to the findings of the present investigation and those by Black (1953), Brett (1956) and Trembley (1960), Neill and Magnuson (1972) found that there was no difference between the numbers of white sucker in a heated plume and natural temperature areas in Lak Monona, Wisconsin. The white sucker avoided the heated effluent from late spring to early autumn as plume temperatures (25-37 C) frequently exceeded the upper lethal temperatures of 27 C and 29.3 C as reported by Black (1953) and Brett (1956), respectively. Comparable results were reported by Trembley (1960) who also found that the white sucker disappeared from maximum temperature areas in the heated effluent in the summer.

Hypentelium nigricans (LeSueur), hog sucker

All of the 242 hog suckers (29-293 mm) were collected from August, 1972 through May, 1974, 90% of which occurred in the third year. Abundance was directly correlated with percent occurrence on the southside of the river throughout the year (Table 3). The number ($\overline{X}$ = 5.6) of hog suckers was significantly greater when temperatures ranged from 19-20 C (September) than those ($\overline{X}$ = 0-3.0) in other periods (Table 4; Fig. 18). Likewise, abundance means (2.87-3.0) were significantly greater when temperatures ranged from 24-26 C (July-August) and 6-12 C (October-November) than those (0-1.53) in other periods (Table 4; Fig. 18). No hog suckers were collected at nearshore areas when temperatures ranged from 3-6 C (December-March) (Table 4; Fig. 18). Only in September were numbers ($\overline{X}$ = 5.6) of fish on the southside of the river (19-20 C) significantly greater than those ($\overline{X}$ = 0.5) in the heated plume (25-27 C) (Fig. 18).

Mean numbers (1.1-3.0) of hog suckers were significantly greater when temperatures at nearshore areas in the heated effluent ranged from 15-22 C (October-November), 17-20 C (April-May) and 25-29 C (May-June) than those (0-0.15) in other periods (Table 5; Fig. 18). No fish were collected in the heated effluent when plume temperatures exceeded 33 C (July-August) (Fig. 18).

The greatest abundance and occurrence of the hog sucker at nearshore habitats on the southside of the river occurred during the summer and autumn when the largest number of food organisms (aquatic insect larvae and naiads; Woolcott, 1974) were available. Numbers of hog suckers at nearshore areas declined with decreasing temperatures in the autumn; none were collected in the winter period. Trautman (1957) indicated that this species remained in deep pools of rivers during winter and did not return to nearshore areas until temperatures began to rise during spring. Although, in the present study, numbers of hog suckers at nearshore areas increased in the spring they did not approach the numbers present in the autumn when temperatures were comparable to those in the spring. The low abundance in the spring may have been the result of mature specimens moving from the river into tributaries for spawning activities. Reighard (1920) and Trautman (1957) reported that this is a migratory species which spawns in smaller steeper gradient tributaries of larger streams.

Relatively little information exists as to the movement of the hog sucker in relation to heated effluents. Stauffer et al. (1974) indicated that this species prefers temperatures ranging from 20-27 C and found that, under laboratory conditions, the fish could be acclimated up to 33 C. In the present investigation, H. nigricans moved into shore areas in the thermal effluent when temperatures ranged from 25-29 C (May-June). From July through September when temperatures reached a high of 37 C in the heated effluent, relatively few hog suckers were present, indicatory that under field conditions this species prefers water of lower temperature.

Moxostoma erythrurum (Rafinesque), golden redhorse

One hundred thirty-three golden redhorse (22-384 mm) were collected during the three-year investigation. Five individuals were captured in the first year, all from the southside of the river when temperatures ranged from 14-24 C (April-August); and nine in the second year from the same side of the river at temperatures ranging from 17-23 C (June-October). No specimens were collected from the heated effluent at a Δt of 4 C or greater than ambient water temperature during these two years.

Over 80% of the 119 golden redhorse from the third year occurred on the southside of the river. Abundance was directly correlated with percent occurrence at nearshore areas (Table 3). The greatest mean abundance (2.8) occurred when temperatures ranged from 19-20 C (September) and was significantly greater than those ($\bar{X}$ = 0-0.13) at temperatures ranging from 3-23 C (December-June) but not from those (1.3-1.4) in the other two periods (Table 4; Fig. 19). No specimens were collected when temperatures ranged from 3-6 C (December-March) and 19-23 C (May-June) (Fig. 19).

Only 15 individuals were captured in the heated effluent, 12 of which occurred at temperatures ranging from 15-22 C (October-November) (Fig. 19). Sample means during this period were significantly greater than those in all other periods (Tables 5 and 7; Fig. 19). No specimens were collected in the heated effluent when temperatures ranged from 25-37 C (April-September) (Fig. 19).

There was no evidence of a nearshore spawning run in the spring as abundance remained low during this period (Fig. 19). Possibly, as postulated for the other suckers included in this investigation, the golden redhorse moves to smaller streams for spawning in the spring. Reighard (1920) and Trautman (1957) reported that they do; however, Gerking (1953) indicated that the spawning golden redhorse in Indiana usually remain within their parent stream. The movement of golden redhorse into shore areas in the summer and autumn coincided with the greatest abundance of chironomid larvae and ephemeropteran naiads, which Meyer (1962) indicated to be the dominant food items for this species. Benda and Gammon (1968) also found that golden redhorse move into shallow areas in streams in Indiana during the summer but did not relate it to any environmental factor. As temperatures declined in autumn the fish moved offshore and probably wintered in deeper water, as was reported for this form by Trautman (1957) and Benda and Gammon (1968).

Golden redhorse avoided the heated effluent when plume temperatures ranged from 27-37 C (July-September) but when effluent temperatures in the James River ranged from 15-22 C (October-November) numbers of golden redhorse increased at the plume area. This movement does not appear to be related to a preference for warmer temperatures provided by the heated effluent as comparable numbers of individuals occurred on the southside of the river where temperatures ranged from 6-12 C during this period. Comparable results were reported by Gammon (1973) who found that numbers of this species were greatest in a heated effluent in the Wabash River when temperatures ranged from 24-27 C but declined when effluent temperatures ranged from 30-35 C. He referred to this fish as thermally intolerant and proposed temperatures from 20-27.5 C as its preferred range. Dendy (1945) reported that golden redhorse were probably tolerant of a wide range of temperatures below 27 C. The numbers of golden redhorse decreased throughout the winter, with declining temperatures on both sides of the river.

Moxostoma macrolepidotum (LeSueur), northern redhorse

Abundance of the northern redhorse was extremely variable among the three years. The two individuals (248 and 251 mm) captured in the first year (15 C, $\Delta t = 6$) were in the thermal plume. In the second year, 39 individuals (40-385 mm) were collected, most of which occurred during summer and autumn; fifteen were taken from ambient temperature locations when temperatures ranged from 21-28 C (August-September) and 12 at temperatures ranging from 7-19 C (October-November). Three were collected from the heated effluent at temperatures ranging from 31-33 C (Δ t 10-11) in September.

The majority (197) of northern redhorse suckers (38-380 mm) was collected during the third year. About 75% of these occurred on the southside of the river, where abundance was directly correlated with percent occurrence (Table 3). Numbers of the northern redhorse ($\overline{X}$ = 8.2) collected at temperatures ranging from 19-20 C (September) were significantly greater than those ($\overline{X}$ = 3.1) taken in other periods (Tables 4 and 5; Fig. 20). No fish were captured when temperatures ranged from 3-6 C (December-March) and 19-23 C (May-June) (Fig. 20).

Only 25% of the 197 individuals occurred in the heated effluent. Abundance was directly correlated with percent occurrence throughout the year (Table 3). Numbers ($\overline{X}$ = 3.1) of fish at temperatures ranging from 15-22 C (October-November) were significantly greater than those ($\overline{X}$ = 0-0.5) in all periods except those ($\overline{X}$ = 1.0) captured at 17-20 C (April-May) (Table 5; Fig. 20). No specimens were collected in the heated effluent when plume temperatures ranged from 25-37 C (July-September) (Tables 5 and 7).

The movement of northern redhorse suckers into shore areas in September coincided with the greatest abundance of available food organisms and periods of low river discharge. Meyer (1962) and Zach (1967) indicated that the northern redhorse has stricter habitat requirements than the golden redhorse and is usually found only over rock, gravel and rubble bottoms in fast moving water and avoids areas with mud bottoms. During the winter when the fish probably moved into deeper water, few individuals were collected. Northern redhorse suckers usually spawn in late April in water 0.6-1 m deep when temperature reaches 11.1 C (Meyer, 1962). Although comparable temperatures were recorded in the study area in April (11-14 C), abundance, which was expected to be high due to spawning aggregations, averaged less than one fish for the entire period.

No published literature is available on the thermal responsiveness of the northern redhorse to heated effluents. In this investigation no fish were collected from July through September when temperatures ranged from 25-37 C. The presence of fish at shore areas in the plume during the autumn reflects a return of the fish to the area after avoiding the higher temperatures of 25-37 C in the summer. It does not indicate a preference for the warmer temperatures as comparable numbers of the northern redhorse occurred on the southside of the river during the same period. As did the fish in the ambient temperature habitat, those in the plume left the area in winter as evidenced by the decrease in abundance and percent occurrence.

Ictaluridae

Ictalurus punctatus (Rafinesque), channel catfish

One hundred fifty-three channel catfish (32-643 mm) were collected during the investigation, 67% of which occurred during the third year. About 50% of the 103 fish from the last year were captured on the southside of the river. Abundance was directly correlated with percent occurrence throughout the year (Table 3). Numbers ($\overline{X}$ = 2.1) of fish were significantly greater when temperatures ranged from 19-20 C (September) than those ($\overline{X}$ = 0.04-0.73) of other periods (Tables 4 and 6; Fig. 21). Abundance was lowest in the winter and early spring, averaging less than one fish for each period (Fig. 21).

Data for the distribution of the channel catfish (Tables 5 and 7; Fig. 21) in the plume demonstrates that the abundance ($\overline{X}$ = 2.1) of channel catfish was significantly greater at temperatures ranging from 15-22 C (October-November) than those ($\overline{X}$ = 0.05-0.83) in all other periods. There was no significant difference among the mean number of fishes when temperatures ranged from 17-20 C (April-May), 25-29 C (May-June), 33-37 C (July-August) and 22-27 C (September). Lowest abundance was recorded at temperatures ranging from 9-12 C (December-March).

The channel catfish was over five times more abundant than the combined numbers of native ictalurid species captured from the study area. The greatest abundance of the channel catfish at nearshore areas on the southside of the river coincided with the peak abundance of trichopteran larvae, which Woolcott (1974) reported as the main food item for this form from July through September. Abundance in the October-November period declined with decreasing temperatures and was lowest in the winter. Trautman (1957) reported that young channel catfish winter under boulders in swiftly flowing water whereas the adults move into deeper water.

Spawning usually occurs in tunnel-like holes or nests under overhanging banks in the spring of the year when temperatures are in the lower 20 C (Lagler et al., 1962; Breder and Rosen, 1966; Carlander, 1969). In the late spring numbers of channel catfish increased with rising temperatures (19-23 C) at shore areas but whether this was associated with spawning was not determined.

The great abundance of channel catfish at nearshore areas in the plume, as compared with those in ambient temperature water when temperatures ranged from 18-22 C in October and November, suggests that it prefers the warmer areas. Channel catfish appeared to avoid nearshore areas in the plume in September when temperatures ranged from 25-27 C as abundance was significantly lower than that on the southside of the river (20 C). This avoidance was probably due to the near complete absence of food organisms in the heated effluent during the September period (Woolcott, 1974) as ictalurids have been found to be one of the most eurythermal species of freshwater fishes with an upper lethal temperature of 37 C (Carlander, 1969). Stauffer et al. (1974) indicated that while channel catfish were relatively well distributed when temperatures ranged from 23-32 C, they occurred in congregations and were the most abundant species in the plume when temperatures ranged from 34-35 C. Trembley (1960) and Benda and Proffitt (1974) reported that channel catfish were more abundant in heated effluents in the summer when temperatures ranged from 34-36 C than in any other period of the year. In contrast, results of the present investigation indicate that channel catfish did not congregate in the heated effluent (29-37 C) in the summer as numbers here did not differ significantly from those on the southside of the river (26 C) (Fig. 21).

Anguillidae

Anguilla rostrata (LeSueur), American eel

Two hundred sixty-seven eels (75-650 mm) were captured during the investigation, one-half of which occurred during the third year. Approximately 77% of the 146 specimens from the third year were collected from the southside of the river, where abundance was directly correlated with percent occurrence (Table 3). Mean numbers (2.3-3.1) of eels collected when temperatures ranged from 24-26 C (July-September) were significantly greater than those (0.04-0.93) collected in other periods (Tables 4 and 6; Fig. 22). Mean abundance declined to 0.93 individuals per period when temperatures ranged from 4-12 C (October-November) and was lowest (0.04) at 3-6 C (December-March) (Tables 4 and 6; Fig. 22); thereafter, mean abundance increased to 0.5 when temperatures ranged from 19-23 C (May-June) (Fig. 22). Numbers of eels on the southside of the river were significantly greater than those in the plume from 24-26 C (July-August) and 19-20 C (September) when average Δt's in the plume were 10 and 7 C, respectively (Fig. 22).

In the plume, numbers of eels ($\bar{X} = 1.8$) taken when temperatures ranged from 23-29 C (October-November) were significantly greater than those ($\overline{X}$ = 0-0.3) captured in other periods (Tables 5 and 7; Fig. 22). No eels were collected in the heated effluent when temperatures ranged from 25-37 C (May-August) (Fig. 22). Mean numbers of eels were significantly greater in the plume at temperatures ranging from 15-22 C than they were on the southside of the river from October through November when the average Δt ranged from 9-11 C (Fig. 22).

The greatest abundance of eels at nearshore areas on the southside of the river in the summer and early autumn occurred when food was most abundant. The decline in abundance of eels during mid and late autumn may be attributed to the spawning migration of mature individuals which move downstream in the autumn to spawning areas in the sea (Eales, 1968; Carlander, 1969). However, as most eels spend from 9-12 years in freshwater (Nikol'skii, 1961), with a maximum up to 20 years (Ogden, 1970), and may remain in one place in a river for long periods of time (Grunning and Schoop, 1962), it may be that the scarcity of specimens at nearshore areas is attributed to overwintering in deep pools as described by Adams and Hankinson (1928) in Ogden (1970) and Wenner and Musick (1975).

Information concerning movement of eels in relation to heated effluents is limited. Trembley (1960) found eels in a heated effluent when temperatures ranged from 33-35 C. In the present investigation no eels were captured in the heated effluent at temperatures above 30 C. However, eels moved into shore areas in the plume during autumn when temperatures reached 15-22 C. On the southside of the river they moved away from shore areas when temperatures ranged from 6-11 C.

Centrarchidae

Lepomis auritus (Linnaeus), redbreast sunfish

The redbreast sunfish was one of the most abundant species collected during the three-year investigation. Over half of the 1326 individuals (14-177 mm) were collected in the third year. Abundance was directly correlated with percent occurrence at nearshore areas on the southside of the river (Table 3). The mean abundance (8.7) of redbreast sunfish was significantly greater when temperatures ranged from 19-20 C (September) than those abundances ($\overline{X}$ = 0.32-5.27) in all other periods (Tables 4 and 6; Fig. 23). Correspondingly, mean numbers (3.13-5.27) of fish captured when temperatures ranged from 11-26 C (April-August) were significantly greater than those (0.32-1.07) taken at temperatures ranging from 3-12 C (October-March) (Tables 4 and 6; Fig. 23). The number ($\overline{X}$ = 5.27) of redbreast sunfish at

24-26 C (July-August) at nearshore areas on the southside of the river was significantly greater than that ($\overline{X} = 0.67$) in the heated effluent when plume temperatures ranged from 33-37 C (Fig. 23).

The abundance of redbreast sunfish was directly correlated with percent occurrence at nearshore areas in the heated effluent throughout the year (Table 3). Mean numbers (1.65-5.3) of fish collected when temperatures ranged from 15-27 C (September-November) and 17-29 C (April-June) were significantly greater than those ($\overline{X} = 0.67 - 1.45$) captured when temperatures ranged from 33-37 C (July-August) and 9-13 C (December-March) (Tables 5 and 7; Fig. 23). The number ($\overline{X} = 5.3$) of fish at nearshore areas in the heated effluent when temperatures ranged from 15-22 C (October-November) was significantly greater than that ($\overline{X} = 1.07$) on the southside of the river (6-11 C) (Fig. 23).

The greatest abundance of redbreast sunfish occurred during the summer and early autumn when its main food organisms (ephemeropterans and trichopterans; Woolcott, 1974) were most abundant. Woolcott (1974) found that more of these food organisms were present in stomachs of this species during these periods than in other ones. Mean numbers of fish declined in the late autumn and were lowest at nearshore areas in the winter. Breder and Nigrelli (1935) indicated that as autumn sets in, *L. auritus* seeks deep water in ponds and lakes avoiding the ruffled surface waters of autumn and winter. Most riverine fishes move away from the banks in winter to avoid the varying temperatures of the shallower shore regions (Nikolsky, 1963). Mean abundance of fish increased at nearshore areas on the southside of the river in the spring as temperatures increased to 11-14 C (April-May) from those (3-6 C) in the winter (December-March). Mean numbers of fish contined to increase at nearshore areas in the late spring when temperatures ranged from 19-23 C. Warmer weather attracts fishes to the banks for reproduction and feeding activities (Breder and Rose, 1966). Breder and Nigrelli (1935) indicated that as warming takes place in lakes and ponds, the redbreast sunfish begins to move about, and when the water reaches 16 C, males seek the shallow shoreline and start nest construction. Davis (1971), in a study of the spawning behavior of this species in North Carolina, reported that it spawns in shallow waters during late spring and early summer when water temperatures reached 22-26 C.

The greatest abundance of redbreast sunfish at nearshore areas in the heated effluent occurred in late autumn when plume temperatures ranged from 11-22 C (Fig. 23). During the same period significantly fewer fish were collected on the southside of the river (Fig. 23). It appears that the fish were attracted to the warmer plume temperatures. Brett (1956) indicated that most fish congregate within an area with temperatures within their preferred range. Abundance of fish in the winter declined as plume temperatures decreased and it is probable that the fish moved offshore into deeper water thus avoiding the fluctuating temperatures at the banks.

Lepomis macrochirus (Rafinesque), bluegill sunfish

Four hundred ninety-five bluegills (22-168 mm) were collected during the study, 50% of which occurred in the third year. Over half of the 255 individuals in the third year were collected on the southside of the river. Abundance was directly correlated with percent occurrence throughout the year on this side of the river (Table 3). Mean numbers of bluegill captured when temperatures ranged from 19-29 C (May-September) were significantly greater than those collected in other periods (Tables 4 and 6; Fig. 24). Lowest mean abundance occurred when temperatures were 3-13 C (October-May) (Tables 4 and 6; Fig. 24).

There was no statistical difference among the mean numbers of fish (range 1.3-2.3 fish per period) at nearshore areas throughout the year in the heated effluent (Table 5; Fig. 24). Although mean numbers of bluegill in the thermal plume were higher than those on the southside of the river during most periods (4), only when temperatures ranged from 15-22 C (October-November) were numbers of fish in the plume significantly greater than those on the southside of the river (Fig. 24).

There was a definite seasonal trend on the southside of the river (Fig. 24). Greatest abundance occurred from May-June which coincides with the spawning movement described by Breder and Rose (1966). Relatively equal numbers of bluegills were collected in the summer and early autumn when temperatures ranged from 19-24 C (July-September), a time when the greatest abundance of dipterans and ephemeropterans were present. Flemer and Woolcott (1966) indicated that these insects were the most abundant food organisms in the guts of bluegills taken from Tuckahoe Creek. As temperatures declined in October, numbers of fish decreased at nearshore areas. Lowest mean abundance of fish along the shore occurred when temperatures ranged from 3-6 C in the winter and presumably bluegills moved offshore and into deeper water.

A relatively constant standing crop of the bluegill was present in the heated effluent throughout the year (Fig. 24). Even during summer (July-August) when plume temperatures frequently ranged from 33-37 C (Δt 9-11), numbers of bluegills were comparable to those in winter(9-13 C; Δt 5-7). Although Fry and Pierce (1952) reported that the bluegill prefers temperatures around 32 C, the maximum abundance of fish in the present investigation occurred at 25-27 C (September). Similar results were reported by Dendy (1945), who indicated that bluegill prefer temperatures around 26 C. Correspondingly, Trembley (1960) indicated that maximum abundance of the bluegill in a heated effluent in the Delaware River occurred when temperatures ranged from 23-29 C (October-November). However, he also reported that they were relatively abundant from 34-38 C (May-July). Neill and Magnuson (1972) consistently found more bluegills in a heated effluent (10-30 C) than in reference areas (7-25 C) in Lake Monona, Wisconsin from July through November.

Micropterus dolomieui (Lacépède), smallmouth bass

Three hundred sixty-two smallmouth bass (18-390 mm) were collected, 70% of which occurred in the third year. Although the seasonal trend on the southside of the river in the second year paralleled that in the third, only those data in the latter year were of sufficient numbers for a thorough statistical analysis. Fifty-seven percent of the 253 individuals were collected from the southside of the river. Abundance was directly correlated with percent occurrence of fish at nearshore areas on the southside of the river throughout the year (Table 3). Mean numbers of fish were significantly greater when temperatures ranged from 19-20 C (September) than those from 3-6 C (December-March) but not from those in other periods (mean min. and max. temp. 10 and 25 C, respectively) (Table 4; Fig. 25). In general, maximum abundance occurred in the autumn and minimum in winter (Fig. 25).

In the heated effluent, mean abundance was significantly greater when temperatures ranged from 15-22 C (October-November) than those in other periods (Table 5; Fig. 25). Lowest abundance occurred in the heated effluent when mean temperatures ranged from 25-37 C (Δt 6-11) (Fig. 25).

The largest concentration of smallmouth bass at nearshore areas on the southside of the river occurred in the summer and early autumn and coincided with the greatest abundance of ephemeropteran naiads. Woolcott et al. (1975) reported that immature mayflies were the most abundant food organisms in stomachs of smallmouth bass during this part of the year. As temperatures declined in October, mean numbers of fish decreased at nearshore areas (Fig. 25). Abundance of this species was lowest in the winter when temperatures ranged from 3-6 C (December-March) and increased with rising temperatures in the spring (April-May). In a study of the movements of smallmouth bass in the Middle Snake River, Idaho, Munther (1970) indicated that they occupied shallow areas during the summer, moved into deeper water in the late autumn when the temperature dropped below 15.5 C and back into shallow areas in the spring. Similarly, Trautman (1957) said that smallmouth bass winter in deep water in rivers with a gradient (0.8 m/km) comparable to that in the present study area. Micropterus dolomieui is the first of the centrarchids to spawn with the coming of spring (Breder and Rose, 1966). Spawning usually occurs around 17 C but may begin as low as 13 C (Tester, 1932). In the present investigation the occurrence of smallmouth bass increased when comparable temperatures were recorded in the study area in April and May (Table 1; Fig. 25).

Smallmouth bass avoided the thermal effluent when plume temperatures ranged from 25-37 C (May-August). The greatest abundance and frequency of occurrence of fish in the heated effluent was in late autumn when temperatures ranged from 15-27 C. This range of temperatures approximates the preferred range of 20-28 C proposed by Ferguson (1958). The increase probably represents a preference for the warmer water because numbers of smallmouth bass in the plume were significantly greater than those on the southside of the river where temperatures averaged 6-12 C (Fig. 25). As temperatures continued to decline during the winter (av. plume temp. 9-13 C) and fell below the preferred range, numbers of fish decreased but were never as low as those on the southside of the river for this period.

Summary and Conclusions

The maximum abundance and percent occurrence of ten of the 17 species of fishes at nearshore areas on the southside of the river occurred in early autumn. Deviations from this pattern include N. analostanus, equally abundant throughout the year, and L. osseus, N. amoenus, N. ardens, N. rubellus, C. commersoni and L. macrochirus which were taken most often in periods other than early autumn.

In contrast, seven species of fishes at nearshore areas in the heated effluent attained maximum abundance in late autumn. Notable exceptions were L. macrochirus, equally abundant throughout the year, and L. osseus, C. carpio, N. rubellus and H. nigricans, which were more abundant in the spring. Except for L. macrochirus, all fishes were either absent or scarce at nearshore areas in the heated effluent when temperatures exceeded 30 C in the summer and early autumn, periods of greatest occurrence and abundance in ambient temperature water. In the winter abundance values of fishes in the heated effluent usually were comparable to those on the southside of the river.

The greatest abundance of some species of fishes, particularly cyprinids and catostomids, in the third year as compared to those in the first and second years, may possibly be related either to inherent year to year fluctuations of the species or to the influence of the flood associated with tropical storm Agnes in June, 1972. Although short term (three months) effects of the flood in this section of the river were reported by Woolcott et al. (1973), no attempt was made to analyse the long-range consequences (e.g. substrate alteration and/or changes in the availability of food organisms). Starrett (1950) encountered the same problem in his study on factors affecting the year to year abundances of fishes in the Des Moines River and said that the cause of yearly fluctuations of fishes and the effects of environmental and biological forces upon them are unknown. However, a report by Larimore (1954) showed that the time of flooding affected the producitivity of fishes in streams in Illinois by favoring certain spawning species and hindering others, therefore resulting in increases of numbers of some forms and decreases in others during certain years. Similar results were reported by Jones (1972) who stated that high water in Sagehen Creek, California in the summer may have benefitted the survival of some young-of-the-year species.

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Table 1. Mean water temperatures (C) on the south (ambient) and north (heated) sides of the James River near Bremo Bluff, Virginia on collection dates from August, 1971 - June, 1974. A horizontal line separates temperature periods.

1971-1972	Temperature ($\overline{X}$)		1972-1973	Temperature ($\overline{X}$)		1973-1974	Temperature ($\overline{X}$)	
	Amb.	Heat.		Amb.	Heat.		Amb.	Heat.
August 30	24	34	July 19	26	28	July 26	26	37
September 16	24	33	August 17	22	23	August 3	24	33
October 15	18	20	August 29	26	28	August 16	24	34
November 11	9	15	September 26	22	33	September 10	20	25
December 9	9	12	October 13	14	17	September 26	19	27
January 3	5	14	October 25	14	18	October 19	11	22
February 1	5	11	November 24	6	7	November 7	6	15
March 2	9	14	December 8	8	12	November 28	12	16
April 14	15	19	December 20	6	11	December 12	4	10
May 2	19	23	January 3	7	11	January 8	4	9
June 16	25	35	January 17	4	7	February 1	6	12
			February 14	2	6	February 20	3	10
			March 13	12	13	March 14	6	13
			April 16	11	14	April 1	11	17
			May 8	16	20	April 15	14	20
			June 4	21	25	May 6	13	18
						May 22	19	25
						June 19	23	29

Table 2. Species of fishes collected in the James River near Bremo Bluff, Virginia from August, 1971 to June, 1974. An asterisk denotes sample size sufficiently large for analysis of seasonal nearshore distributions.

Lepisosteidae - gars
Lepisosteus osseus - longnose gar *

Clupeidae -herrings
Dorosoma cepedianum - gizzard shad

Esocidae - pikes
Esox niger - chain pickeral

Cyprinidae - minnows and carps
Cyprinus carpio - carp *
Exoglossum maxillingua - cutlips minnow
Hybognathus nuchalis - silvery minnow
Nocomis leptocephalus - bluehead chub
Nocomis raneyi - bull chub *
Notemigonus crysoleucas - golden shiner
Notropis amoenus - comely shiner *
Notropis analostanus - satinfin shiner *
Notropis ardens - rosefin shiner *
Notropis cornutus - common shiner
Notropis hudsonius - spottail shiner *
Notropis procne - swallowtail shiner
Notropis rubellus - rosyface shiner *
Pimephales notatus - bluntnose minnow
Rhinichythys atratulus - blacknose dace
Semotilus corporalis - fallfish

Catostomidae - suckers
Carpiodes cyprinus - quillback
Catostomus commersoni - white sucker *
Erimyzon oblongus - creek chubsucker
Hypentelium nigricans - hog sucker *
Moxostoma cervinum - black jumprock
Moxostoma erythrurum - golden redhorse *
Moxostoma macrolepidotum - shorthead redhorse *
Moxostoma rhothoecum - torrent sucker

Table 2. Continued

Ictaluridae - freshwater catfishes
Ictalurus catus - white catfish
Ictalurus natalis - yellow bullhead
Ictalurus nebulosus - brown bullhead
Ictalurus punctatus - channel catfish *
Noturus insignis - margined madtom

Anguillidae - freshwater eels
Anguilla rostrata - American eel *

Poecilliidae - livebearers
Gambusia affinis - mosquito fish

Aphredoderidae - pirate perches
Aphredoderus sayanus - pirate perch

Centrarchidae - sunfishes
Lepomis auritus - redbreast sunfish *
Lepomis gibbosus - pumpkinseed
Lepomis gulosus - warmouth
Lepomis macrochirus - bluegill *
Micropterus dolomieui - smallmouth bass *
Micropterus salmoides - largemouth bass
Pomoxis nigromaculatus - black crappie

Percidae - perches
Etheostoma flabellare - fantail darter
Etheostoma nigrum - Johnny darter
Etheostoma olmstedi - tessellated darter
Etheostoma vitreum - glassy darter
Perca flavescens - yellow perch
Percina crassa - Piedmont darter
Percina notogramma - stripeback darter
Percina peltata - shield darter

Table 3. Correlation coefficients for abundance and occurrence data for each of the 17 species of fishes collected near Bremo Bluff, Virginia (July, 1973-June, 1974). An asterisk denotes significant correlation at $p = 0.05$ level.

Species	Correlation coefficient Southside (Ambient)	 Northside (Heated)
Lepisosteus osseus	0.9638*	0.9943*
Cyprinus carpio	0.9094*	0.7628
Nocomis raneyi	0.8740*	0.9554*
Notropis amoenus	0.8898*	0.2134
Notropis analostanus	-0.5259	0.4895
Notropis ardens	0.8118	0.9403*
Notropis hudsonius	0.7185	0.6532
Notropis rubellus	0.3729	0.9986*
Catostomus commersoni	0.9621*	0.9830*
Hypentelium nigricans	0.9092*	0.5052
Moxostoma erythrurum	0.8806*	0.9360*
Moxostoma macrolepidotum	0.8756*	0.8973*
Ictalurus punctatus	0.9612*	0.7996
Anguilla rostrata	0.9145*	0.9862*
Lepomis auritus	0.8622*	0.8874*
Lepomis macrochirus	0.8992*	0.5927
Micropterus dolomieui	0.8876*	0.7843

Table 4. Results of Duncan's new multiple test for mean numbers of fish for each of the 16 species of fishes collected at nearshore areas on the southside of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).[1] Underscored means do not differ significantly at $p = 0.05$ level.

Species	Southside					
Lepisosteus osseus						
Temp. period	D-M	S	A-M	M-J	J-A	O-N
$\overline{X}$	0.00	0.10	0.13	0.50	0.53	0.70
Cyprinus carpio						
Temp. period	O-N	D-M	M-J	J-A	S	A-M
$\overline{X}$	0.00	0.00	0.00	0.07	0.10	0.13
Nocomis raneyi						
Temp. period	D-M	A-M	O-N	M-J	J-A	S
$\overline{X}$	0.00	0.13	0.47	0.60	2.30	3.90
Notropis analostanus						
Temp. period	M-J	A-M	D-M	J-A	S	O-N
$\overline{X}$	5.40	10.30	10.40	13.50	15.70	17.80

Table 4. Continued

Species	Southside					
Notropis ardens						
Temp. period	M-J	J-A	D-M	S	O-N	A-M
$\bar{X}$	0.20	0.20	0.76	1.10	2.87	3.07
Notropis hudsonius						
Temp. period	D-M	M-J	A-M	O-N	J-A	S
$\bar{X}$	0.04	0.40	5.27	19.30	23.07	90.70
Notropis rubellus						
Temp. period	M-J	D-M	J-A	O-N	S	A-M
$\bar{X}$	0.00	0.16	0.30	1.53	1.20	1.40
Catostomus commersoni						
Temp. period	J-A	D-M	S	O-N	A-M	M-J
$\bar{X}$	0.07	0.20	0.20	0.27	0.33	0.60
Hypentelium nigricans						
Temp. period	D-M	M-J	A-M	J-A	O-N	S
$\bar{X}$	0.00	0.30	1.53	2.87	3.00	5.60

Table 4. Continued

Species	Southside					
Moxostoma erythrurum						
Temp. period	D-M	M-J	A-M	J-A	O-N	S
$\bar{X}$	0.00	0.00	0.13	1.27	1.40	1.80
Moxostoma macrolepidotum						
Temp. period	D-M	M-J	A-M	J-A	O-N	S
$\bar{X}$	0.04	0.30	0.40	1.13	2.07	8.20
Ictalurus punctatus						
Temp. period	D-M	A-M	O-N	M-J	J-A	S
$\bar{X}$	0.04	0.07	0.27	0.30	0.73	2.10
Anguilla rostrata						
Temp. period	D-M	A-M	M-J	O-N	J-A	S
$\bar{X}$	0.04	0.47	0.50	0.93	2.27	3.10
Lepomis auritus						
Temp. period	D-M	O-N	A-M	M-J	J-A	S
$\bar{X}$	0.32	1.07	3.13	4.60	5.27	8.30

Table 4. Continued

Species	Southside					
Lepomis macrochirus						
Temp. period	D-M	O-N	A-M	S	J-A	M-J
$\overline{X}$	0.08	0.40	0.67	1.50	1.67	2.60
Micropterus dolomieui						
Temp. period	D-M	O-N	M-J	A-M	J-A	S
$\overline{X}$	0.04	0.73	0.80	1.07	1.53	2.50

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[1] Abbreviations for temperature periods from July, 1973-June, 1974 used in Tables 4-7:

J-A	(July-August, Summer)
S	(September, early Fall)
O-N	(October-November, late Fall)
D-M	(December-March, Winter)
A-M	(April-early May, early Spring)
M-J	(late May-June, late Spring)

Table 5. Results of Duncan's new multiple range test for the mean numbers of fish for each of 16 species of fishes collected at nearshore areas on the northside (heated) of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). Underscored means do not differ significantly at $p = 0.05$ level.

Species	Northside					
Lepisosteus osseus						
Temp. period	J-A	D-M	S	O-N	A-M	M-J
$\bar{X}$	0.10	0.20	0.30	1.50	2.00	2.10
Cyprinus carpio						
Temp. period	J-A	S	D-M	M-J	O-N	A-M
$\bar{X}$	0.00	0.00	0.30	0.30	1.50	2.00
Nocomis raneyi						
Temp. period	M-J	A-M	D-M	S	J-A	O-N
$\bar{X}$	0.00	0.00	0.00	0.00	0.10	0.70
Notropis analostanus						
Temp. period	J-A	S	A-M	O-N	M-J	D-M
$\bar{X}$	0.40	1.40	8.50	9.50	13.80	36.60

Table 5. Continued

Species	Northside					
Notropis ardens						
Temp. period	J-A	A-M	S	D-M	M-J	O-N
$\bar{X}$	0.00	0.00	0.00	0.40	0.85	1.40
Notropis hudsonius						
Temp. period	J-A	S	M-J	D-M	A-M	O-N
$\bar{X}$	0.00	0.00	2.30	2.50	4.70	20.00
Notropis rubellus						
Temp. period	J-A	S	M-J	O-N	D-M	A-M
$\bar{X}$	0.00	0.00	0.00	0.08	1.70	2.00
Catostomus commersoni						
Temp. period	J-A	S	O-N	M-J	A-M	D-M
$\bar{X}$	0.00	0.00	0.00	0.00	0.50	0.66
Hypentelium nigricans						
Temp. period	J-A	D-M	S	O-N	A-M	M-J
$\bar{X}$	0.00	0.05	0.15	1.10	1.50	3.00

Table 5. Continued

Species	Northside					
Moxostoma erythrurum						
Temp. period	M-J	J-A	S	D-M	A-M	O-N
$\bar{X}$	0.00	0.00	0.00	0.10	0.70	1.03
Moxostoma macrolepidotum						
Temp. period	J-A	S	D-M	M-J	A-M	O-N
$\bar{X}$	0.00	0.00	0.30	0.50	1.00	3.10
Ictalurus punctatus						
Temp. period	D-M	M-J	A-M	J-A	S	O-N
$\bar{X}$	0.05	0.40	0.48	0.57	0.83	2.10
Anguilla rostrata						
Temp. period	J-A	M-J	A-M	D-M	S	O-N
$\bar{X}$	0.00	0.00	0.20	0.30	0.30	1.80
Lepomis auritus						
Temp. period	J-A	D-M	M-J	A-M	S	O-N
$\bar{X}$	0.67	1.45	1.65	2.70	3.65	5.30

Table 5. Continued

Species	Northside					
Lepomis macrochirus						
Temp. period	D-M	J-A	M-J	A-M	O-N	S
$\overline{X}$	1.30	1.30	1.30	1.50	2.20	2.30
Micropterus dolomieui						
Temp. period	J-A	M-J	D-M	A-M	S	O-N
$\overline{X}$	0.10	0.15	0.68	1.30	1.40	6.20

Table 6. Results of Duncan's new multiple range test for mean percent occurrences for each of the 17 species of fishes collected at nearshore areas on the southside of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). Underscored means do not differ significantly at p = 0.05 level.

Species	Southside					
Lepisosteus osseus						
Temp. period	D-M	O-N	A-M	S	M-J	J-A
$\bar{X}$	0.00	6.70	10.00	10.00	30.00	46.70
Cyprinus carpio						
Temp. period	M-J	D-M	O-N	A-M	J-A	S
$\bar{X}$	0.00	0.00	0.00	6.70	6.70	10.00
Nocomis raneyi						
Temp. period	D-M	A-M	O-N	M-J	S	J-A
$\bar{X}$	0.00	13.30	33.30	40.00	70.00	73.30
Notropis amoenus						
Temp. period	M-J	S	D-M	A-M	J-A	O-N
$\bar{X}$	0.00	0.00	4.00	13.30	13.30	33.30

Table 6. Continued

Species	Southside					
Notropis analostanus						
Temp. period	D-M	S	J-A	O-N	A-M	M-J
$\bar{X}$	88.00	90.00	93.30	93.30	93.30	100.00
Notropis ardens						
Temp. period	J-A	M-J	D-M	S	O-N	A-M
$\bar{X}$	13.30	20.00	36.00	40.00	40.00	46.70
Notropis hudsonius						
Temp. period	D-M	M-J	A-M	J-A	O-N	S
$\bar{X}$	4.00	30.00	33.00	73.30	86.70	90.00
Notropis rubellus						
Temp. period	M-J	S	D-M	O-N	A-M	J-A
$\bar{X}$	0.00	10.00	16.00	20.00	26.70	26.70
Catostomus commersoni						
Temp. period	J-A	S	D-M	O-N	A-M	M-J
$\bar{X}$	6.70	10.00	20.00	26.70	33.00	50.00

Table 6. Continued

Species	Southside					
Hypentelium nigricans						
Temp. period	D-M	M-J	A-M	O-N	J-A	S
$\bar{X}$	4.00	30.00	46.70	60.00	66.70	80.00
Moxostoma erythrurum						
Temp. period	D-M	M-J	A-M	J-A	S	O-N
$\bar{X}$	0.00	0.00	13.30	40.00	60.00	66.70
Moxostoma macrolepidotum						
Temp. period	D-M	M-J	A-M	O-N	J-A	S
$\bar{X}$	4.00	30.00	33.00	46.70	46.70	80.00
Ictalurus punctatus						
Temp. period	D-M	A-M	O-N	M-J	J-A	S
$\bar{X}$	5.00	6.70	20.00	30.00	46.70	80.00
Anguilla rostrata						
Temp. period	D-M	A-M	M-J	O-N	S	J-A
$\bar{X}$	4.00	33.00	50.00	53.30	90.00	93.30

Table 6. Continued

Species	Southside					
Lepomis auritus						
Temp. period	D-M	O-N	A-M	M-J	J-A	S
$\bar{X}$	20.00	66.70	73.30	80.00	86.70	100.00
Lepomis macrochirus						
Temp. period	D-M	O-N	A-M	J-A	S	M-J
$\bar{X}$	8.00	33.00	33.00	53.30	80.00	80.00
Micropterus dolomieui						
Temp. period	D-M	O-N	M-J	J-A	A-M	S
$\bar{X}$	4.00	40.00	50.00	60.00	67.00	80.00

Table 7. Results of Duncan's new multiple range test for the mean percent occurrences for each of 16 species of fishes collected at nearshore areas on the northside (heated) of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). Underscored means do not differ significantly at p = 0.05 level.

Species	Northside					
Lepisosteus osseus						
Temp. period	J-A	D-M	S	O-N	A-M	M-J
$\overline{X}$	11.00	16.60	29.00	83.30	100.00	100.00
Cyprinus carpio						
Temp. period	J-A	S	O-N	M-J	D-M	A-M
$\overline{X}$	0.00	0.00	16.70	25.00	30.00	66.70
Nocomis raneyi						
Temp. period	M-J	A-M	D-M	S	J-A	O-N
$\overline{X}$	0.00	0.00	0.00	0.00	8.30	25.00
Notropis analostanus						
Temp. period	S	J-A	D-M	M-J	O-N	A-M
$\overline{X}$	25.00	33.00	80.00	87.50	91.70	100.00

Table 7. Continued

Species	Northside					
Notropis ardens						
Temp. period	J-A	S	A-M	D-M	O-N	M-J
$\overline{X}$	0.00	0.00	0.00	20.00	33.00	50.00
Notropis hudsonius						
Temp. period	J-A	S	M-J	A-M	O-N	D-M
$\overline{X}$	0.00	0.00	25.00	33.00	66.70	70.00
Notropis rubellus						
Temp. period	M-J	J-A	S	O-N	D-M	A-M
$\overline{X}$	0.00	0.00	0.00	8.30	73.40	83.30
Catostomus commersoni						
Temp. period	M-J	J-A	S	O-N	D-M	A-M
$\overline{X}$	0.00	0.00	0.00	0.00	48.40	50.00
Hypentelium nigricans						
Temp. period	J-A	D-M	S	M-J	O-N	A-M
$\overline{X}$	0.00	5.00	16.50	25.00	41.70	66.70

Table 7. Continued

Species	Northside					
Moxostoma erythrurum						
Temp. period	M-J	J-A	S	D-M	O-N	A-M
$\bar{X}$	0.00	0.00	0.00	10.00	41.70	50.00
Moxostoma macrolepidotum						
Temp. period	J-A	S	D-M	M-J	A-M	O-N
$\bar{X}$	0.00	0.00	10.00	25.00	66.70	83.30
Ictalurus punctatus						
Temp. period	D-M	J-A	M-J	S	A-M	O-N
$\bar{X}$	5.00	22.00	41.50	46.00	50.00	66.70
Anguilla rostrata						
Temp. period	M-J	J-A	A-M	D-M	S	O-N
$\bar{X}$	0.00	0.00	16.70	23.40	25.00	83.30
Lepomis auritus						
Temp. period	J-A	M-J	A-M	D-M	O-N	S
$\bar{X}$	44.30	55.70	66.70	73.40	100.00	100.00

Table 7. Continued

Species	Northside					
Lepomis macrochirus						
Temp. period	J-A	D-M	M-J	O-N	A-M	S
$\bar{X}$	44.70	46.60	75.00	75.00	83.30	83.50
Micropterus dolomieui						
Temp. period	J-A	M-J	D-M	A-M	S	O-N
$\bar{X}$	11.00	16.50	31.60	66.70	87.50	100.00

Figure 1. The James River, Virginia study area.
Capital letters denote collecting transects.
1 mile equals 1.6 km.

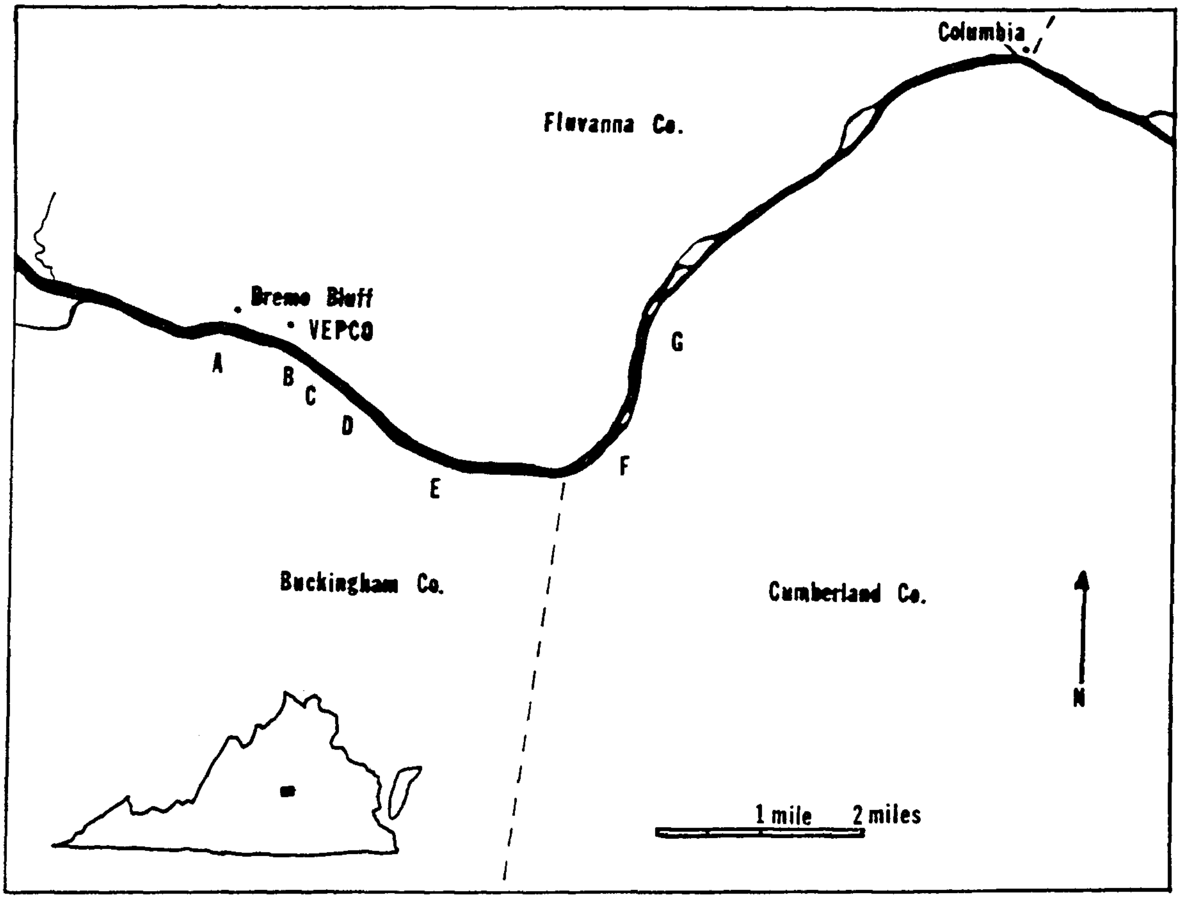
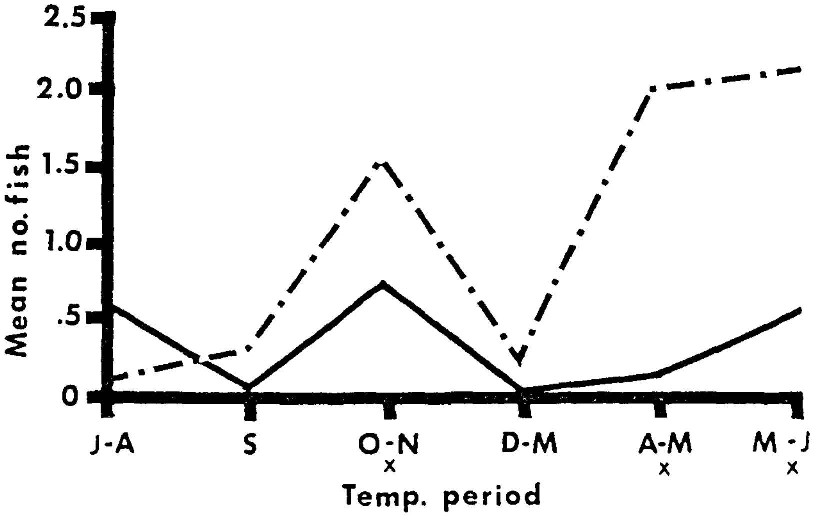
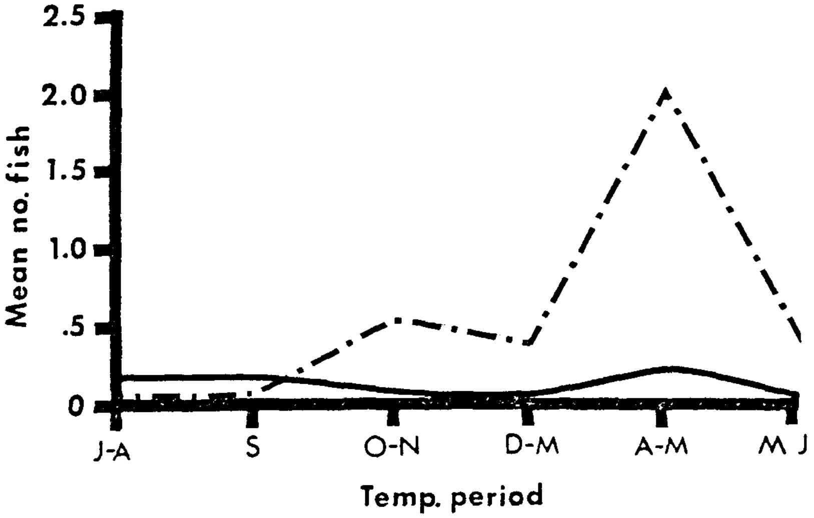

Columbia
Fluvanna Co.
Bremo Bluff
VEPCO
A
B
C
D
E
F
G
Buckingham Co.
Cumberland Co.
N
1 mile
2 miles

Figure 2. Mean numbers of Lepisosteus osseus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference ($p=0.05$) between sides.

Figure 3. Mean numbers of Cyprinus carpio by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).



Mean no. fish
2.5
2.0
1.5
1.0
.5
0
J-A
S
O-N
x
D-M
A-M
x
M-J
x
Temp. period

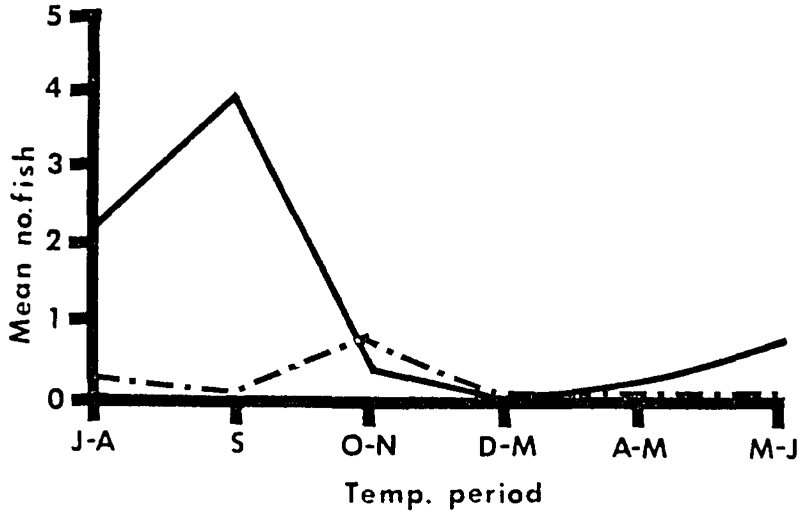


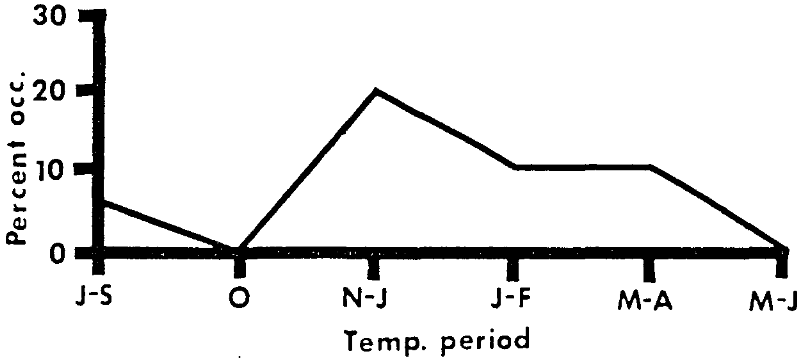
Mean no. fish
2.5
2.0
1.5
1.0
.5
0
J-A
S
O-N
D-M
A-M
M J
Temp. period

Figure 4. Mean numbers of Nocomis raneyi by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference ($p = 0.05$) between sides.

Figure 5. Mean percent occurrences of Notropis amoenus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1972-June, 1973).

Figure 6. Mean percent occurrence of Notropis amoenus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).


Mean no.fish
5
4
3
2
1
0
J-A
S
O-N
D-M
A-M
M-J
Temp. period


Percent occ.
30
20
10
0
J-S
O
N-J
J-F
M-A
M-J
Temp. period

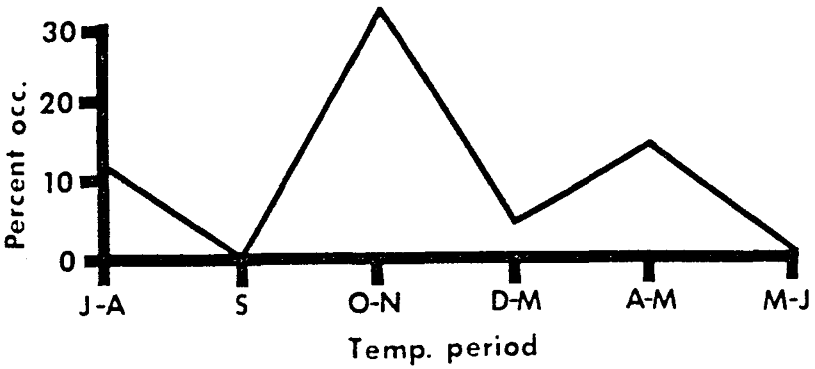
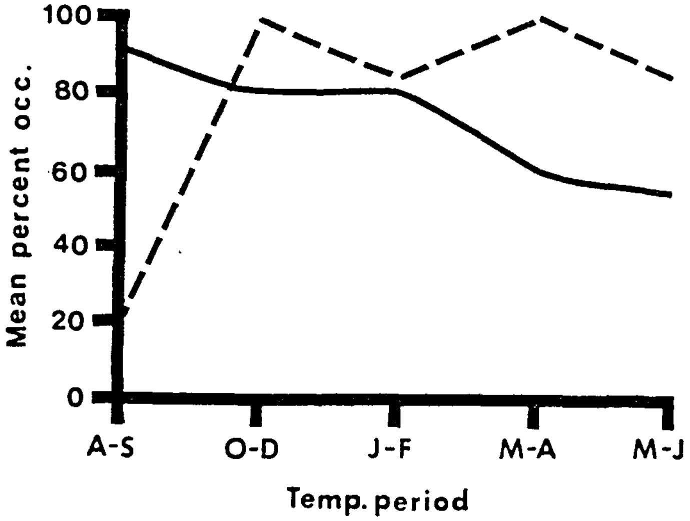

Percent occ.
30
20
10
0
J-A
S
O-N
D-M
A-M
M-J
Temp. period

Figure 7. Mean percent occurrence of Notropis analostanus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (August, 1971-June, 1972). An x by the temperature period denotes significant difference (p = 0.05) between sides.

Figure 8. Mean percent occurrence of Notropis analostanus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference (p = 0.05) between sides.


Mean percent occ.
100
80
60
40
20
0
A-S
O-D
J-F
M-A
M-J
Temp. period

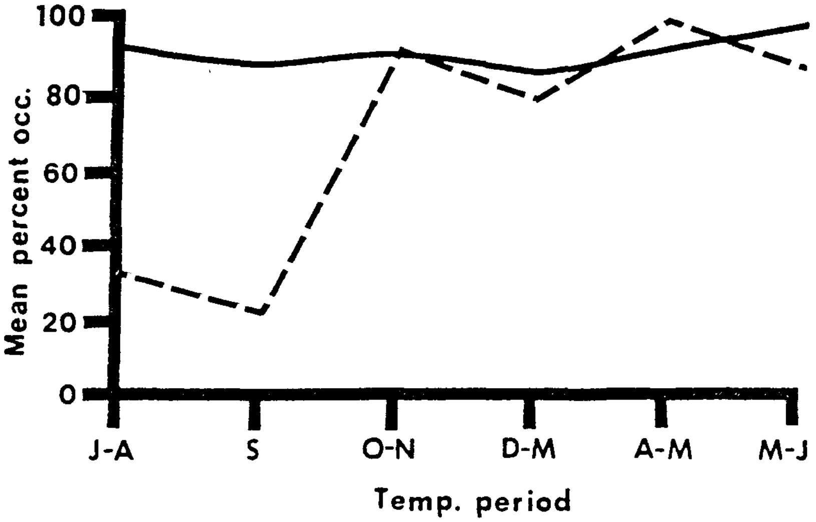
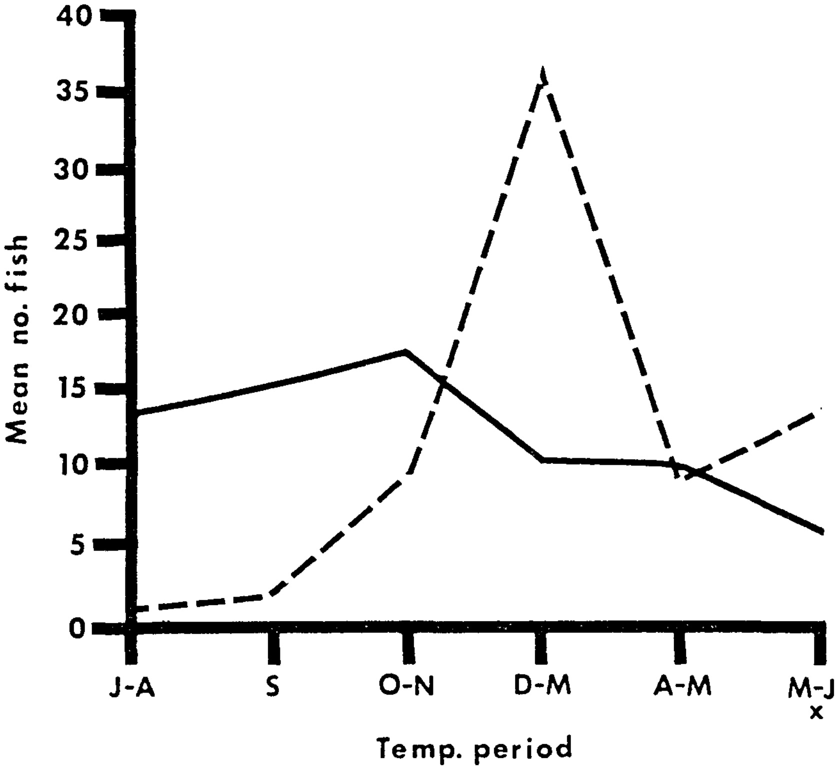

Mean percent occ.
100
80
60
40
20
0
J-A
S
O-N
D-M
A-M
M-J
Temp. period

Figure 9. Mean numbers of Notropis analostanus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x by the temperature period denotes significant difference ($p = 0.05$) between sides.

Figure 10. Mean percent occurrences of Notropis ardens by temperature period at nearshore areas on the south side (ambient; continuous line) of the James River near Bremo Bluff, Virginia (July, 1972-June, 1973).


40
35
30
25
20
15
10
5
0
Mean no. fish
J-A
S
O-N
D-M
A-M
M-J
x
Temp. period

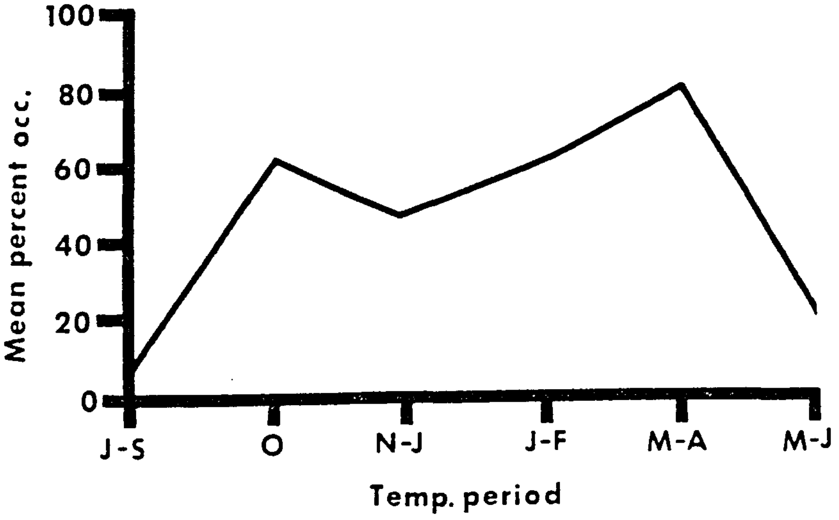
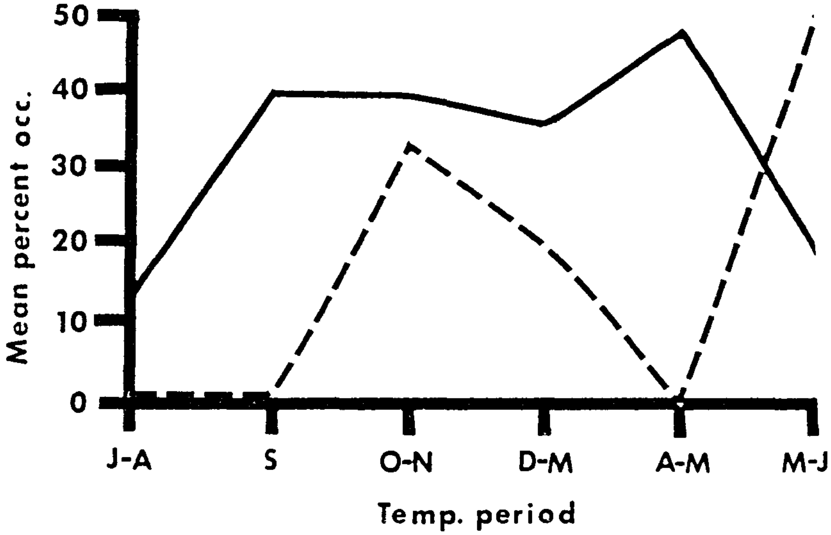

100
80
60
40
20
0
Mean percent occ.
J-S
O
N-J
J-F
M-A
M-J
Temp. period

Figure 11. Mean percent occurrences of Notropis ardens by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).

Figure 12. Mean numbers of Notropis ardens by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).


50
40
30
20
10
0
Mean percent occ.
J-A
S
O-N
D-M
A-M
M-J
Temp. period

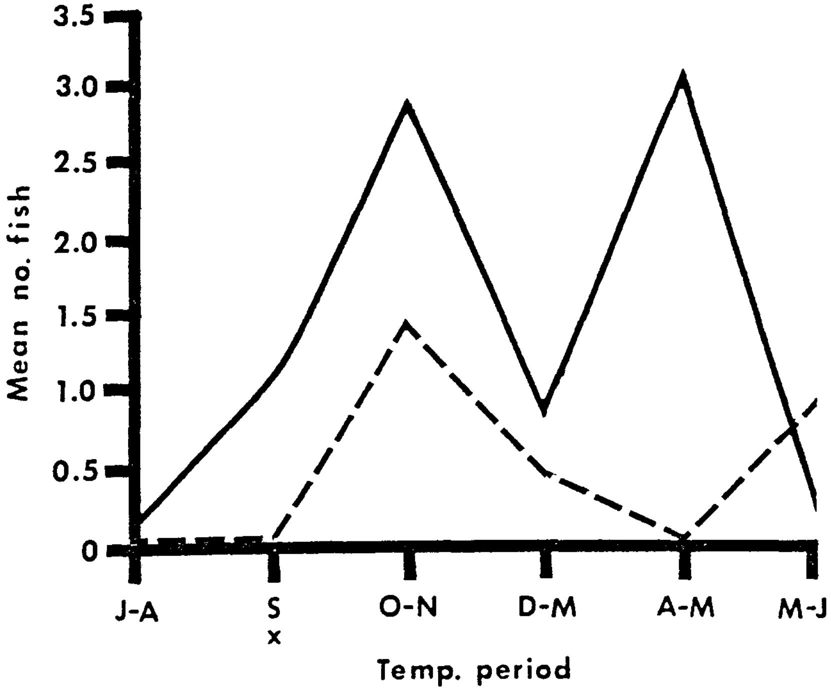
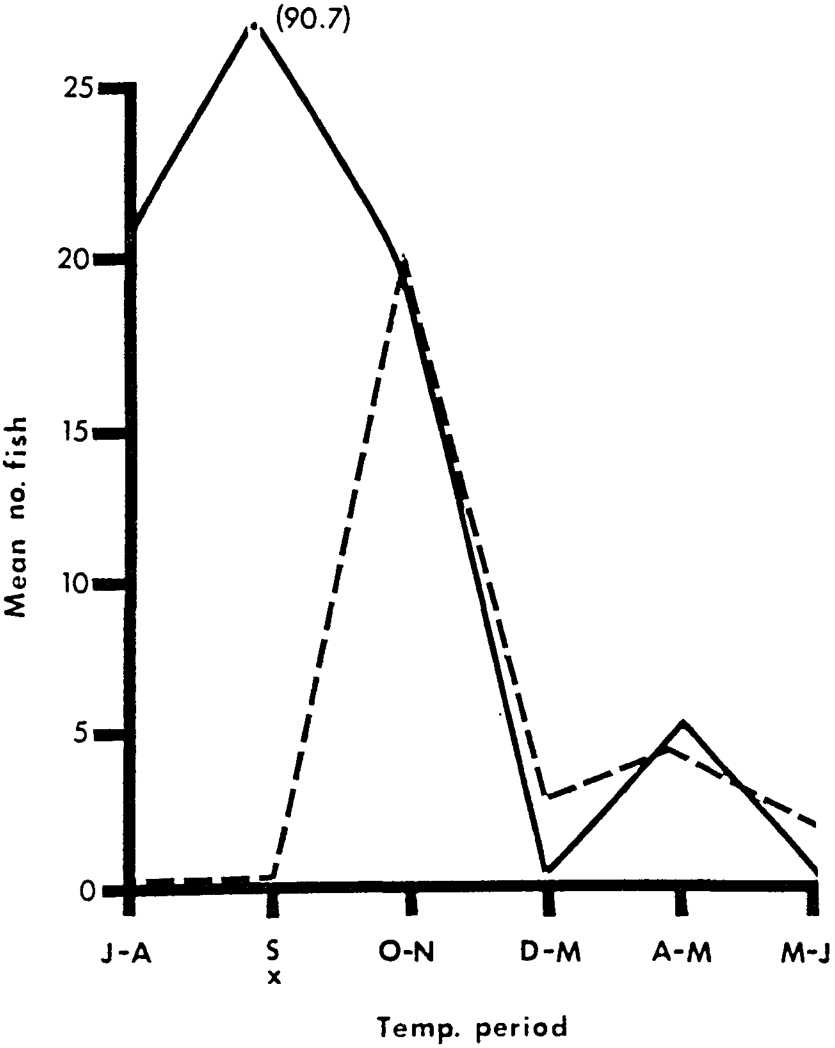

3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Mean no. fish
J-A
S
x
O-N
D-M
A-M
M-J
Temp. period

Figure 13. Mean numbers of Notropis hudsonius by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference (p= 0.05) between sides.

Figure 14. Mean numbers of Notropis rubellus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference (p = 0.05) between sides.


(90.7)
25
20
15
10
5
0
Mean no. fish
J-A
S
x
O-N
D-M
A-M
M-J
Temp. period

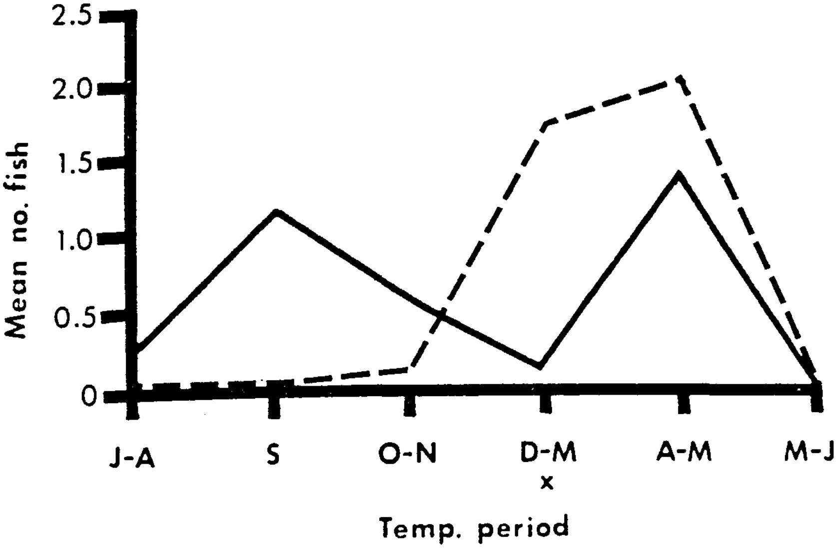
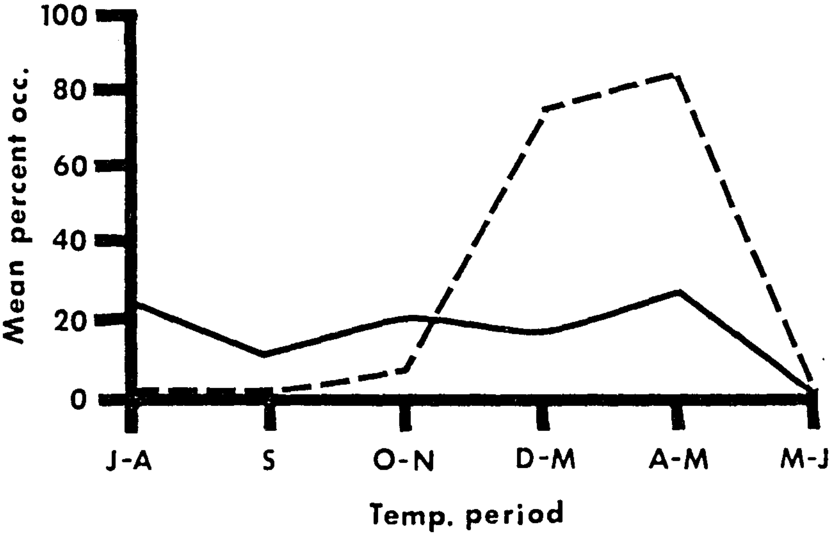
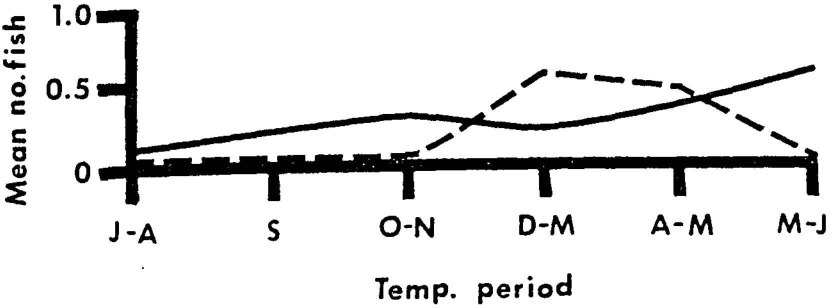

2.5
2.0
1.5
1.0
0.5
0
Mean no. fish
J-A
S
O-N
D-M
x
A-M
M-J
Temp. period

Figure 15. Mean percent occurrences of Notropis rubellus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).

Figure 16. Mean numbers of fish of Catostomus commersoni by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).

Figure 17. Mean percent occurrences of Catostomus commersoni by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).


100
80
60
40
20
0
Mean percent occ.
J-A
S
O-N
D-M
A-M
M-J
Temp. period


1.0
0.5
0
Mean no.fish
J-A
S
O-N
D-M
A-M
M-J
Temp. period

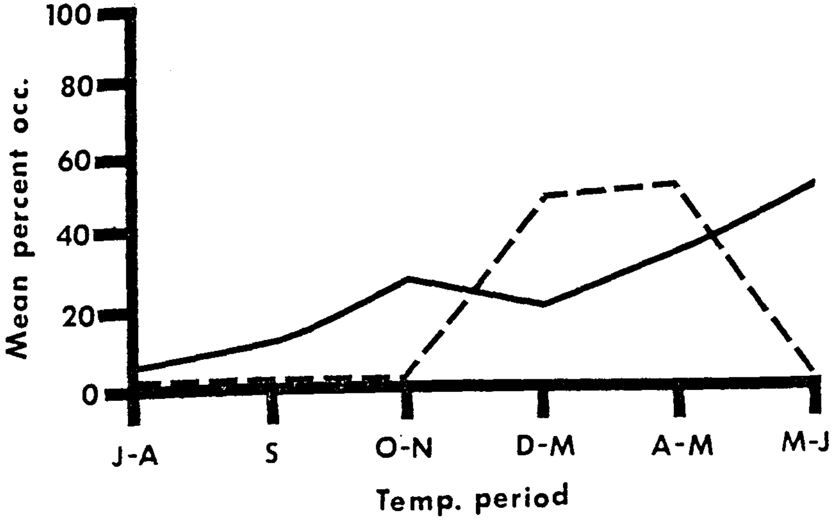
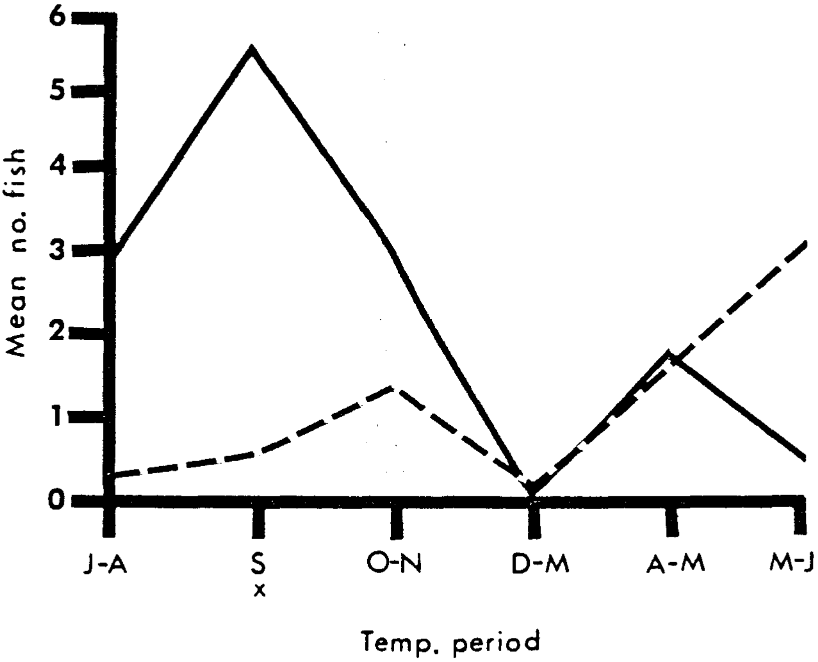

100
80
60
40
20
0
Mean percent occ.
J-A
S
O-N
D-M
A-M
M-J
Temp. period

Figure 18. Mean numbers of _Hypentelium nigricans_ by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference ($p = 0.05$) between sides.

Figure 19. Mean numbers of _Moxostoma erythrurum_ by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).


Mean no. fish
0
1
2
3
4
5
6
J-A
S
x
O-N
D-M
A-M
M-J
Temp. period

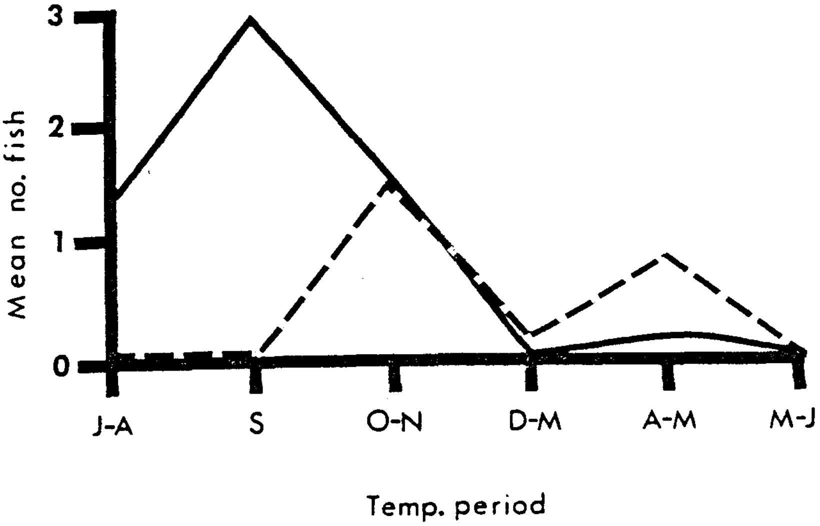
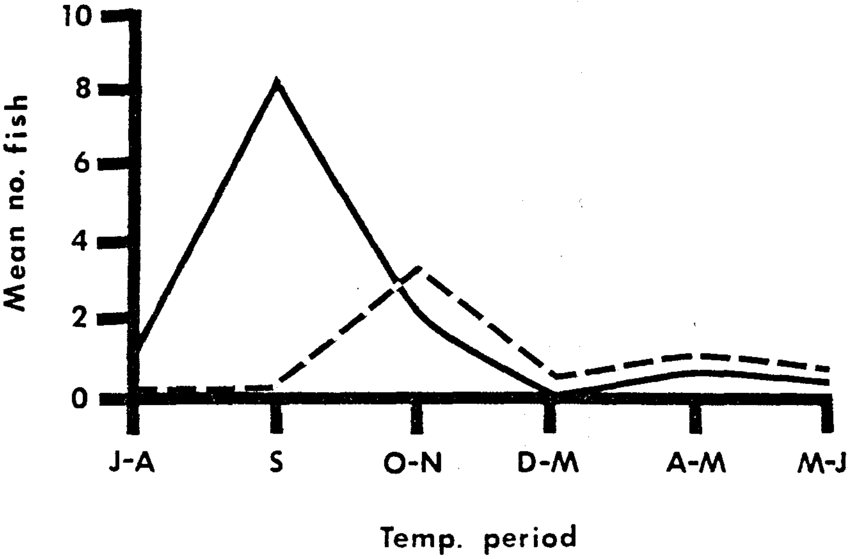

Mean no. fish
0
1
2
3
J-A
S
O-N
D-M
A-M
M-J
Temp. period

Figure 20. Mean numbers of Moxostoma macrolepidotum by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974).

Figure 21. Mean numbers of Ictalurus punctatus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference ($p = 0.05$) between sides.


10
8
6
4
2
0
Mean no. fish
J-A
S
O-N
D-M
A-M
M-J
Temp. period

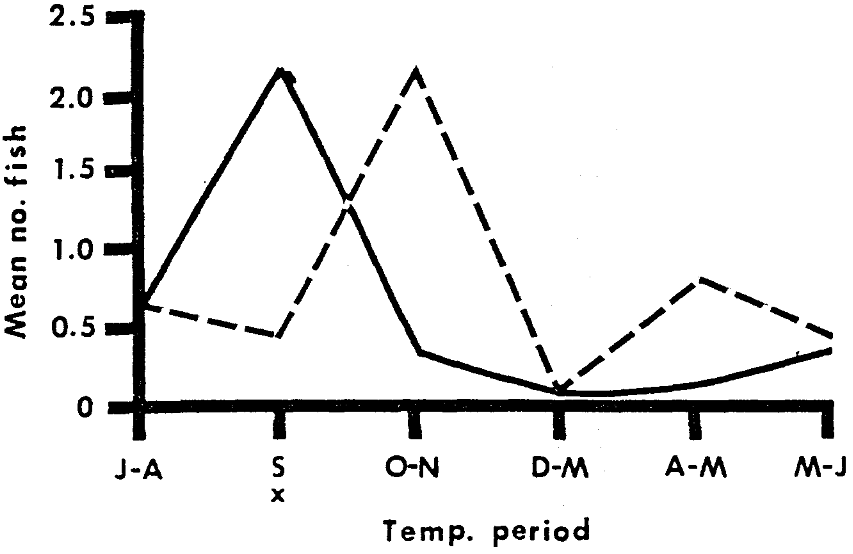
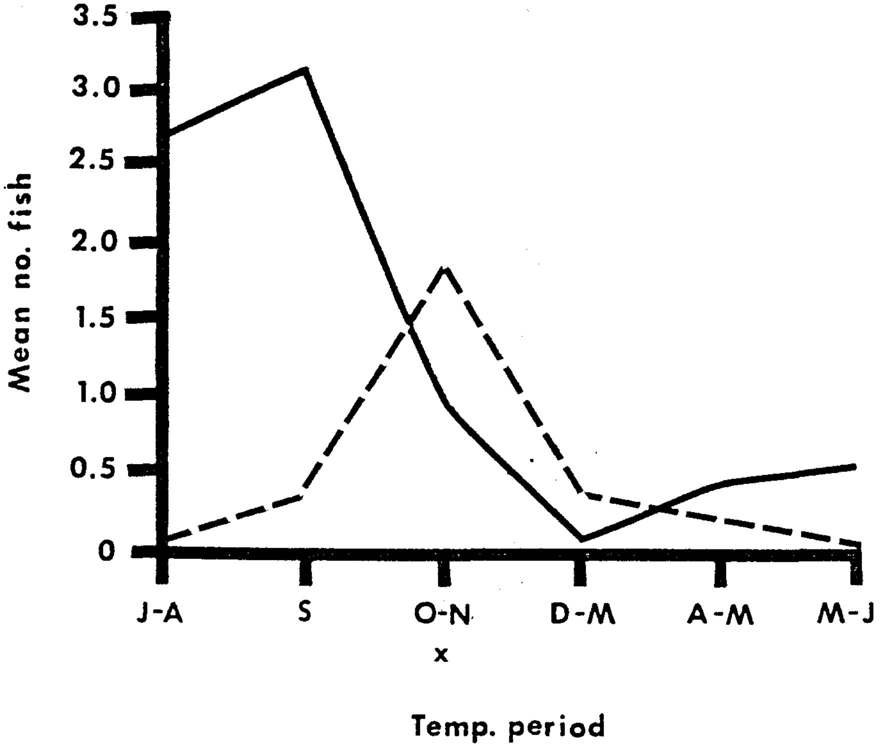

2.5
2.0
1.5
1.0
0.5
0
Mean no. fish
J-A
S
x
O-N
D-M
A-M
M-J
Temp. period

Figure 22. Mean number of <u>Anguilla</u> <u>rostrata</u> by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference (p = 0.05) between sides.

Figure 23. Mean numbers of <u>Lepomis</u> <u>auritus</u> by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference (p = 0.05) between sides.


3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Mean no. fish
J-A
S
O-N
x
D-M
A-M
M-J
Temp. period

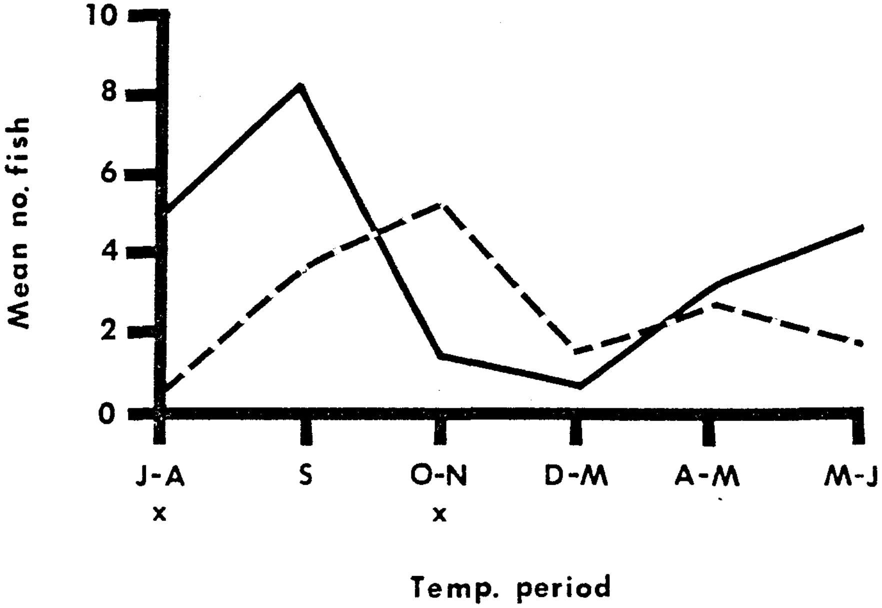
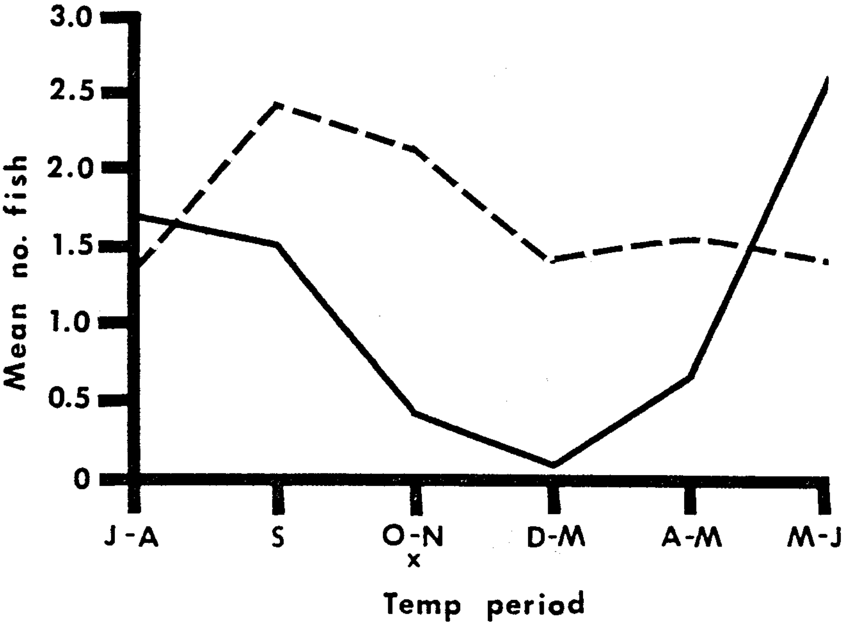
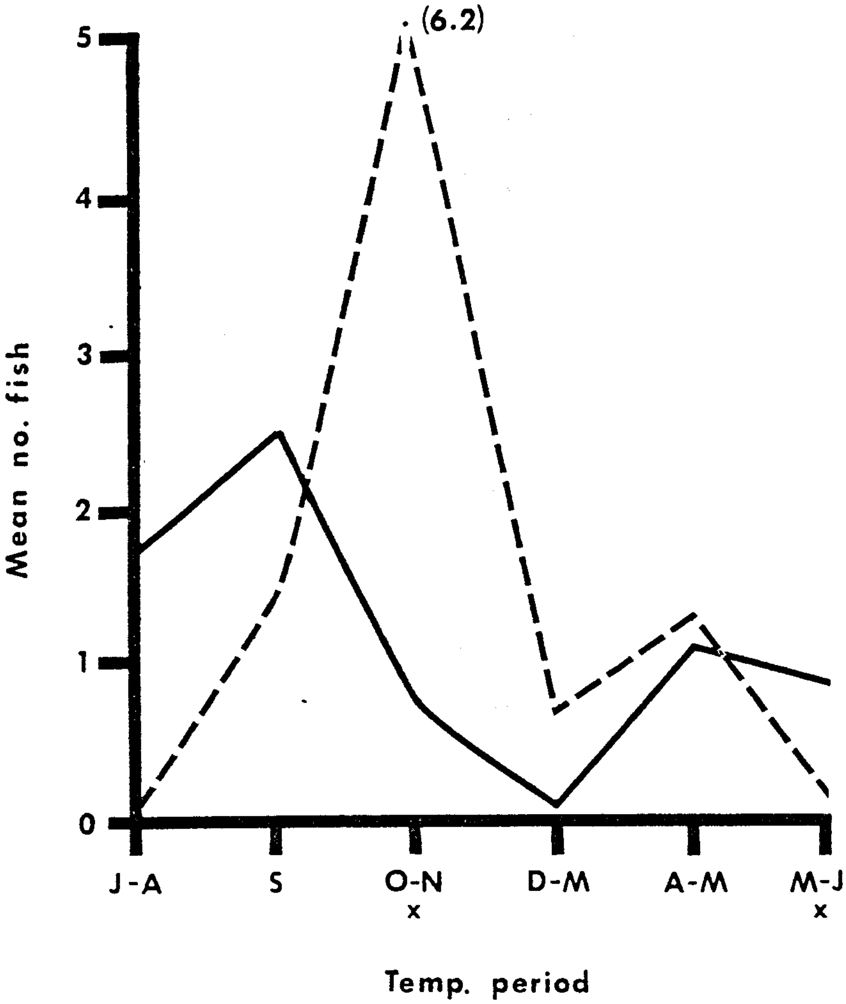

10
8
6
4
2
0
Mean no. fish
J-A
x
S
O-N
x
D-M
A-M
M-J
Temp. period

Figure 24. Mean numbers of Lepomis macrochirus by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference ($p = 0.05$) between sides.

Figure 25. Mean numbers of Micropterus dolomieui by temperature period at nearshore areas on the south (ambient; continuous line) and north (heated; broken line) sides of the James River near Bremo Bluff, Virginia (July, 1973-June, 1974). An x at the temperature period denotes significant difference ($p = 0.05$) between sides.


3.0
2.5
2.0
1.5
1.0
0.5
0
Mean no. fish
J -A
S
O-N
x
D-M
A-M
M-J
Temp period


(6.2)
5
4
3
2
1
0
Mean no. fish
J -A
S
O-N
x
D-M
A-M
M-J
x
Temp. period

Vita

Eugene George Maurakis was born October 23, 1948 in Danville, Virginia where he attended public schools. He entered Richmond College in 1967 and during his part-time enrollment, worked for three and one-half years at the Virginia State Water Control Board and in the Division of Aquatic Biology at the Virginia Institute for Scientific Research. He received a Bachelor of Arts degree from the University of Richmond in May, 1974. The following autumn he began graduate study at the University of Richmond where he was initiated into Beta Beta Beta Biological Honor Society and the Society of Sigma Xi. During his tenure as a graduate student he worked as a part-time laboratory assistant and instructor in the Biology Department. Requirements for the Master of Science degree from the University of Richmond were completed in August, 1976.