BIOLOGICAL IMPACT ASSESSMENT

V. BIOLOGICAL IMPACT ASSESSMENT

A. Introduction

Biological field investigations relating to the preoperation and operation of the J. M. Stuart Station were initiated in 1970. Reports relating to these studies include: Miller (1970-1971), Miller, Kallendorf and Reed (1971-1972), Miller and Kallendorf (1972-1973), Reed et al. (1974), Smiddy (1974), Hater (1975), Miller et al. (1975), Gammon and Norris (1970), Norris and Gammon (no date), Hatch and Gammon (1973), Lesniak and Gammon (1974), Yoder and Gammon (1975), Yoder and Gammon (1976).

Summaries of the relevant conclusions will be presented as they relate to direct biological impact on major trophic levels. Indirect or synergistic effects of the thermal effluent will be discussed in Section VI of this document.

B. Phytoplankton

Studies of the effects of the J. M. Stuart Station thermal effluent on primary productivity in Little Three Mile Creek (LTMC) and the Ohio River have been conducted since 1970 (Miller, 1970-1971; Miller, Kallendorf and Reed, 1971-1972; Miller and Kallendorf, 1972-1973; Reed et al., 1974; Hater, 1975; and Miller et al., 1975). Summaries of the results are presented herein; the complete reports are available as appendices to this document. Figure V-1 shows the study area and sampling locations (IA, IB, II and III) utilized throughout these studies.

Data presented by Miller and Kallendorf (1972-1973, p. 12-14) represent the effect of the J. M. Stuart Station thermal effluent on photosynthesis on a seasonal basis (Figure V-2). When ambient Ohio River temperatures (Figure V-3) exceeded 10°C (50°F) (April-November), primary production was reduced in LTMC (on the average of 70 percent at Station IA and 35 percent at Station IB) when compared to an upstream control area (Station II) on the Ohio River. However, when ambient Ohio River temperatures were less than 10°C (50°F) (December-March), photosynthesis at LTMC Station IA was enhanced 60 percent of the time. Photosynthetic rates at Station III were annually 20 percent higher than at Station II. These data indicate that the reduction of phytoplankton photosynthesis occurring in LTMC from April through November was buffered by thermal mixing occurring in the Ohio River. Miller and Kallendorf (1972-1973, p. 14) conclude: "In summary, the response of the photoplankton production to thermal increases of IA were similar in 1971 and 1972, except that with the higher mean temperature increases during 1972, the repression of photosynthesis in Little Three Mile Creek was more severe than in 1971 (greater than 90 percent inhibition on three days). However, like 1971 little effect of the addition of the thermally enriched waters in the channel of Little Three Mile Creek could be found in the warm water plume as it mixed with the Ohio River water (Station III). The mixture of warm and cool waters stimulated the primary production more often than not (6 out of 10 dates)."

This type of recovery was seen in laboratory experiments (Miller, Kallendorf and Reed, 1971-1972, p. 34-35) with an Ohio River algal assemblage within three hours after an exposure to 17°C (30.6°F) ΔT thermal shock for one hour (acclimation temperature = 5°C). A pattern of no recovery from thermal shock was seen in Ohio River algae after exposure to a 27°C (48.6°F) ΔT thermal shock for one hour.

Another series of experiments showed that the effects of an 8-minute shock and a 2-hour shock were very similar in their effects on algal photosynthesis (Miller et al., 1971-1972, p. 43). Thus, it appears that either a direct discharge of thermal effluent into the Ohio River or into a discharge channel like LTMC would result in similar short-term stimulation or depression of photosynthetic rate after returning to ambient temperature downstream.

Results of primary productivity analyses for 1973 studies (Reed et al., 1974) are shown in Figure V-4. These results show a similar relationship between the Ohio River and LTMC as discussed above.

Miller et al. (1975) summarized the four years of data by clumping the proportionate change in primary production of heated stations compared to ambient (Station II, Figure V-1) by 5°C intervals for ambient temperature and for temperature increase (ΔT). Figure V-5 shows the photosynthetic response surface for variation in ambient temperature and ΔT. Small temperature increases (ΔT<5°C) are stimulatory over a range of ambient temperatures up to 20 to 25°C (68 to 77°F) and large ΔT's are stimulatory only at cold ambient temperatures (<5°C). This plot represents only the mean response; the average coefficient of variation for the points plotted was 57 percent of the mean. Thus, on any given date the pattern may deviate from this substantially. Variation caused by mechanical effects, time lag effects and seasonal variation in phytoplankton composition confounds the analysis. In general, any absolute temperature (ambient temperature + ΔT) less than 25°C (77°F) caused stimulation of primary production. At ambient temperatures greater than 25°C (77°F), however, all temperature increases on the average caused inhibition of plankton production (Table V-1) (Miller *et al.*, 1975).

The retention of entrained phytoplankton in the discharge channel allowed a significant recovery of primary production between Stations IA and IB. The null hypothesis that the difference between primary production rates at Stations IA and IB was zero was tested using a group comparison 't' test. The observed 't' = 2.038 > critical $'t'_{.05(82)}$ = 2.00; thus, there appears to be a significant difference in the production rates between the two stations. Since no differences in species composition or biomass of algae were found at Station IB, either the algae became acclimated to the warmer water at Station IB in the hour of retention or the apparent recovery was caused by a drop in temperature of about 3°C between stations. The average production rate at Station IA was 6.56 mg $C/m^3/hr$ and at Station IB, 9.57 mg $C/m^3/hr$. The average difference in ΔT between Stations IA and IB was 2.2°C in 1971, 2.8°C in 1972, 0.3°C in 1973, and only 0.1°C in 1974 on the dates both stations were evaluated (Table V-1). Thus, recovery might come both from acclimation to changed temperature and from temperature decreases at Station IB.

In order to determine whether the observed photosynthetic rate changes at Station IA were caused by the temperature rise or by mechanical damage from passing through the condenser tubes and the aerators, Miller et al. (1975) collected duplicate bottles of water from the control station (II), transferred them to the dark and incubated them with $NaH^{14}CO_3$ at 10 cm depth in the hot water stations, IA or IB. On 16 dates when the average primary production of entrained phytoplankton at Station IA was 7.96 mg C/m^3/hr (Coefficient of variation = 146 percent), bottle-transferred phytoplankton at Station IA had an average production of 10.9 mg C/m^3/hr (Coefficient of variation = 177 percent). Although the transferred algae appeared to fix carbon at a higher rate, a group comparison 't' test showed that the difference between the paired determinations was not significantly different from zero (observed 't' = 0.971 < critical $'t'_{.05(30)}$ = 2.042, NS). Thus, stimulation or inhibition of primary production at higher temperature stations appeared to be primarily a temperature response.

During most of 1971 the plant operated two units; summer, 1972 and 1973, three units; and 1974, four units. During 1974 the condenser cooling function of one unit was always handled by a natural draft cooling tower. The ΔT increased from 1971 to 1972-73 and dropped in 1974. An increasing and then decreasing inhibition of algal production at Stations IA and IB over that period agree with the pattern of temperature increase and decrease from 1971 to 1974 (Table V-1). If the proportion of experimental dates on which algal production was reduced is examined, the same pattern emerges (Table V-1, values in parentheses). At Station III the mild temperature increases were on the average stimulatory to algal production, and the percentage of dates on which inhibition was observed has been reduced compared to Stations IA and IB.

A list of algal taxa identified during these studies is presented in Table V-2.

The overwhelming conclusion from these studies is that the thermal discharge from the J.M. Stuart Station has decreased primary productivity from approximately April to November in LTMC, but has not caused appreciable harm to the photosynthetic capacity of the Ohio River. Studies further indicate that natural phenonema such as heavy rains, increased river discharge, and increased silt load cause far greater variation in the year-to-year total primary production than the thermal load from the J.M. Stuart Station (Miller and Kallendorf, 1972-1973; Hater, 1975). Miller and Kallendorf (1972-1973, p. 20) state: "The effect of the operation of the Stuart Station in no way can compare to this natural year-to-year variation. The slight temperature increases of the plume in the Ohio River were actually stimulatory of algal production (120 percent mean increase at Station III compared to Station II), even though there was marked inhibition at Station IA (30 percent of the Station II control at Station IA, April-November, 1972)."

C. Periphyton

Periphyton primary production on artificial substrates (glass slides) was measured at the J. M. Stuart Station from 1970 to 1972 (Miller, 1970-1971; Miller, Kallendorf and Reed, 1971-1972).

Miller et al. (1971-1972, p. 51-52) found that the ash-free dry weight of periphyton ranged from 50 to 1400 mg organic weight/m^2 of surface area. The maximum biomass in the Ohio River occurred during the summer and fall when Ohio River flow was lowest, whereas it occurred during the winter in February and March of both 1971 and 1972 in the heated areas of LTMC (Miller et al., 1971, p. 52). The minimum biomass in LTMC occurred during the summer.

The primary production of the periphyton increased most rapidly in the Ohio River in May and June, remaining high until October. In the warm water stations, IA and IB, the production rate in the spring increased more rapidly than in the river (Figure V-6). The highest production rate, 205 mg/m^2/hr, occurred at Station III in the autumn when again temperature may have been optimal for growth, before the high flows began. The following sequence was noted in terms of maximum periphyton growth and production (Miller et al., 1971-1972, p. 53): "The temperature optimum for attached algal growth caused a sequence of maximum production first in the spring in the warmest water Stations IA and IB, then at ambient in the summer at Station II, and finally at slightly above ambient at Station III downstream from the weir."

Thus, although decreases in periphyton production and biomass on artificial substrates occurred at the heated stations during the summer, the impact on the naturally-occurring periphyton community is difficult to assess. The Ohio River offers very limited natural surface area for periphyton growth where light penetration is suitable for photosynthesis (Miller, 1970-1971, p. 23-24). This fact reduces the considerations of appreciable harm on this community component.

D. Zooplankton

Results of zooplankton mortality studies at the J. M. Stuart Station during July, August, and September, 1974 have been reported by Reed et al. (1974) and Miller et al. (1975). These reports are included as an appendix to this document and the pertinent results are summarized herein.

Zooplankton mortality, measured during the summer of 1974, was significantly increased by retention at high temperatures during the transit time from Station IA to IB (Figure V-1). These stations had an average ΔT of 7 to 8°C (12.6 to 14.4°F) over the study dates, with a maximum ΔT of 10°C (18°F). The ambient temperatures decreased seasonally from 28.5 to 20.5°C (83.3 to 68.9°F) over that period (Figure V-7). Zooplankton density was maximal during July (200 animals/liter) and declined through mid-September to less than 10 animals/liter (Figure V-8). The decline was probably caused by the effect of declining temperature on zooplankton reproduction rates. In September, increased discharge effectively increased the washout rate. The total densities were not significantly different between stations; however, the average percentage of dead zooplankton (cladocera, copepods and rotifers) increased from Station II (16.1%) to Station IB (37.8%) (Figure V-9). A two-way analysis of variance to partition the variance in the percentage dead (arcsine transform) between sample date and station showed that both main effects were significant (Table V-3).

The mortality was taxon-selective, being especially high in the larger cladocera, Daphnia sp. (Reed et al., 1974). In July at Station IB, 100 percent of the cladocera were dead compared to 22.7 percent of the copepoda and zero percent of the rotifers.

Entrained zooplankton suffered a substantial increase in mortality as the water passed down the channel. At the discharge (Station IA) mortality was 5.1 percent higher than in the river; at the weir (Station IB), 21.7 percent higher on the average. Apparently, increased numbers of animals were dying in the discharge channel and the sensitivity of the animals was greatest in mid-summer when the absolute temperature was the highest. Storr (1974), at two power plants, could not find a significant latent effect. Carpender et al., (1973) found that mortality of zooplankton at the condenser discharge was only 15 percent; however, the eventual mortality could be as high as 70 percent. Recovery of mobility up to 20 percent has been reported four hours from the time of discharge (Butz et al., 1974). Reed et al., (1974) and Miller et al., (1975) found that temperatures greater than 30°C (86°F) had significant zooplankton mortalities associated with them, although it was impossible to separate mechanical damage from thermal damage with these data.

Even if 100 percent mortality occurred during summer months, at a flow of 11,500 cfs, for example, the plant would remove less than 13 percent of the population, based on a three-unit intake of 1,458 cfs and assuming even distribution of zooplankters. Realistic mortality figures reduce this percentage considerably. It is therefore reasonable to conclude that the J. M. Stuart Station operation will not appreciably harm this component of the aquatic community.

E. Macroinvertebrates

Investigations of the impact of the J. M. Stuart Station thermal effluent on the macroinvertebrates of LTMC and the Ohio River have been conducted by Gammon and Norris (1970); Norris and Gammon (no date); Reed et al., (1974); and Miller et al., (1975). Analyses have included general substrate identification (Norris and Gammon, no date), use of artificial substrates such as Hester-Dendy multiple-plate samplers and rock basket samplers (Gammon and Norris, 1970; Norris and Gammon, no date; Reed et al., 1974; Miller et al., 1975) and sampling of natural substrates (Norris and Gammon, no date; Reed et al., 1974). The detailed results of these studies are too extensive to be included in this report; consequently, a brief summary of the conclusions will be presented and the complete reports included as appendices.

Norris and Gammon (no date) studied the macroinvertebrate fauna before and after the J. M. Stuart Station began operation. Hester-Dendy samplers were used in the summer of 1970 before and after initial plant operation and a series of Peterson dredge samples were taken in 1971. The change in macroinvertebrate colonization of Hester-Dendy samplers in LTMC before and after plant start-up (Norris and Gammon, no date, pp. 31-38) was primarily due to a shift from an abundance of midges to an abundance of caddisfly pupae, respectively. It is not clear from the data what was responsible for the shift, although the authors (p. 38) concluded that it was increased temperature. It is possible that thermal elevations from the J. M. Stuart Station caused emergence of caddisflies and midges after plant start-up in September. Since there was a four-month spread between sampling dates, and a 79-day spread in incubation time, the change may have been due to normal seasonal variations and completion of life cycles.

A general description of the bottom sediments present at the various sampling locations (Figure V-10) during 1970-1971 is shown in Table V-4. After 1971, station designations were changed as illustrated in Figure V-1.

During the period 1970-1974 benthic macroinvertebrates and macroinvertebrates colonizing artificial substrate samplers were virtually eliminated from the thermally affected reach of LTMC by the summer of 1973 (Figure V-11) as ΔT's rose with increased generating capabilities and loads (Reed _et al_., 1974). Before the plant began operation in 1970, Hester-Dendy samplers placed in LTMC yielded an average of 74 organisms/sampler in July (after 44 days incubation); by October, 1970 (after 123 days incubation) after the plant had become operational with one unit (Unit 2), a subsequent set of samplers contained an average of 66 organisms/sampler (Norris and Gammon, no date). In 1973, with three once-through units operational, no macroinvertebrates were collected on artificial substrate basket samplers from the thermally affected area of LTMC during the period June to October (Reed _et al_., 1974, p. 24). Samples from the Ohio River stations yielded between 54-107 organisms/sampler (Station II), representing 10 taxa and from 12-71 organisms/sampler (Station III), representing 9 taxa (Reed _et al_., 1974, p. 24).

During the summer of 1974 macroinvertebrates were able to recolonize the artificial substrate samplers implaced in LTMC (Miller _et al_., 1975). Hester-Dendy samplers contained 17-21 organisms/sampler at Station IB in September-October, representing 6 taxa. The density at Stations II and III (Ohio River) ranged from 13-151 (5 taxa) and 33-74 (4 taxa) individuals/sampler over the summer.

Benthic macroinvertebrate density and diversity in the Ohio River (natural substrates, Station II) showed much the same pattern between 1973 and 1974 (Figures V-11 and V-12). The groups in order of numeric importance were oligochaetes, midges, _Chaoborus_, fingernail clams, and damselfly larvae (Miller _et al_., 1975, p. 15-16). In May, June, and July, 1974, Stations IB, II, and III had very similar densities (Figure V-12); however, in 1973 at Stations IA and IB (LTMC), almost all organisms had disappeared from samples by late June as the maximum temperature reached 40°C. By May, 1974 the density at Station IB had increased to approximately 5,000 organisms/m^2 similar to Ohio River Stations II and III (Figure V-11). In contrast to 1973, the density at Station IB remained as high as Station II throughout the summer of 1974.

Regarding the results of benthic grab samples and colonization of artificial substrate basket samplers in LTMC, Reed _et al_., (1974 p. 26) states:

"Thus, containment of once-through cooling water in LTMC did support a lesser density of benthic invertebrates than did the Ohio River. This area was probably not a major food source for fish prior to plant construction. Thus, the decrease is of little consequence to the food base for fish in the Ohio River. However, the complete elimination of drift organisms on drift samples suggests that all drift organisms entrained by the plant are destroyed, or behaviorally they do not prefer to settle in the hot water environment of LTMC. Biologically, life for invertebrates in LTMC is difficult, particularly during the summer temperature maximum (42°C in 1973)."

When considered in relation to the effects on Ohio River biota, Reed (1974, p.45) concludes:

"No really significant or detectable change has occurred in the Ohio River after the condenser cooling and river waters have mixed despite the apparent reductions and inhibitions of the entrained organisms in LTMC."

Regarding the macroinvertebrates collected in LTMC, Miller et al., (1975, p.20) states:

"In 1974 macroinvertebrates returned and remained throughout the summer, a summer in which the maximum temperature did not exceed 36.8°C and the average ΔT was 9.5°C. We have another empirical limit of perhaps 37°C above which stationary macroinvertebrates normally found in the Ohio River simply do not survive."

He further concluded (Miller, 1975, p. 21):

"We have summarized the extent of thermal effects on entrained organisms and macroinvertebrates that occur in the discharge canal of the Stuart Station. Each group has several attributes which allow us to determine the impact of temperature elevation or mechanical damage. The Stuart Station overall has little effect on these groups in the Ohio River as a whole. It is doubtful that many statistically significant effects could be isolated after the heated waters have been diluted, at least 5:1 in the 300 meters required to reach Station III. Except for the proportion of the total river flow that actually passes through the plant, (never to exceed 15%), little ecological change in the Ohio River can be shown."

F. Fishes

Studies of the fishes of lower Little Three Mile Creek (LTMC), the adjacent Ohio River, and a control backwater area, Kennedy Creek, have been conducted since July 1970. Reports attached to this document as appendices are: Gammon and Norris (1970), Norris and Gammon (no date), Hatch and Gammon (1973), Lesniak and Gammon (1974), Yoder and Gammon (1975), and Yoder and Gammon (1976).

Two fish surveys in July and September 1970 were conducted with the pumps for two units in operation without the addition of condenser heat. Studies of commercial operating conditions began in the fall of 1970. summer and fall investigations were subsequently conducted in 1971-1973. A more intensive once-per-month sampling program was begun in June 1974 and continued with only occasional equipment or flood-related interruption through October 1975. This later study included an electrofishing survey in 39 river and 23 backwater zones in a 301 km section of the middle Ohio River. This long river segment study is being continued in 1976, although field sampling is not yet complete.

1. General Ecology of the Ohio River

Yoder and Gammon (1976) summarized the changes which have occurred in the Ohio River in the last 150 years, and the effects these changes have had on the fisheries of the stream. They pointed out that just prior to 1800 the river was described by Rafinesque (1820) as being clear with a sandy, gravelly to rocky bottom with good aquatic plant growth and shading of shoreline areas and mouths of tributaries by overhanging trees. In addition, there were many riffles and some rapids with high water occurring only after extended periods of rainfall. Numerous oxbows, swamps, and marshes were present along the river and throughout the drainage basin.

The present-day Ohio River is essentially a series of long, slow-flowing, thermally unstratified pools with attendant backwaters at the mouths of tributaries. In addition, the river now fluctuates widely in stage and flow with only moderate rainfall due to man-made changes in the assimilative and holding capacity of the watershed. High dams are present throughout the stream; municipal and industrial wastes in some areas are significant, commercial barge and tow traffic is heavy, and basin agricultural activities contribute quantities of silt, fertilizers, insecticides, and herbicides to the stream.

2. Habitat Description of the J. M. Stuart Study Zones

Collections during the various studies cited above were made in five study zones in 1970 to 1973, with a sixth zone being added in 1974. Figure V-13 shows the J. M. Stuart study area and the location of fish collection zones. Hatch and Gammon (1973) describe Zones 1 to 5 as follows:

Zone 1 - is the dredged lower portion of Little Three Mile Creek which serves as the discharge canal for the J. M. Stuart Station. A concrete and steel weir at its lower end provides a means of jetting the heated water into the mid-stream flow of the Ohio River. Width of the weir opening has varied from 6.3 meters (1970-1973) to the present 18.9 meters. The zone itself is 1.57 kilometers long and has virtually no vegetation along its banks except near the weir. The substratum is mud and very little submerged cover is present. About half-way down the north bank a smaller, intermittent creek enters the canal. During the spring and early summer this creek provides enough cool water to form a small pocket of lower temperature. Fish have been observed to enter this pocket in large numbers and remain there while temperatures in the canal itself were prohibitively high.

Zone 2 - is the area immediately upstream from the weir along the north shore of the Ohio and serves as the control zone in the river. This zone is about 0.40 kilometers in length and has a substrate varying from mixed sand and mud to rocks. Most of the shoreline is devoid of overhanging vegetation except for a small clump of trees in the upper third of the zone. This same area also contains a large number of submerged stumps, logs, and snags.

Zone 3 - is located just below the weir and constitutes the first thermally-affected zone in the Ohio River proper. This zone is about 0.80 kilometers in length, beginning with a deep eddy created by the weir discharge and ending over a shallow mud flat. The upper two-thirds of the shoreline is covered with dense overhanging vegetation, while the corresponding waters contain many submerged logs, stumps, and snags.

Zone 4 - is located about 1.06 kilometers downstream from Zone 3. It begins as a shallow mud flat and gradually becomes deeper with a sandy to rocky bottom ending in a deep rocky pit. The lower half of the shoreline affords a moderate amount of vegetative overhang.

Zone 5 - is Kennedy Creek, a small tributary of the Ohio on the Kentucky side. It serves as a control zone for LTMC. This area is a sluggish backwater and has banks covered with trees, shrubs, and other vegetation. A myriad of submerged habitats exist throughout the zone which is about 0.61 kilometers long.

Zone 6 - is not carefully described by the authors, but this zone is located upstream of the barge unloading terminal at the J. M. Stuart Station. Little use was made of the data obtained from this zone since the data were from a comparatively limited time period.

3. Habitat Description of the 301 Kilometer Study Area

Yoder and Gammon (1976) selected five habitat types for both river and backwater areas according to the variety and quality of cover and substrate, depth, and the general overall character of the site.

The five river habitat types were described by the authors as follows:

- open sand beach with few or no trees, sparse submergent cover, mono-substrate of sand or silt, and shallow (less than 100 cm)
- sand beach with scrub tree growth (Salix sp.), sparse submergent cover, mono-substrate of sand or silt, and relatively shallow (100-125 cm)
- cover consisted entirely of large mats of submergent vegetation, dominantly Ceratophyllum and Myriophyllum; substrate of sand/silt; moderately shallow (120-150 cm)
- sand beach with larger hardwoods (Acer), good diversity of submergent cover in the form of partially submerged stumps and logs; substrate of sand/gravel/silt; moderately shallow (120-150 cm)
- rocky riprap shoreline, much submergent cover in the form of partially submerged stumps, logs, and boulders; substrate of sand/gravel/rubble/boulder being relatively silt free; relatively deep (greater than 140 cm)

The backwater habitat types were described as:

- highly modified areas with little natural cover of canopy, mono-substrate of silt (marinas, boat harbors, dredged backwaters)
- good canopy (usually Acer), sparse submergent cover, substrate of silt/detritus
- larger tributaries entering the main river characterized by high banks on the outside bends, a steady and constant current, and substrate of sand/gravel/silt
- partial canopy (Acer), numerous forms of submergent cover such as partially flooded over stumps, trees, and logs; substrate of silt/detritus

- excellent canopy (Acer), numerous forms of submergent cover such as stumps, logs, and brush piles; substrate of silt/detritus/gravel (more natural-type backwater as opposed to those formed largely as a result of impoundment)

The 301 kilometer study area was divided into nine segments, each varying in distance and number of zones, based on their proximity to thermal effluents, municipalities, and locks and dams (Figure V-14). The segments are described as follows:

- River Mile 341.4 to 348.9 (2 river zones, 1 backwater zone) below Greenup locks and dam to Little Scioto River, called "below Greenup Dam"
- River Mile 351.4 to 368.4 (4 river zones, 4 backwater zones) - Detroit Steel to Kinniconnik Creek, called "Portsmouth"
- River Mile 372.5 to 398.6 (6 river zones, 4 backwater zones) below Portsmouth, Ohio area to above J. M. Stuart segment, called "below Portsmouth"
- River Mile 403.4 to 406.2 (4 river zones, 2 backwater zones) - J. M. Stuart segment called "J. M. Stuart"
- River Mile 410.3 to 435.6 (5 river zones, 4 backwater zones) below Maysville, Kentucky to Big Snag Creek, called "Maysville-Ripley"
- River Mile 436.7 to 448.6 (3 river zones, 1 backwater zone) below Meldahl Locks and Dam to New Richmond, Ohio, called "below Meldahl Dam"
- River Mile 453.1 to 464.9 (3 river zones, 1 backwater zone) below W. C. Beckjord Plant to above metropolitan Cincinnati, Ohio, called "above Cincinnati"
- River Mile 470.1 to 491.0 (5 river zones, 4 backwater zones) - Greater Cincinnati, Ohio/Newport-Covington, Kentucky metropolitan area to Great Miami River, called "Cincinnati"
- River Mile 494.1 to 527.5 (7 river zones, 2 backwater zones) below Tanners Creek Plant to above Markland Locks and Dam, called "below Cincinnati"

4. Fish Survey Methods

Relative abundance indices and determinations of the distributions for the different species of fish were obtained through the use of a boat-mounted electrofishing device for all aspects of the study. Stationary D-nets and a 15.2 meter X 1.8 meter, 6 and 10 mm mesh bag seines were used in the seasonal studies at the J. M. Stuart segment only.

Alternating current was used in 1970. In all subsequent years, electrofishing was conducted with a Smith-Root type VI DC electrofishing unit. Alternating current produced by a 3500-watt gas-powered generator was converted to DC by the Smith-Root unit at 4 to 6 amperes and 60 pulses per second, then passed through an electrode system mounted on a 5 meter fiber glass skiff. Fishing was conducted at night during the preoperational and construction phases of the J. M. Stuart study during 1970-1973. However, the scheme was changed to daytime electrofishing during all work after June 1974 and produced similar results. Each zone was fished sequentially, or monthly in the case of the seasonal study, by moving the boat in a slow and steady course downstream near shore and near submerged logs and stumps whenever possible. Sampling stations along the length of the 301 kilometer section were approximately 1 km in length (with a few exceptions) and were located (when possible) along the outside bends of the river. Previous studies on smaller unimpounded rivers have demonstrated that the abundance and diversity of fishes were greater near shore, especially on the outside bends (Gammon, 1973; Woolcot, 1974). Of the 62 zones in the study area, 39 were located in the river at intervals ranging from 3.2 km to 9.8 km (most in the 7 to 8 km range), and 23 were located in backwaters. Three sequential downriver passes were made in each zone when possible; one each in July, August, and October 1975. This method of collection proved to be selective for surface-dwelling and littoral species. Relative abundance was based on number/km and kg/km.

D-nets constructed of metal frame covered with 1.9 cm wire mesh were set at eight locations in the J. M. Stuart segment. Of the eight nets set monthly, two each were fished for a 24-hour period in Zones 1, 3, and 4, with one net each in Zones 2 and 5. This method was selective for bottom fishes. Relative abundance was based on number/net-set and kg/net-set.

Captured fish were placed in a holding tank filled with water from the zone sampled. Total lengths were measured to the nearest millimeter and weights were taken to the nearest gram. Nearly all fish taken by electrofishing and in D-nets were returned to the river unharmed.

Seining was performed with a 15.2 meter X 1.8 meter bag seine with 6 and 10 mm mesh. Two persons pulled the seine parallel to the shoreline for a distance of approximately 40 meters. At the end of each haul the net was quickly drawn into shore where the catch was secured and concentrated in the bag. Larger fish were quickly identified, weighed, and released; smaller individuals were preserved in 10 percent Formalin for later identification and weighing in the laboratory. This method was selected for shore area species and juveniles of surface-dwelling, littoral, and bottom species. Relative abundance was based on numbers/haul and grams/haul.

Raw data from each collection were compiled in sequence and recorded on computer magtape and analytical programs computed parameters including numbers/km, numbers/net-set, kg/km, kg/net-set, number of species, and Shannon-Wiener diversity indices (Shannon, 1948) based on numbers and weights. Information was also calculated for individual species populations in terms of numbers caught, weight caught, mean length and weight.

5. Study Results and Discussion

Background temperature information is succinctly summarized by Yoder and Gammon (1976, p. 20, 21, and 23) in Table V-5, Figure V-15 and Figure V-16. Table V-5 indicates that July-August mean temperatures in the thermal effluent portion of LTMC at the time of sampling averaged about 27°C (80.6°F) prior to start-up, 36°C (96.8°F) in 1971-1972, and about 38°C (100.4°F) in 1973-1975.

Mean effluent ΔT's averaged a fairly consistent 10° (18°F). Figure V-15 documents that the ambient river zones (2 and 6) were warmer than the backwater (Kennedy Creek, Zone 5) in June-November and cooler than the backwater in December-May. This point will become important in the later discussion on backwater fisheries. The plume data presented in Figures IV-24 and V-16 indicates that during the warmest months and presumably low-flow periods, the highest plume temperatures occur away from the productive shoreline areas. Data presented earlier in this document illustrated that these highest temperatures were also restricted to the upper few feet of the stream.

A tremendous amount of individual data has been generated to date in the seven years of fish sampling effort at the J. M. Stuart Station. This summary will attempt to succinctly draw conclusions based on the balance of the total effort. Yoder and Gammon (1976) have attempted to put the sampling effort at the local J. M. Stuart zones into context with a 301 kilometer study of the middle Ohio River. This extensive field effort will be evaluated with regards to backwater versus main river fishes.

Basic questions reflecting potential concerns include the following:

(a) Has the thermal effluent reduced a significant portion of usable habitat in the Ohio River proper for important species?

(b) Has the thermal effluent altered available habitat in LTMC for important species? During which periods of the year?

(c) How has the thermal effluent altered the expected backwater fisheries composition in LTMC?

(d) Has the thermal effluent adversely affected spawning migrations into the upper portion of LTMC?

(e) Has the thermal effluent altered expected spawning activity in lower LTMC?

(f) Has the thermal effluent altered the expected overwintering activity in LTMC? Are fish successfully able to survive the winters in LTMC?

(g) How has the thermal effluent affected recreational fishing in LTMC and the adjacent Ohio River?

(h) Has the operation of J. M. Stuart Station caused any significant fish mortalities? What is the significance of the fish kills to the fisheries complex of LTMC and the Ohio River? What is the likelihood of future fish kills?

(i) Are any endangered or threatened fish species being adversely affected by the thermal effluent?

(j) What is the overall impact of the thermal effluent on the fisheries of the LTMC-Ohio River complex?

Table V-6 presents a comparison of mean electrofishing catches in Zones 1 through 4 as a way of evaluating general yearly fluctuations and trends in abundance. These data should be cautiously evaluated, of course, because the numbers per unit distance are small for many species and the results from each zone are combined, thereby masking some of the reasons for some of the changes. Also, the authors (Yoder and Gammon, 1976) make frequent comparisons of "populations" of given species. We interpret the data presented to be a comparison of catch-per-effort (distance), and therefore most likely only indicative of changes in the populations, although certainly large observed changes in the catch rate are most likely due to changes in the actual populations.

Table V-7 is a summary of six years of D-net data in Zones 1, 2, 3, and 4 at the J. M. Stuart study segment. Again, most of the catch rates were low, and comparisons and conclusions should be carefully formulated. The year-to-year local changes in abundance as reflected by the catch-per-unit distance appear large enough to allow for interpretation for gizzard shad, longnose gar, white bass, skipjack herring, river carpsucker, and sauger. Other fishes were captured only sporadically or in very low numbers. These data indicate that electrofishing catches were dominated by gizzard shad in all July-October periods. This is a normal occurrence on the Ohio River (WAPORA, 1971, 1972, 1973, 1974, 1975). Longnose gar were not captured by electrofishing prior to plant start-up and the catch rate increased about five-fold by 1975 (Table V-6).

White bass were also captured in higher numbers in 1975 and skipjack herring appear to have decreased locally since 1970 (Table V-6). River carpsucker catch rates appear to be fairly constant, although some reduction in captured specimens may be evident in 1974 and 1975 catches. Sauger catch rates have dropped off since 1971. Discussion of other species would appear to be unwarranted considering the low catch rates and sporadic occurrences.

D-net catch rates (Table V-7) appear to be high enough to enable some interpretation for bluegill and white crappie only. The catch rates for other species are low and sporadic, and variations in expected catch rates due to seasonal and sampling zone differences would make interpretation difficult. Bluegill catch rates varied a great deal from year to year. The 1973 catch rate reflected one particularly large sample.

These data (general relative abundance over a period of years) indicate some changes in the apparent abundance of various species. It is now important to look at data from the various individual collection zones in order to isolate some of the apparent changes in relation to the thermal effluent.

Comparisons of yearly mean numbers/km, kg/km, Shannon-Wiener diversity based on numbers and weights, and number of species for electrofishing catches for Zones 1 through 4 for the years 1970 through 1975 are presented in Figure V-17. Yoder and Gammon (1976, p. 22-28) discuss the implications of these data. They included only Zones 1 through 4 in the analysis, since these represented the zones directly influenced by plant operation and construction. Further, they only considered results from the summer because the majority of directly comparable sampling occurred during these months when the fish community was considered relatively stable. Gizzard shad were excluded from the catch analyses because they were represented by highly dominant and widely variable numbers. The authors observed the following trends:

- Relative density and biomass (as reflected in electrofishing catch rates) decreased from 1970 to 1972 and then increased gradually from 1973 through 1975, probably reflecting a normal trend in the Ohio River.

- Community diversity indices were fairly uniform throughout the study period.

- Community indices in Zone 1 (LTMC) decreased to zero in 1972 and 1973 but then increased to 1970 and 1971 levels in 1974 and 1975.

- The two thermally-influenced river zones (Zones 3 and 4) exhibited a similar, but less extreme, pattern of change.

- Indices in Zone 2 (ambient) gradually decreased during the six-year period.

Results from the systematic series of collections from June 1974 through October 1975 are summarized in Figures V-18 through V-20 for electrofishing and Figures V-21 and V-22 for D-net collections (Yoder and Gammon, 1976, p. 34-46). The five community parameters presented in Figures V-18 and V-21 were subjected to various statistical testing, including a nested one-way analysis of variance after square root transformation and a Student-Newman-Keuls multiple comparison test.

It was determined that four seasons could be defined according to relative seasonal stability within the fish community (Yoder and Gammon, 1976, pg. 34). Two periods of relative stability were found, July through October (summer) and December through February (winter). These were linked by two short periods of transition, November (fall) and April through May (spring). In spite of widely overlapping results among many of the various parameter categories, some important seasonal trends were observed.

Yoder and Gammon (1976, p. 40-42) note the following about seasonal trends as revealed by catch rates:

- Indices were near zero in the discharge canal and highest in the ambient river zones during both summer seasons.

- Indices were lower in the ambient river zones and highest in LTMC during the winter.

- Species attracted to the discharge canal during Winter included longnose gar, white bass, smallmouth buffalo, river carpsucker, quillback carpsucker, and carp.

- Species occurring in relative abundance over the gradient of thermal conditions encountered during the summer and transitional periods were, in order of decreasing thermal preference: longnose gar, carp, quillback carpsucker, white bass, river carpsucker, largemouth bass, spotted bass, skipjack herring, gizzard shad, and sauger.

- Spotted sucker, bluegill, and white crappie preferred the backwater during all seasons.

In addition to the electrofishing and D-net results, Yoder and Gammon (1976, p. 48-51) also present seining data for above (Seining Station 1 [S1]) and below (Seining Station 2 [S2]) the J. M. Stuart Station. These data are presented in Table V-8 and Figures V-23 and V-24. The authors determined from the seining data that:

- There were no significant differences between S1 and S2 sampling locations for all months as well as for numbers/haul, grams/haul, and number of species. The data were subjected to a nested two-way analysis of variance at the 95 percent level.

- Community density (as measured by seining) and biomass peaked during the late summer months of August through October in the shallow areas of the Ohio River. This was most likely due to the recruitment of young-of-the-year individuals into the catch rates.

- Gizzard shad and emerald shiner catches made up nearly 90 percent of the total catch by number and 75 percent by weight.
- Young-of-the-year and juvenile gizzard shad were most abundant at Station S1.
- Young-of-the-year and juvenile river carpsucker and river shiner were generally more common at Station S2.

Has the thermal effluent reduced a significant portion of usable habitat in the Ohio River proper for important species? Based on a careful examination of the data presented above and a careful reading of the appended reports, it is concluded that the answer to the question is "no." Hatch and Gammon (1973, p. x) state that "with the exception of the elimination of all species from LTMC during the summer, no specific detrimental effects due to the thermal effluent were demonstrated." Yoder and Gammon (1976, p. 65) conclude that "the avoidance of the discharge canal during summer and ambient river zones during winter suggests that there are critical winter months as well as critical summer months." Yoder and Gammon (1976, p. ix-x) do state that "notable changes observed in individual species populations from 1970 through 1975 were attributed to power plant (J. M. Stuart Station) operation." They further state that golden redhorse essentially disappeared from the study area after 1971, and that sauger densities decreased dramatically from 1970-1971 through 1975. It appears that the catch rates for sauger in Zones 1 through 4 reflect what is most likely a real difference which may be attributable to the thermal effluent. However, Figure V-25 indicates that the river segments in the J. M. Stuart area contained some of the highest catch rates for sauger within the 301 km study area. Hence, it is concluded that if the decrease in catch rate was real it was only local in influence. It would appear that the data on catch rates of golden redhorse may be too few to support the above statement regarding this species. Thermal tolerance data on sauger and golden redhorse do, however, lead to a conclusion that some habitat for these species will be eliminated during the summer months for a short distance downstream of the point of entry of LTMC into the Ohio River. On balance, however, it is concluded that an insignificant portion of the Ohio River has been affected with respect to important fish species.

Has the thermal effluent altered available habitat in LTMC for important species? During which periods of the year? Gammon and Yoder (1976) thoroughly discussed the seasonal changes, catch rates, and apparent abundance of various species in LTMC. They observed the following:

- The canal portion of LTMC was consistently devoid of fish during the two warmest months, July and August, of every year when temperatures exceeded 34 to 36°C (93.2 to 96.8°F).
- Fish were absent in the canal portion of LTMC in 1972 and 1973 most likely because of increased

velocity at the weir due to the additional generating units and cooling water flow as well as high effluent temperatures.

- Community abundance was highest during October 1970 through 1975 when temperatures ranged from 28° to 31°C (82.4 to 87.8°F). However, community indices were zero in October 1973 when effluent temperatures exceeded 34°C (93.2°F).

- Most species avoided the canal portion of LTMC from June through September except for bluegill and white crappie which were attracted to it during October through May. Fish avoided the near-freezing temperatures and increased flow of the ambient river from December through February.

We conclude from this summary and from the careful evaluation of the appended reports that when temperatures in the canal exceed 34°C the canal portion of LTMC is removed as habitat for many important fish species.

How has the thermal effluent altered the expected backwater fisheries composition in LTMC? The expected backwater fisheries in LTMC will be determined to a large extent by abiotic factors, such as the diversity and quality of available habitat. The present-day lower LTMC has been described earlier as a dredged canal 1.57 kilometers long with virtually no vegetation along its banks except near the weir. The substratum is mud and very little submerged cover is present. The depth is a fairly consistent 10 to 12 feet at mean normal pool (485.0 feet MSL) and canal velocities range from an average of 1.06 fps to a maximum of 1.32 fps (calculated values based on average maximum flows of 754 and 942 mgd, respectively at normal pool level).

In order to determine the expected fisheries of LTMC, one must determine the changes in habitat anticipated in the absence of effluent flows and effluent temperatures. We have determined from a careful examination of river stages and contours that lower LTMC would initially have essentially the same water depth (10 feet) but, of course, velocities during most of the year would be very slight. Temperatures would, of course, be reduced. The present-day lack of submerged habitat (logs, debris, etc.) is undoubtedly the result of scour from the discharged heated effluents. The canal likely would quickly fill with debris within a year or two due to downstream spring floods in LTMC and deposited debris from Ohio River flooding. If the canal banks were no longer maintained erosional properties and the natural tendencies of the stream to meander would return the lower portion of the creek to a more natural state within five to ten years. Additional purposeful dredging and deliberate planting of vegetative cover could, of course, more rapidly affect these habitats.

So, we conclude that within a ten-year period or so, the lower portion of LTMC would look very similar to Kennedy Creek (Zone 5) across the Ohio River. The habitat available to the fishes would then be very similar and, hence, we would suppose that the fishes might also be very similar. Although Kennedy Creek and LTMC would certainly not be identical, we feel that an examination of the data collected in Kennedy Creek will yield some conclusions about the expected fisheries of LTMC in the absence of the J. M. Stuart Station discharge.

The basic community of a more natural LTMC might well look something like the following list:

Bluegill
White crappie
Black crappie
Spotted sucker
White sucker
Golden redhorse
Silver redhorse
Rockbass
Longear sunfish
Orange spotted sunfish
Largemouth bass
Spotted bass
Warmouth
Carp
Gambusia
Notropis spp. (varied species, depending on flow and temperature)
Logperch
Fantail darter
Yellow bullhead

Of course, the above list does not include specific spawning or overwintering aggregations. These migratory activities will be discussed later in this section.

Based on the above list and comparing this list to data contained in the appended reports, we conclude that the combination of higher temperature and higher flows in the present-day LTMC is, indeed, considerably different in fish species composition than might be expected in a more natural Little Three Mile Creek.

Figure V-26 illustrates the gradation in fish species composition from river to backwater habitat. The dominant abiotic factor most likely responsible for the shift in species is current velocity. Figures V-19, V-20, and V-22 were utilized to compile the following list of dominate species for present-day LTMC: smallmouth buffalo, river carpsucker, quillback carpsucker, longnose gar, white bass, carp, sauger, and channel catfish.

These species, of course, do not occur in LTMC with regularity when effluent temperatures exceed 34 to 36°C (93.2 to 96.8°F), but they obviously constitute a fauna very similar to the more riverine habitat (Figure V-26). We submit that LTMC, although certainly different from Kennedy Creek and certainly affected during some months by high effluent temperatures, nevertheless does possess during the cooler months a viable fishery composed of primarily riverine species.

Has the thermal effluent adversely affected spawning migration into the upper portion of LTMC? Trautman (1957) described some pre-Meldahl collections in creeks similar to LTMC, and from the data it would appear that upper LTMC probably supported a very limited fish fauna. WAPORA (unpublished data, 1971) examined many of the small streams along the Ohio side of the Ohio River during a spring spawning reconnaissance. The majority of the small streams had very little flow, appeared to be largely wet-weather streams based on the paucity of benthos observed, and contained few fishes during the surveys except possibly near the stream mouths which were not sampled.

Although we do not have any actual spring collection data from upper LTMC (above the extent of the Ohio River backwater area), we have carefully examined the physical habitat available, and we conclude in the absence of data and in our professional judgment, that it would be very unlikely that riverine species utilized or would be likely to utilize upper LTMC for major spawning activities with or without the presence of a thermal effluent.

Has the thermal effluent altered expected spawning activities in lower LTMC? Yoder and Gammon (1976) stated in reference to Kennedy Creek that "the abundance of ripe males and/or gravid females of gizzard shad, spotted sucker, river carpsucker, carp, spotted bass, white crappie, and bluegill in Zone 5 during spring strongly suggests that the backwater was important for spawning." WAPORA (1972) on the Wabash River also noted that similar backwater areas were utilized for spring spawning by bigmouth buffalo, longnose and shortnose gar, and several species of Notropis. WAPORA (1973) on the Illinois River noted that backwater areas were successfully utilized for spawning by gizzard shad.

The conditions for spawning of the above discussed species appeared to be a stable flooded backwater with little or no flow and submerged bank vegetation and debris. Except for the extreme lower portions near the mouth of the effluent canal during Ohio River backflooding, LTMC does not provide the appropriate habitats for many of the apparent backwater spawners. Perhaps also many of the larval fishes produced would be flushed into the Ohio River by the higher effluent canal velocities rather than remaining in the relative security of the backwater. However, the preferred habitat and survival values of the backwaters for larval fishes is very poorly understood, and WAPORA investigators have observed that fry are often flushed from the natural backwater areas of the Wabash, Illinois, and Ohio Rivers.

Hatch and Gammon (1973) state that "throughout the winter, carp continue to inhabit the canal and numbers increased as spring approached. Although spawning in the Ohio River apparently occurs in early May (WAPORA, 1971), the warm water of the canal has induced carp to spawn as early as April 1. Temperatures in the canal at this time fell within the optimum range of 19° to 23°C reported by Swee and McCrimmon (1966). Unfortunately, there is no information on the actual success of the carp spawn in LTMC." This is apparently the only observed spawning activity in LTMC.

In our professional judgment, we conclude that the thermal effluent has altered expected spawning activity in lower LTMC, however, the magnitude of change cannot be accurately determined by the present data.

Has the thermal effluent altered the expected overwintering activity in LTMC? Are fish successfully able to survive the winters in LTMC? Nikolsky (1963) states that overwintering is part of the life cycle of some fishes and is characterized by reduced activity, complete cessation or sharp reduction of the consumption of food, and a fall in the level of metabolism and its maintenance at the expense of energy resources accumulated in the organism, particularly fat deposits. He further states that overwintering is an adaptation that ensures survival in the population through a period of the year which is unfavorable for an active mode of life (poor oxygen conditions, lack of food, low temperatures, drought, etc.). Overwintering is widely represented in freshwater fishes, especially those of temperate latitudes; however, overwintering is less common among fishes which live in rivers (Nikolsky, 1963). Nikolsky (1963) states that in Russian rivers like the Amur, various phytophagous fishes such as the grass carp aggregate in pits in stream beds and that their bodies become covered over with a thick layer of slime.

In the majority of fishes, the start of the wintering migration is connected with the attainment of a definite condition and fat content which would ensure the successful overwintering of the fish. Nikolsky (1963) summarized some data on carp (from Poliakov; 1950, 1958) in the following table.

Average Coefficient of Condition	Average Fat Content	Average Time of Survival When Starved
2.56	2.15%	141 days
2.81	4.25%	191 days

The following table by Kirpichnikov, 1958, summarizes survival data for carp fingerlings kept at a temperature near zero degrees centrigrade.

Average Coefficient of Condition	Time of Survival at 0°C
1.92	6 days
2.29	10 days
2.33	15 days
2.40 - 2.50	over 40 days

Nikolsky (1963) further states that the signal for the start of overwintering in temperate and high latitudes is a drop in the temperature below a certain value. However, if the fish has not attained a certain state of preparedness or if the temperature key is not realized, then it usually continues to feed and does not enter the state of overwintering.

Again, one must consider a typical backwater without higher velocities and higher temperatures to establish a norm. A careful review of the appended reports indicates that the following species most likely overwinter in Kennedy Creek: bluegill, white crappie, carp, and golden redhorse. Spotted sucker and certain Lepomis species utilized the backwater during all seasons.

Do fish "overwinter" in LTMC? In the strict sense of the definition the answer is probably "no." Fishes do spend the winter months in LTMC but due to the higher metabolism regulated by the relatively higher temperatures of the effluent, it is likely that most LTMC fishes continue in an active feeding state throughout the winter. Yoder and Gammon (1976) stated that species attracted to LTMC during the winter included: longnose gar, white bass, smallmouth buffalo, river carpsucker, quillback carpsucker, and carp. Hatch and Gammon (1973) stated that "several species, most notably channel catfish and carp, overwinter in the canal and have provided excellent winter fishing for local fishermen."

One of the important questions concerning the fishes utilizing LTMC in the winter is their ability to find adequate food in the canal to maintain a suitable condition. Merriman (1970) noted a marked marasmus in bullheads inhabiting the effluent canal in the winter at the Connecticut Yankee Plant.

Table V-9 presents data by Hatch and Gammon (1973) as regards to condition factor of channel catfish collected in LTMC and the Ohio River. They concluded (1973, p. 60-61) that "catfish in the canal and J. M. Stuart revealed no consistent statistical degradation when compared with catfish caught in the river." Hatch (personal communication) collected creel census data from several LTMC fishermen throughout the winter of 1972, and found that the general condition of the captured fishes appeared to be good. At the present time, there exists no data on other species which pass the winter in the thermal effluent. We conclude that the thermal effluent does alter the expected overwintering activity in LTMC, but that several species of fish do pass the winter in the canal. We do not believe that the removal of this one creek from the available overwintering habitat constitutes more than a local change. It also appears from limited data that some species which would normally overwinter in the pits on the bottom of the Ohio River do successfully pass the winter in LTMC.

How has the thermal effluent affected recreational fishing in LTMC and the adjacent river? Hatch and Gammon (1973) reported that "winter fishing in LTMC for channel catfish was excellent." The other data regarding recreational fishing comes from unpublished observations of the various investigators and from DP&L personnel. It has been observed that the highest concentration of fishing boats and bank fishermen for most suitable fish days were found in or immediately downstream of LTMC. It has also been observed that when summer effluent temperatures reached critical levels

(34° to 36°C) that the fishermen leave the canal and move downstream into the thermal plume (Zone 3 and 4) to fish. The Ohio DNR has stated that prior to plant start-up, LTMC was a good backwater recreational fishing area. This statement would certainly appear to be reasonable. It has also been observed by WAPORA at almost every power plant studied on the Ohio, Illinois, and Mississippi Rivers, that more fishermen utilize the effluent areas for recreational fishing than any other areas in the immediate vicinity of the studied plants.

We conclude that recreational fishing has been altered by the thermal effluent, and that overall recreational usage may now be greater than prior to start-up. The summer LTMC fishing has of course been degraded, but the winter fishing has been greatly enhanced. We believe that on balance the trade-off is acceptable.

Has the operation of J. M. Stuart Plant caused any significant fish mortalities? What is the significance of the fish kills to the fisheries complex of LTMC and the Ohio River? What is the likelihood of future fish kills? The number of recorded fish kill incidents has been discussed earlier in Section III-A-4 of this document. The largest kill (7,540 fish) occurred due to reverse thermal shock. The smaller fish kills apparently occur when some fish are trapped in a small, cool pocket of water in LTMC formed by the entrance of a small run-off creek. The significance of all the recorded fish kills certainly must be considered as minimal; however, all fish kills are undesirable and should be prevented if possible.

The possibility of another large reverse shock thermal kill appears to be very remote. The present multi-unit operation at J. M. Stuart should normally preclude simultaneous shutdown of all units. However, an emergency shutdown of all units is always a remote possibility. The smaller (possible annual) fish kills are caused by fish seeking the small, cool pocket of water in the canal. These fish would undoubtedly avoid the high critical temperatures of LTMC by migrating out of the canal if this cool pocket of water was not available. We regard such small fish mortalities as probably insignificant to the LTMC-Ohio River complex.

Table V-10 illustrates the preferred and lethal temperatures of selected Ohio River fishes, many of which are reported in collections near the J. M. Stuart Station. This list serves as a basis of comparison for the previous discussion concerning the movements of fishes in relation to the J. M. Stuart Station thermal effluent.

Are any endangered or threatened fish species being adversely affected by the thermal effluent? The endangered fish species list (Table V-11) included in the October 29, 1974 Draft Ohio EPA 316(a) Guidelines was developed by the Ohio Department of Natural Resources pursuant to Amended Substitute Bill 35 enacted by the Ohio General Assembly on June 28, 1973 and "shall be used to determine whether a species is considered endangered." The following species have been collected in the vicinity of the J. M. Stuart Station (Gammon and Norris, 1970; Norris and Gammon (no date); Hatch and Gammon, 1973; Lesniak and Gammon, 1974; Yoder and Gammon, 1975; and Yoder and Gammon, 1976) and also appear on the above referenced endangered species list:

Common Name	Scientific Name
Shortnose gar	Lepisosteus platostomus
Ghost shiner	Notropis buchanani
Silver chub	Hybopsis storeriana
River redhorse	Moxostoma carinatum

Although the Ohio DNR has revised (effective May 1, 1976) the endangered species list for the State of Ohio, the fish species on the list have not changed. However, these lists are officially applicable only to Ohio waters, which does not include the Ohio River. The State of Kentucky owns the waters of the Ohio River in that area of the Ohio River bordering Kentucky; this would include the Ohio River adjacent to the J. M. Stuart Station. Thus, the Kentucky DNR list (Table V-12) would appear to be the appropriate official list for endangered fish species in the Ohio River in the vicinity of the J. M. Stuart Station. It must be emphasized that neither the Ohio or the Kentucky lists specifically address the Ohio River as a separate entity, nor does ORSANCO, the interstate agency most directly responsible for coordinating the bordering states concerned with such matters.

None of the species on the Kentucky Endangered List (Table V-12) or the United States Endangered and Threatened List have appeared in any of the fish collections at the J. M. Stuart Station. The species on the Ohio Endangered List which have been collected at the J. M. Stuart Station (shortnose gar, ghost shiner, silver chub, and river redhorse), were developed for the entire State of Ohio and must be considered in relation to their occurrence and abundance in the Ohio River.

River redhorse (Moxostoma carinatum) - Trautman (1957), in discussing the habitat and general decline in Ohio populations of this species states that:

"Since 1925, the largest populations have occurred in the deeper waters of the Ohio River and lower portions of its larger tributaries; smaller numbers were present in the upper portions of these tributaries, especially during the spawning season. Since 1940, the largest inland populations appear to have been centered in those sections of the Muskingum River which were the least polluted and had the least turbid waters. The Scioto River, with its more turbid waters, contained smaller numbers, and the heavily polluted Great Miami River contained few. From this avoidance of polluted areas, it is apparent that the River Redhorse like most Moxostomine species, is intolerant to much turbidity and siltation."

Scott and Crossman (1973) note that:

"The habitat is apparently the deeper waters of larger rivers and the lower portions of their larger tributaries. River redhorse are abundant in upper reaches of the tributaries of these rivers only at spawning time. They are apparently intolerant of pollution or heavy siltation. This probably accounts for their diminution in numbers in the United States since 1925. It may also account for their disjunct distribution. They may have been continuous and disappeared from the area between the upper St. Lawrence River and the Ohio River. They may have been in Lake Erie in the past but most published records of their presence there would appear to be misidentification."

One specimen of the river redhorse was reported in electrofishing collections from Zone 1 (Little Three Mile Creek) during the summer, 1970 (Gammon and Norris, 1970, p. 27).

Although temperature tolerance data for this species are lacking, the apparent limiting factors for its decline in numbers in the Ohio River (Trautman, 1957) are siltation effects and the species apparent migratory spawning habits (Scott and Crossman, 1973).

Silver chub (Hybopsis storeriana) - The silver chub is reported to occur in large sandy or silty rivers and lakes in eastern North America (Scott and Crossman, 1973; Carlander, 1969). Trautman (1957) suggests that it normally inhabits pools in slow-moving streams having clean sand or gravel bottom. He further elaborates as follows:

"The Silver Chub occurred in greatest abundance in Lake Erie in waters from 3-60 feet in depth, in large, deep waters of low- or base-gradient streams which had rather clean and usually gravelly bottoms. It was essentially a pool species when the bottom was not covered by flocculent silts; where pool bottoms were so covered it resorted to riffles. When the large streams were very turbid or were depositing unusually large amounts of silt, it would temporarily migrate into clearer streams of higher gradients, such as from the lower-gradient Great Miami into the higher gradients of the Whitewater River of Hamilton County. When the waters were very clear it retired into deep water. If the assumption is correct that this species requires a clean bottom of gravel and sand, it should not be as abundant in the silty-bottomed Ohio River today as it was before 1900 when large areas of clean sand and gravel existed. The Ohio River and Lake Erie populations appear to differ morphologically. Most of the Ohio River specimens are more streamlined in appearance, have less body depth at the dorsal origin, and their heads are less triangular. The snouts of many Ohio River adults are more bulbous and appear to overhand the upper lip more than do the snouts of the Lake Erie adults. Despite the present, turbid waters of the Ohio River, preserved specimens from that stream are more heavily pigmented and less silvery than are Lake Erie specimens, and the usually faint band along the sides and encircling the snout is more distinct than it is in Lake Erie specimens. If found to be subspecifically distinct, the Ohio River population becomes *Hybopsis storeriana lucens* Jordan (1880:238-39)."

The silver chub has been collected in numbers as high as 75 per seining haul both above and below the J. M. Stuart Station thermal effluent along the Ohio River shoreline (Figure V-24) (Yoder and Gammon, 1976, p. 51). It has also been reported to occur in fair numbers at other locations on the Ohio River (Preston, 1975).

However, there remains the question of whether the present Ohio River population represents an identifiable subspecies particularly adapted to the turbid and silty conditions of the Ohio River. Certainly the Ohio River population seems to be holding its own. Until the basic taxonomic problems are resolved, it would seem reasonable to conclude that the Ohio River population has adapted to existing conditions and that it should not be considered endangered in the Ohio River proper.

Shortnose gar (Lepisosteus platostomus) - Few historic records are available for the occurrence of this species in Ohio (Trautman, 1957). Trautman (1957) states in general that:

"The largest populations inhabit lowland lakes, oxbows, and backwaters; smaller populations occur in the still waters of the pools of rivers. In rivers, the species seemingly avoids strong currents and therefore avoids streams of high gradients. Since gars feed by sight, the Shortnose seems to prefer clear waters, although at present, they inhabit our silt-laden rivers sparingly. The species does not appear to be adverse to waters which frequently become densely clouded with plankton. It is not found among rooted aquatic vegetation as often as is the Spotted Gar."

Given the low frequency of occurrence of this species in collections and the lack of temperature tolerance information, it is not possible to say if the thermal effluent from the J. M. Stuart Station has had an adverse effect on its distribution and abundance. Its reported low tolerance to turbid and silt-laden rivers may well override any considerations of thermal effects in the Ohio River population.

Ghost shiner (Notropis buchanani) - Regarding the habitat preference and distribution of this species, Trautman (1957) states:

"The Ghost Shiner definitely sought clear, quiet waters, and a clean sand and gravel bottom, and usually where there were some submerged aquatics, such as pondweeds. The largest concentrations were found invariably in the quieter, clearer waters of an embayment or mouth of a small brook when the Muskingum River was very turbid. This apparent intolerance of turbidity and current may be the reason for its absence in the unimpounded and more turbid Scioto River, and rarity in the Ohio River."

The ghost shiner was, until recently, considered a subspecies of N. volucellus (Mimic shiner) (Trautman, 1957). Due to the subtle differences in morphologic characteristics between these species and the otherwise small numbers of either species reported from J. M. Stuart Station collections, it is impossible to determine the significance of the thermal effluent on the population. Preston (1975) reported substantially larger numbers of the mimic shiner than ghost shiners from collections at the Greenup and Meldahl Locks and Dams during the period 1968 through 1970.

It is therefore reasonable to conclude that if the ghost shiner (N. buchanani) is "rare" in the Ohio River, it is probably due to the species intolerance to turbidity and current.

What is the overall impact of the thermal effluent on the fisheries of the LTMC-Ohio River complex? Certainly, the creation of the LTMC canal and the discharge of heated effluent into that canal has induced many changes in the relationship of fishes to the area. If one only considers the effect on LTMC, then it could certainly be concluded that a normal summer fish community does not exist, and that the expected winter population of various species has been altered. Summer recreational fishing has been eliminated, but winter recreational fishing has been enhanced. Occasional plant-related fish mortalities occur. Expected spawning activities in LTMC have been altered. Once an essentially quiet backwater area, LTMC now for much of the year supports a more typically riverine biota.

The change in the Ohio River proper due to the addition of the heated effluent appears to be less obvious. Some fish avoid the heated plume in the summer, while others are strongly attracted to it. Some fish species apparently utilize the warm-water zones in the winter as opposed to normally overwintering. Recreational fishing appears to have been improved with the warm zones in the river.

Very subtle and complex changes are occurring over time as fish species interact with the thermal effluent. Current knowledge of the effects of such changes on large river fish complexes is far from complete. However, we submit that the observed changes are most likely local and limited, and that measurable changes in the Ohio River fisheries are not likely to occur as a result of the operation of the J. M. Stuart Station. Therefore, we conclude that the overall impact of the thermal effluent of the J. M. Stuart Station on the fisheries of the LTMC-Ohio River complex does not constitute significant, adverse harm.

G. Nuisance Species

The EPA draft (September 30, 1974) 316(a) technical guidelines defines "nuisance species" in the following manner:

"Nuisance species are microbial, plant and animal species, most of which are pollution-tolerant, present in the indigenous community or recruitable from contiguous waters which, by virtue of the direct or indirect effects of the discharge, will be given sufficient advantage to appear in the zone of discharge in large numbers at the expense of other members of the indigenous community."

The guidelines further note that the concept is intended to carry the connotation of "weeds" used in the agricultural sense. The "zone of discharge" used in the above definition is defined as that portion of the receiving waters which falls with the ΔT 2°C isotherm of the plume 30 percent or more of the time.

The biological data discussed previously indicates that although "stimulation" of primary production occurs under certain thermal regimes within the discharge zone of LTMC-Ohio River, the data do not indicate that this stimulation could be considered a "bloom" in the general sense, nor do they indicate an appreciable harmful effect on other flora or fauna. Although the discharge zone appears to attract certain species of fish (e.g., longnose gar, carp, white bass, smallmouth buffalo, river carpsucker, quillback carpsucker, and channel catfish) during the winter, the evidence does not indicate that this occurs at the "expense" of other fishes such that they would be considered "nuisance species."

TABLE V-1 Yearly average temperature, ΔT, and ratio of primary production at Stations IA, IB, and III to that in the Ohio River (mg $C/m^3/hr$) and the percentage of sampling dates when inhibition of primary production was more than 10 percent, 1971-1974 (from Miller *et al.*, 1975).

Year	Station II Ave. Temp. (°C)	Station II Primary Product (mgC/m^3-hr)	Station IA Ave.ΔT (°C)	Station IA Heated PP*** / Control PP	Station IB Ave.ΔT (°C)	Station IB Heated PP / Control PP	Station III Ave.ΔT (°C)	Station III Heated PP / Control PP
1971	14.7°	18.6	11.2°	0.93(53%)*	9.0°	0.91(47%)	2.3°	1.04(35%)
1972	15.7°	11.1	15.6°	0.88(71%)	12.8°	0.89(69%)	3.2°	1.11(45%)
1973	16.7°	32.4	11.8°	0.52(75%)	11.5°	0.62(75%)	2.5°	1.35(38%)
1974	16.6°	69.6	9.2°	1.01(33%)**	9.1°	0.89(61%)	3.2°	1.55(31%)

* Percentage of dates on which this station was reduced more than 10% of station II (control)

** 1974, station IA includes only Jan.-May

*** PP = primary production rate

TABLE V-2 List of algal taxa identified from samples in the vicinity of the J. M. Stuart Station (from Reed *et al.*, 1974).

CHLOROPHYTA
- Chloroccales
  - *Chlorococcum*
  - *Sphaerocystis*
  - *Ankistrodesmus*
  - *Chlorella*
  - *Pamellococcus*
  - *Oocystis*
  - *Selenastrum*
  - *Treubaria*
  - *Golenkinia*
  - *Micractinium*
  - *Dictyosphaerium*
  - *Actinastrum*
  - *Coelastrum*
  - *Crucigenia*
  - *Scenedesmus*
  - *Tetrastrum*
  - *Pediastrum*
- Ulotrichaceae
  - *Hormidium*
  - *Microspora*
- Zygnenatales
  - *Mougoetia*
  - *Closterium*
  - *Hyalotheca*
  - *Staurastrum*

CYANOPHYTA
- Oscillatoriales
  - *Arthrospira*
  - *Oscillatoria*
- Nostocales
  - *Anabaena*
  - *Raphidiopsis*

PYRRHOPHYTA
- Dinokontae
  - *Peridinium*
  - *Ceratium*

CHRYSOPHYTA
- Xanthophyceae
  - *Tribonema*
- Chryomonadales
  - *Dinobryon*

BACILLARIOPHYTA
- *Melosira*
- *Cyclotella*
- *Stephanodiscus*
- *Fragilaria*
- *Synedra*
- *Asterionella*
- *Cocconeis*
- *Navicula*
- *Pinnularia*
- *Cymbella*
- *Nitzschia*
- *Surirella*
- *Gyrosigma*

EUGLENOPHYTA
- *Euglena*
- *Phacus*
- *Trachelomonas*
- *Anisonema*
- *Pedimonas*

TABLE V-3 Analysis of variance of percentage of zooplankton found dead at Stations II, IA, and IB on eight dates from July-September, 1974 (arcsine transformation)(from Miller et al., 1975).

	df	Sum of Squares (SS)	Mean Square (MS)	F Ratio (FS)	Sign. Level
Dates	7	5,130.40	732.91	2.93	.025
Stations	2	3,191.95	1,595.50	6.38	.005
Dates x Stations	14	4,284.83	306.05	1.22	N.S.
Within Subgroups	48	11,992.86	249.85	-	-

TABLE V-4 General description of bottom substrate in LTMC (Zone I), the Ohio River (Zones II, III and IV), and Kennedy Creek (Zone V) (from Norris and Gammon, no date).

Zone	Sample No.	Bottom substrate
I	1	mud and detritus
	2	mud and detritus
	3	mud and detritus
II	1	sand and fine gravel
	2	sand and small gravel
	3	sand (no gravel or benthos)
III	1	mud and detritus
	2	mud and detritus
	3	mud and detritus
IV	1	mud and detritus
	2	mud
	3	mud
V	1	mud and deep detritus
	2	mud and deep detritus
	3	mud and deep detritus

TABLE V-5 Mean temperatures (°C) ± standard error and mean ΔT (°C) in four adjacent zones of the J.M. Stuart Segment, July through August 1970-75 (from Yoder and Gammon, 1976).

Zone	1970	1971	1972	1973	1974	1975
1	27.3 ± 0.3	36.0 ± 0.6	36.1 ± 0.8	38.0 ± 1.5	37.7 ± 0.7	38.4 ± 0.5
3		28.1 ± 0.3	27.9 ± 0.5	32.7 ± 1.4	32.0 ± 0.4	33.3 ± 0.3
4		26.9 ± 0.4	27.1 ± 0.7	30.0 ± 0.3	29.1 ± 0.7	30.5 ± 0.5
2	26.4 ± 0.4	26.0 ± 0.6	26.5 ± 0.4	27.5 ± 0.3	28.4 ± 0.5	28.5 ± 0.4
			Mean ΔT (°C)			
2 versus 1	0.9	10.2	9.6	10.5	9.3	9.9
2 versus 3		2.1	1.4	5.2	3.6	4.8

TABLE V-6 Mean numbers/km of each species collected by electrofishing in four adjacent zones of the J. M. Stuart Segment, July through October 1970-75 (from Yoder and Gammon, 1976).

Species	1970	1971	1972	1973	1974	1975
Gizzard shad	50.64	6.77	19.87	12.91	12.31	26.45
Longnose gar		1.57	0.54	1.13	1.54	6.73
White bass	1.01	1.47	0.34	1.22	1.72	4.74
Skipjack herring	5.96	0.22	0.07		0.48	1.02
Carp	0.55	0.47	0.07	0.11	0.27	0.78
Spotted bass	1.06		0.07	0.15	0.22	0.66
Smallmouth buffalo	0.17		1.12	1.27	0.33	0.63
Largemouth bass	0.39	0.66		1.01	0.50	0.61
Quillback carpsucker	0.09	0.65	0.10	0.19	0.20	0.41
River carpsucker	0.98	1.43	1.75	1.09	0.65	0.35
Bluegill	0.55	0.25	0.66	1.48	0.10	0.33
Sauger	4.80	3.81	0.31	0.36	0.10	0.29
Channel catfish	0.72	1.10	0.07		0.04	0.22
Freshwater drum	0.07	0.19			0.06	0.18
Flathead catfish	0.52		0.10	0.07	0.23	0.10
Carp X goldfish						0.08
Smallmouth bass	0.11		0.77	1.07	0.03	0.06
White crappie		0.24	0.15	0.06		0.06
Goldeye					0.04	
Golden redhorse	1.03	0.28			0.03	
Highfin carpsucker	0.13	0.66				
Shorthead redhorse		0.02	0.07			
Shortnose gar			0.07	0.07		
River redhorse	0.04					
Distance fished (km)	14.59	34.13	13.64	17.70	25.94	16.65
Total number/km	68.82	19.79	26.13	22.19	18.85	43.70
Number of species	18	16	17	15	17	18

TABLE V-7 Mean numbers/net-set of each species collected by D-nets in four adjacent zones of the J. M. Stuart Segment, July through October 1970-75 (from Yoder and Gammon, 1976).

Species	1970	1971	1972	1973	1974	1975
Bluegill	3.00	0.14	0.95	10.60	0.79	0.92
Channel catfish	0.04	0.33	0.05		0.41	0.36
Carp	0.13	0.05		0.10	0.17	0.36
Flathead catfish		0.07	0.03		0.02	0.24
White crappie	1.96	0.56	1.34	3.20	0.36	0.16
Spotted bass	0.50		0.08	0.10	0.05	0.16
Freshwater drum						0.08
White bass	0.17		0.16		0.14	0.04
River carpsucker		0.07	0.06	0.30		0.04
Longnose gar	0.04	0.05	0.03			
Shortnose gar		0.02				
Gizzard shad	0.04				0.17	
Skipjack herring	0.04					
Quillback carpsucker		0.05			0.02	
Smallmouth buffalo					0.02	
Golden redhorse			0.02			
Longear sunfish	0.08		0.02		0.02	
Black crappie	0.17				0.05	
Smallmouth bass				0.10		
Sauger		0.05	0.05			
Number of nets-set	24	43	62	10	58	25
Total number/net-set	6.17	1.39	2.79	14.40	2.22	2.36
Number of species	11	10	11	6	12	9

TABLE V-8 Mean numbers/haul and grams/haul for 23 species collected by seining above (S1) and below (S2) the J. M. Stuart Station, September 1974 through October 1975 (from Yoder and Gammon, 1976).

Species	Numbers/haul	Grams/haul
Emerald shiner	359.6	437.2
Gizzard shad	60.4	297.6
Silver chub	22.6	48.2
River shiner	14.2	25.5
Ghost shiner	5.1	3.4
Freshwater drum	4.4	15.8
Channel catfish	3.2	7.9
River carpsucker	3.0	47.5
Mimic shiner	2.2	1.2
Bluegill	0.5	0.5
Skipjack herring	0.4	13.3
Silver redhorse	0.2	0.4
Longnose gar	0.1	46.5
White bass	0.1	5.6
White crappie	0.1	1.5
Sand shiner	0.4	0.1
Silverjaw minnow	0.4	0.1
Striped bass	0.4	2.1
Smallmouth bass	0.4	0.1
Largemouth bass	0.4	10.0
Longear sunfish	0.4	0.5
Gambusia	0.4	0.1
Sauger	0.4	16.9

Number of seine-hauls:

22

Total numbers/haul:

476.5

Total grams/haul:

981.9

Number of species:

23

TABLE V-9 Comparison of mean condition factors (K_{TL})[1] of channel catfish (Ictalurus punctatus) collected in the canal (LTMC) and the Ohio River in the Fall of 1971 and the Summer of 1972 (from Hatch and Gammon, 1973).

Size Range (mm)	Canal (LTMC)		Ohio River	
	K_{TL}	Number	K_{TL}	Number
Fall 1971				
100 - 149	2.560	1	0.909	2
150 - 199	1.730	2	1.430	5
250 - 299	0.952	1	0.350	1
300 - 349	0.813	1	0.856	4
350 - 399	0.860	2	0.853	11
400 - 449	0.794	2	0.839	4
450 - 499	0.847	1	0.882	2
500 - 549	1.150	1	0.918	4
Summer 1972				
200 - 249	0.967	2	0.567	2
250 - 299	0.794	1	0.711	1
350 - 399	0.819	3	0.818	27
400 - 449	0.861	2	0.781	32
450 - 499	0.894	9	0.835	11
500 - 549	0.842	1	0.801	2

[1] $K_{TL} = W \times 10^5/L^3$, where: W = weight in grams and L = length in millimeters.

TABLE V-10 Preferred and lethal temperatures of selected fishes found in the Ohio River (from WAPORA, Inc., 1975, p. 150).

Species	Source	Acclimation Temperature °C	Lethal Temperature °C	Preferred Temperature °C
Gizzard shad	Clark (1969)		36.0	24.0
Northern pike	U.S. EPA (1972)	25	32.25	
Stoneroller	Cherry, et al (1975)	24		25.3
Goldfish	Ferguson (1958)	25		27.5
	Clark (1969)		41.0	28.5
Carp	Ferguson (1958)	25		30.5
	Snyder & Blahm (1971)		35.5	20-32
Emerald shiner	Hart (1947)	25	30.7	
	Barans & Tubb (1973)	23		22.0-23.0
Spotfin shiner	Cherry, et al (1975)	24		26.5
Bluntnose minnow	Hart (1947)	25	33.3	
	Cherry, et al (1975)	24		25.7
Creek chub	Hart (1947)	25	30.3	
White sucker	Hart (1947)	25	29.3	
Brown bullhead	Welsh & Wojtalik (1968)	30	36.5	
	Ohio EPA (1974)	25	33.8	
Channel catfish	U.S. EPA (1972)	25	33.5	
	Cherry, et al (1975)	24		29.4
White bass	Barans & Tubb (1973)	23		30-32
Rock bass	Welsh & Wojtalik (1968)	24	36.7	
Green sunfish	Cherry, et al (1975)	24		30.4
Pumpkinseed	Welsh & Wojtalik (1968)	21	38.9	
Bluegill sunfish	Clark (1969)		35	32
	Snyder & Blahm (1971)		37.8	
	Cherry, et al (1975)	24		31.2
Longear sunfish	U.S. EPA (1972)	25	35.6	
Smallmouth bass	Snyder & Blahm (1971)		28.0	20.0-21.5
	Cherry, et al (1975)	24		29.8
Spotted bass	Cherry, et al (1975)	24		32.2
Largemouth bass	Welsh & Wojtalik (1968)	24	36.1	
	Clark (1969)		35.5	28.0-32.0
	Snyder & Blahm (1971)		30.0	26.5-29.0
Yellow perch	Hart (1947)	25	29.7	
	Ferguson (1958)	25		24.5
	Snyder & Blahm (1971)		26.5	20.0-25.0

TABLE V-11 List of endangered fish species of Ohio appearing in the October 29, 1974 draft Ohio EPA 316(a) guidelines.

Common Name	Scientific Name
Ohio lamprey	*Ichthyomyzon bdellium*
Northern brook lamprey	*Ichthyomyzon fossor*
Allegheny brook lamprey	*Ichthyomyzon greeleyi*
Silver lamprey	*Ichthyomyzon unicuspis*
American brook lamprey	*Lampetra lamottei*
Lake sturgeon	*Acipenser fulvescens*
Paddlefish	*Polyodon spathula*
Spotted gar	*Lepisosteus oculatus*
Shortnose gar	*Lepisosteus platostomus*
Mooneye	*Hiodon tergisus*
Cisco	*Coregonus artedii*
Great Lakes muskellunge	*Esox m. masquinongy*
Rosyside dace	*Clinostomus funduloides*
Tonguetied minnow	*Exoglossum laurae*
Bigmouth shiner	*Notropis dorsalis*
Pugnose minnow	*Notropis emiliae*
Bigeye shiner	*Notropis boops*
Ghost shiner	*Notropis buchanani*
Blacknose shiner	*Notropis heterolepis*
Silver chub	*Hybopsis storeriana*
Longnose sucker	*Catostomus catostomus*
Greater redhorse	*Moxostoma valenciennesi*
Blue sucker	*Cycleptus elongatus*
River redhorse	*Moxostoma carinatum*

TABLE V-11 (continued)

Common Name	Scientific Name
Lake chubsucker	Erimyzon sucetta
Scioto madtom	Noturus trautmani
Northern madtom	Notorus stigmosus
Mountain madtom	Noturus eleutherus
Pirateperch	Aphredoderus sayanus
Burbot	Lota lota
Banded killifish	Fundulus diaphanus
Iowa darter	Etheostoma exile
Spotted darter	Etheostoma maculatum
Longhead darter	Percina macrocephala
River darter	Percina shumardi
Eastern sand darter	Ammocrypta pellucida
Channel darter	Percina copelandi
Blue pike	Stizostedion vitreum glaucum
Tippecanoe darter	Etheostoma tippecanoe
Slenderhead darter	Percina phoxocephala

TABLE V-12 State of Kentucky (Kentucky Department of Natural Resources) endangered fish species list as of September 1976.

Common Name	Scientific Name
Trout perch	*Percopsis omiscomaycus*
Mud darter	*Etheostoma aspringene*
Harlequin darter	*Etheostoma histrio*
Tippecanoe darter	*Etheostoma tippecanoe*
Longhead darter	*Percina macrocephala*

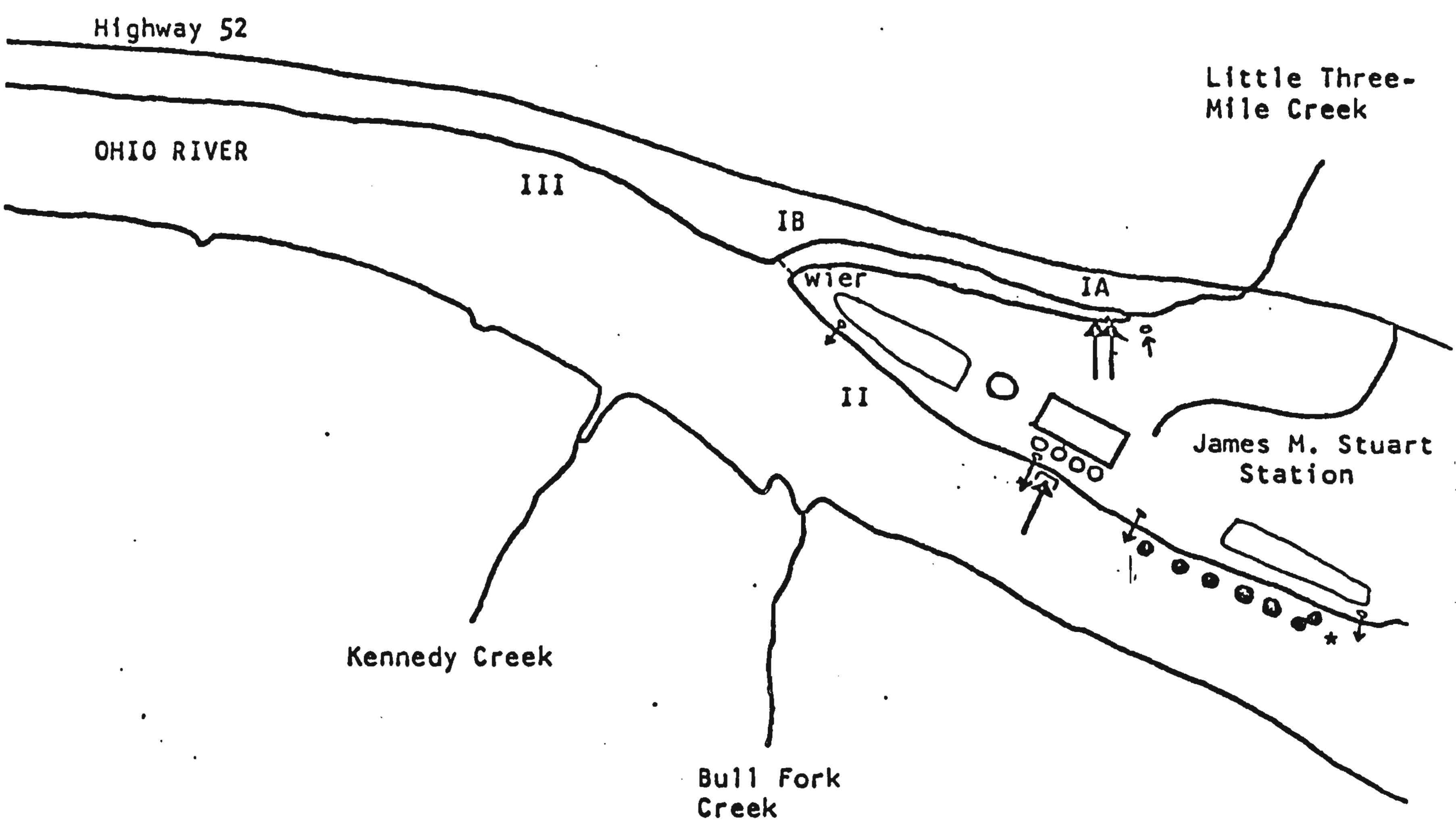

FIGURE V-1 Sampling station locations (IA, IB, II and III) at the J. M. Stuart Station (from Miller and Kallendorf, 1972-1973).

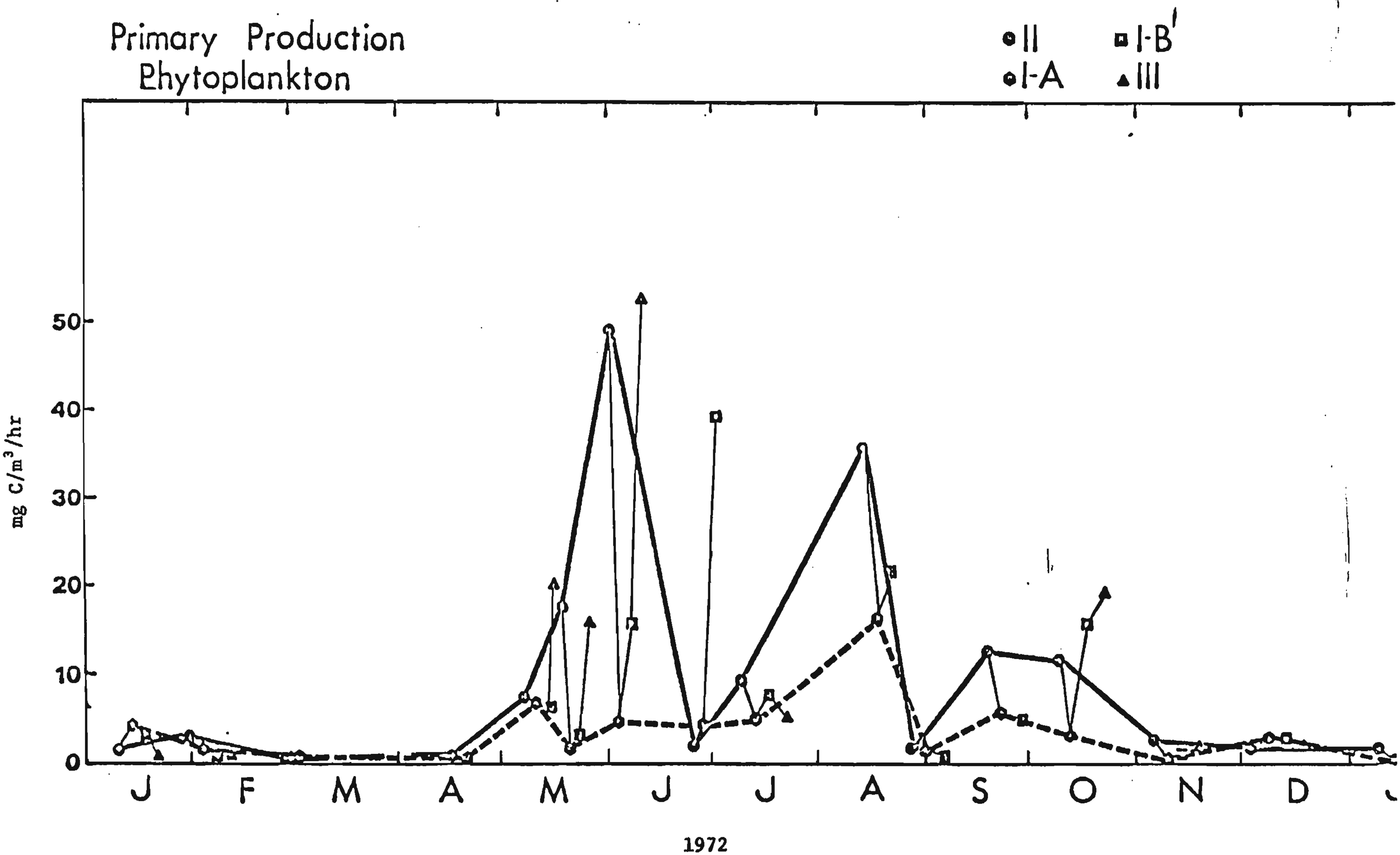

FIGURE V-2 Phytoplanktonic primary production (mg $C/m^3/hr$) during mid-day in the Ohio River (Station II - solid line), and Little Three Mile Creek (Station IA - dashed line), 1972 at 0.1 meter (from Miller and Kallendorf, 1972-1973).

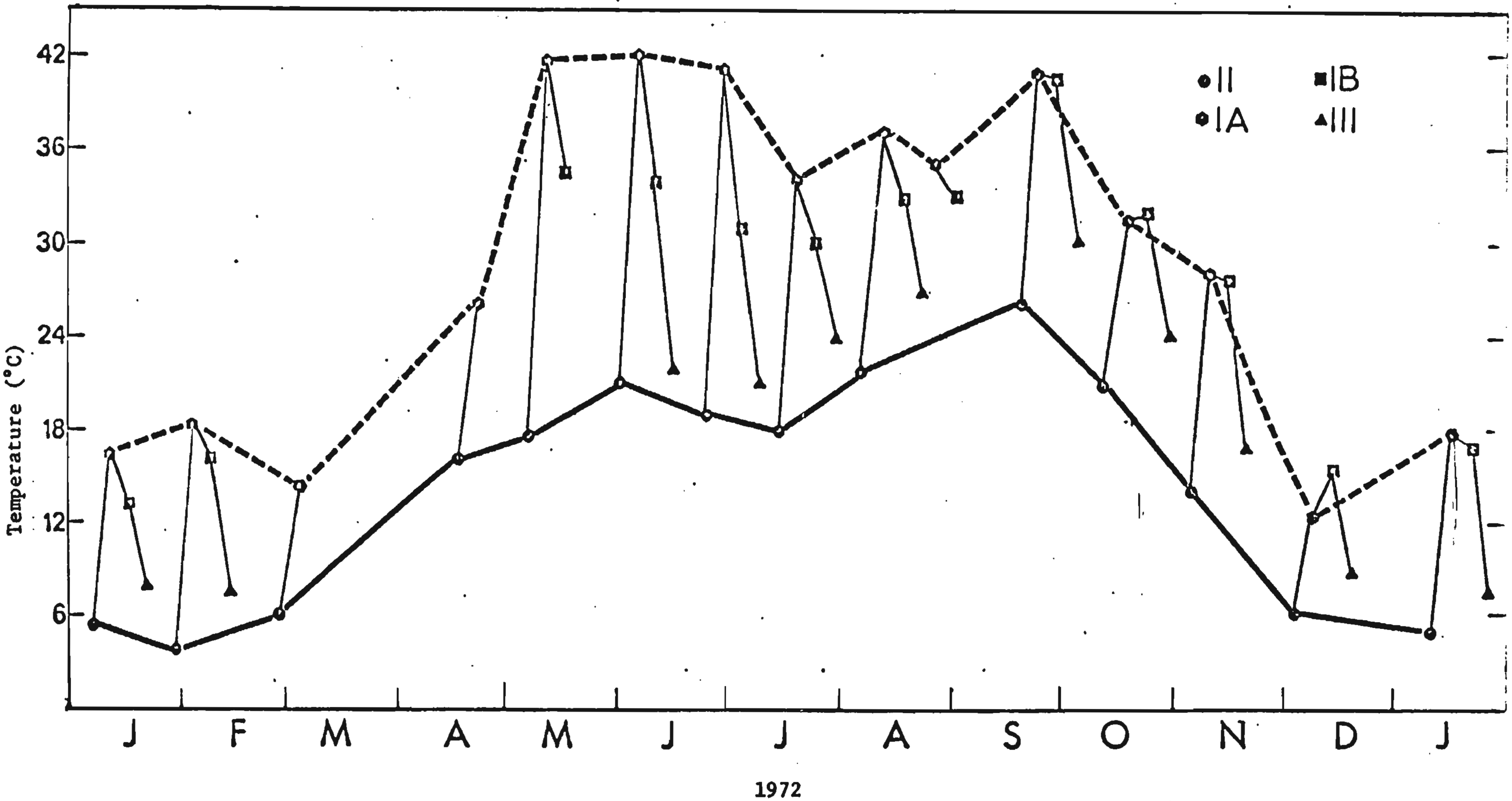

FIGURE V-3 Annual cycle of temperature in the Ohio River (solid line) and of Station IA in Little Three Mile Creek (dashed line) below the outfall of the J. M. Stuart Generating Station, 1972 (from Miller and Kallendorf, 1972-1973).

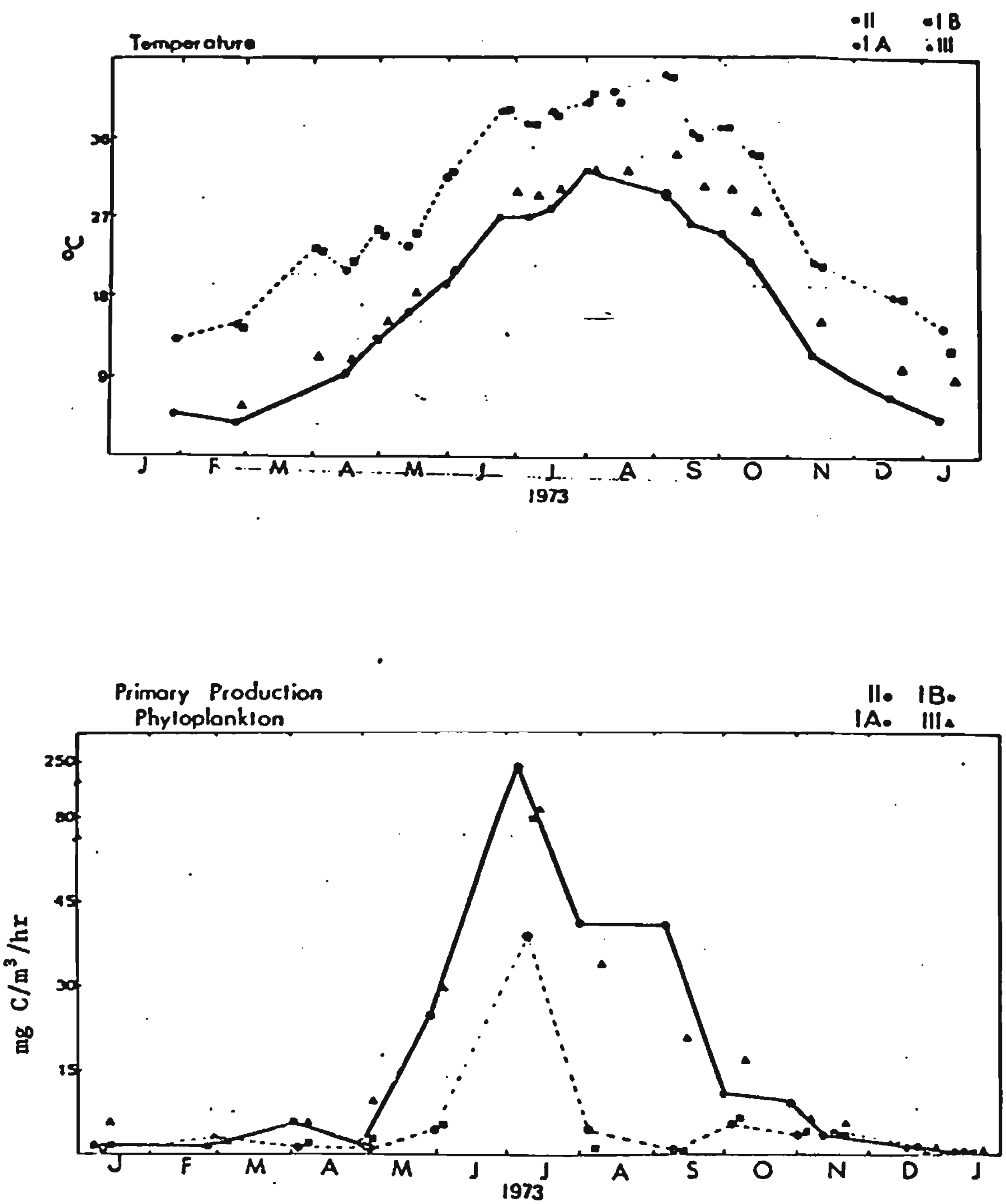

FIGURE V-4 Temperature and phytoplankton primary productivity in the Ohio River (Station II - solid line) and Little Three Mile Creek (Station IA - dashed line) during 1973 (from Reed *et al.*, 1974).

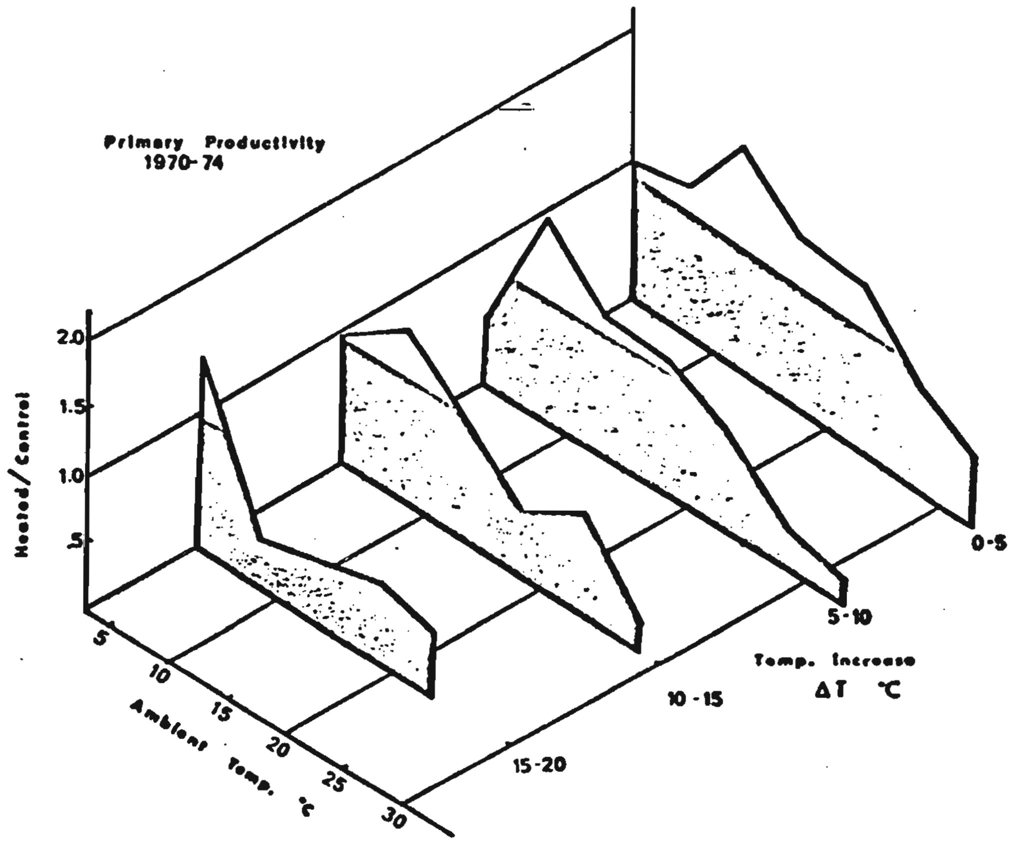

FIGURE V-5 Ratio of primary production at heated stations to the control (Station II) as functions of ambient temperature and ΔT, 1971-1974 (from Miller et al., 1975).

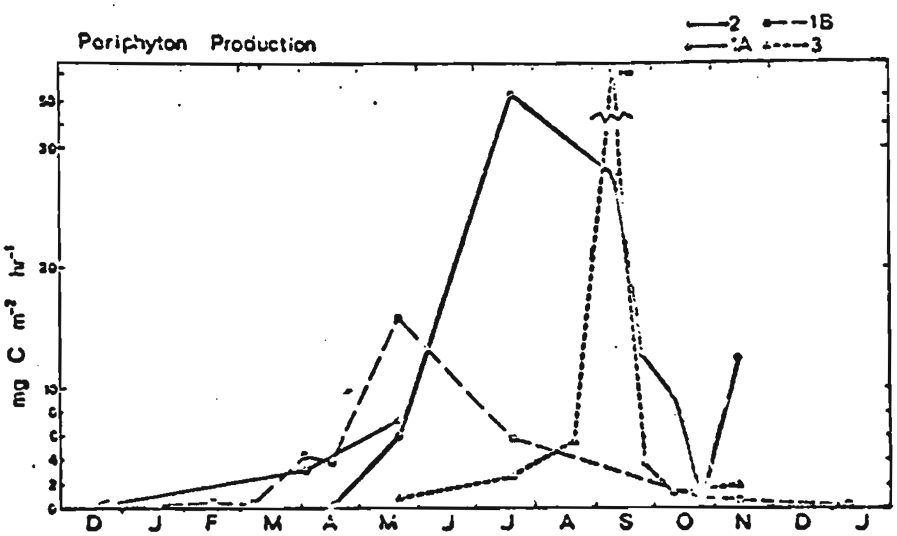

FIGURE V-6 Annual cycle of periphyton production (mg C/m^3/hr) at Stations II, IA, IB, and III (from Miller et al., 1971-1972.)

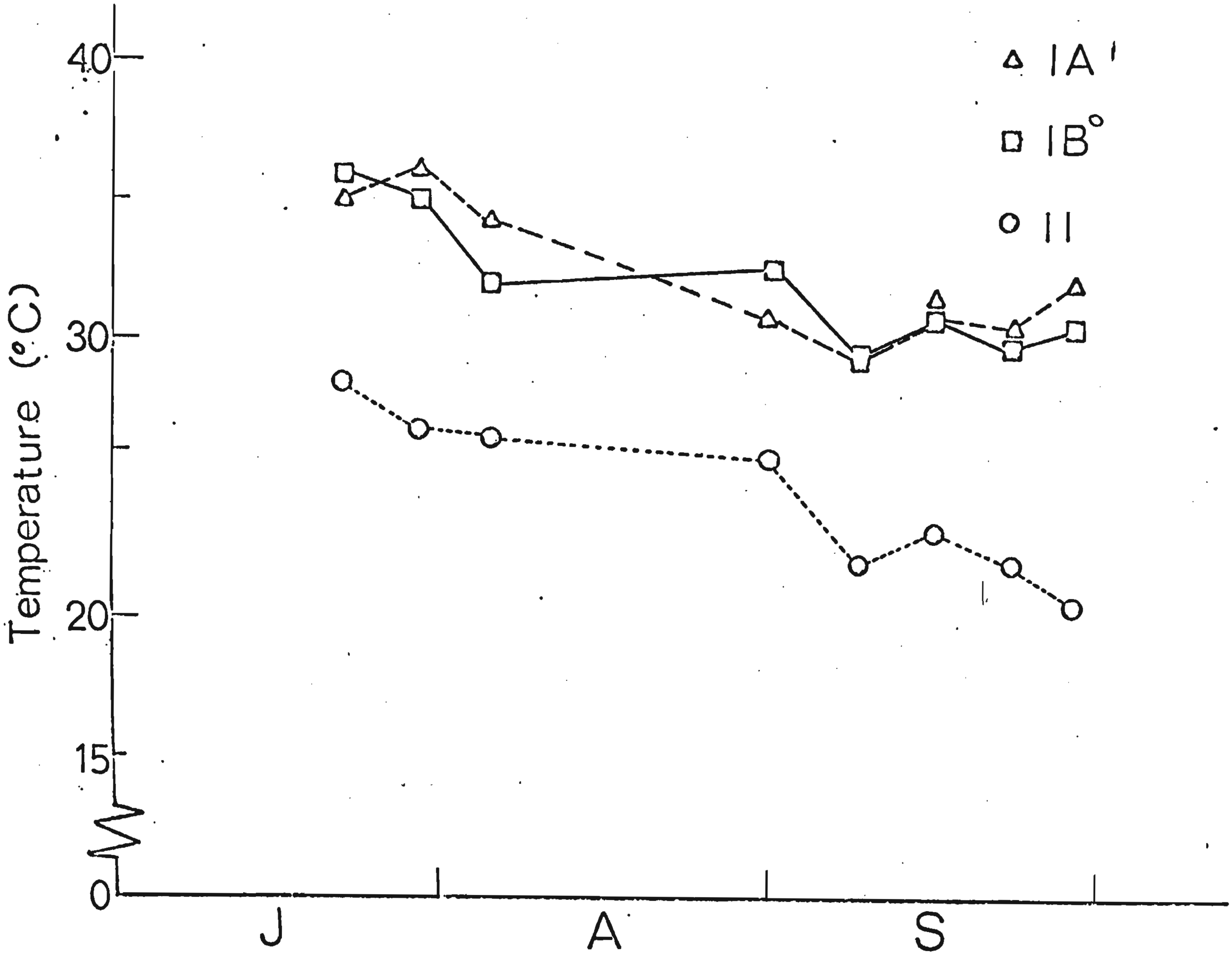

FIGURE V-7 Temperature of surface waters in the Ohio River and two stations in LTMC during the summer of 1974 when zooplankton live-dead analyses were taken (from Reed *et al.*, 1974).

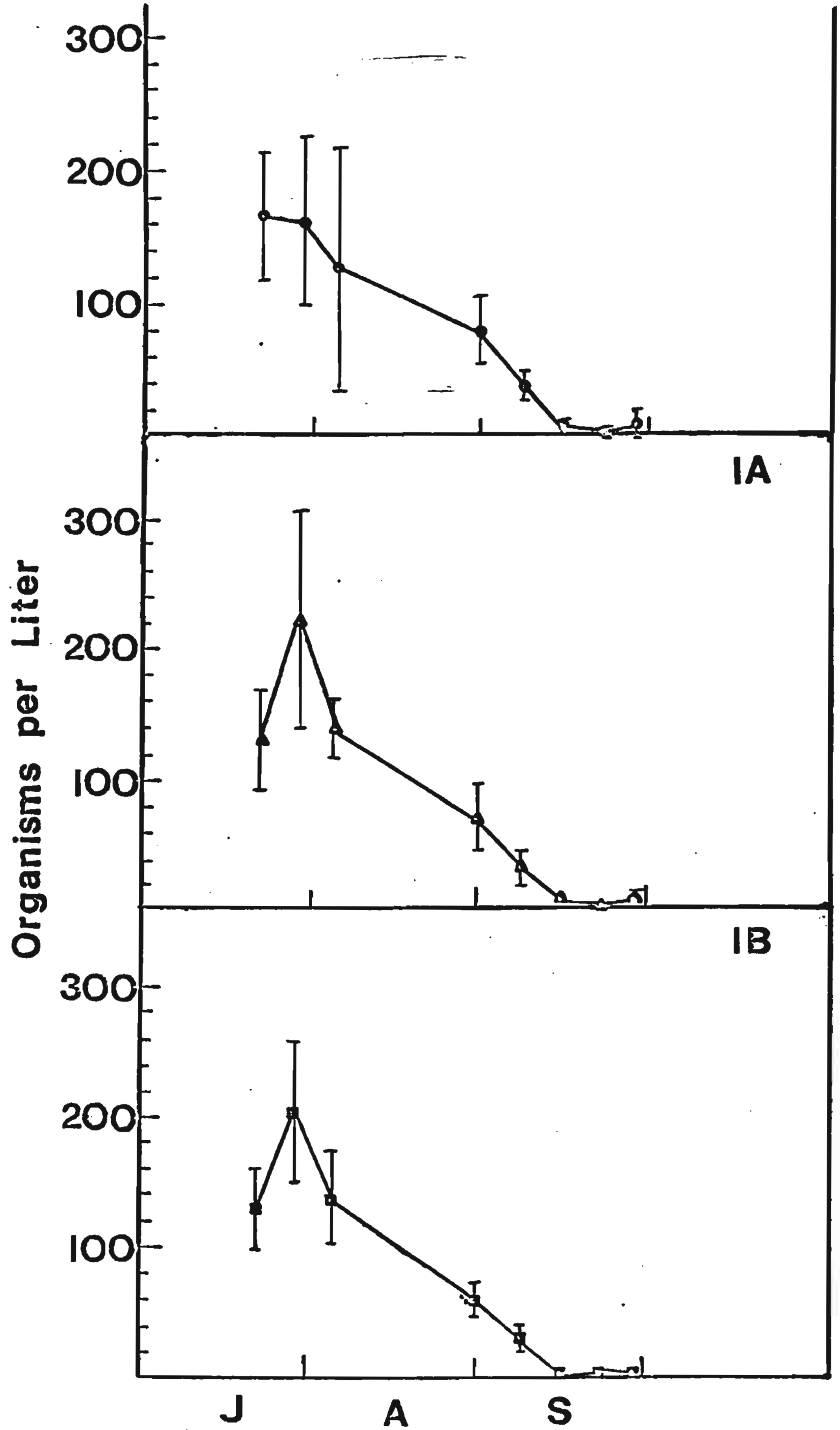

FIGURE V-8 Zooplankton (Cladocera, Copepoda, Rotifera) density in the Ohio River (Station II) and discharge channel (Stations IA and IB) during July-September, 1974 (± standard deviation) (from Miller et al., 1975).

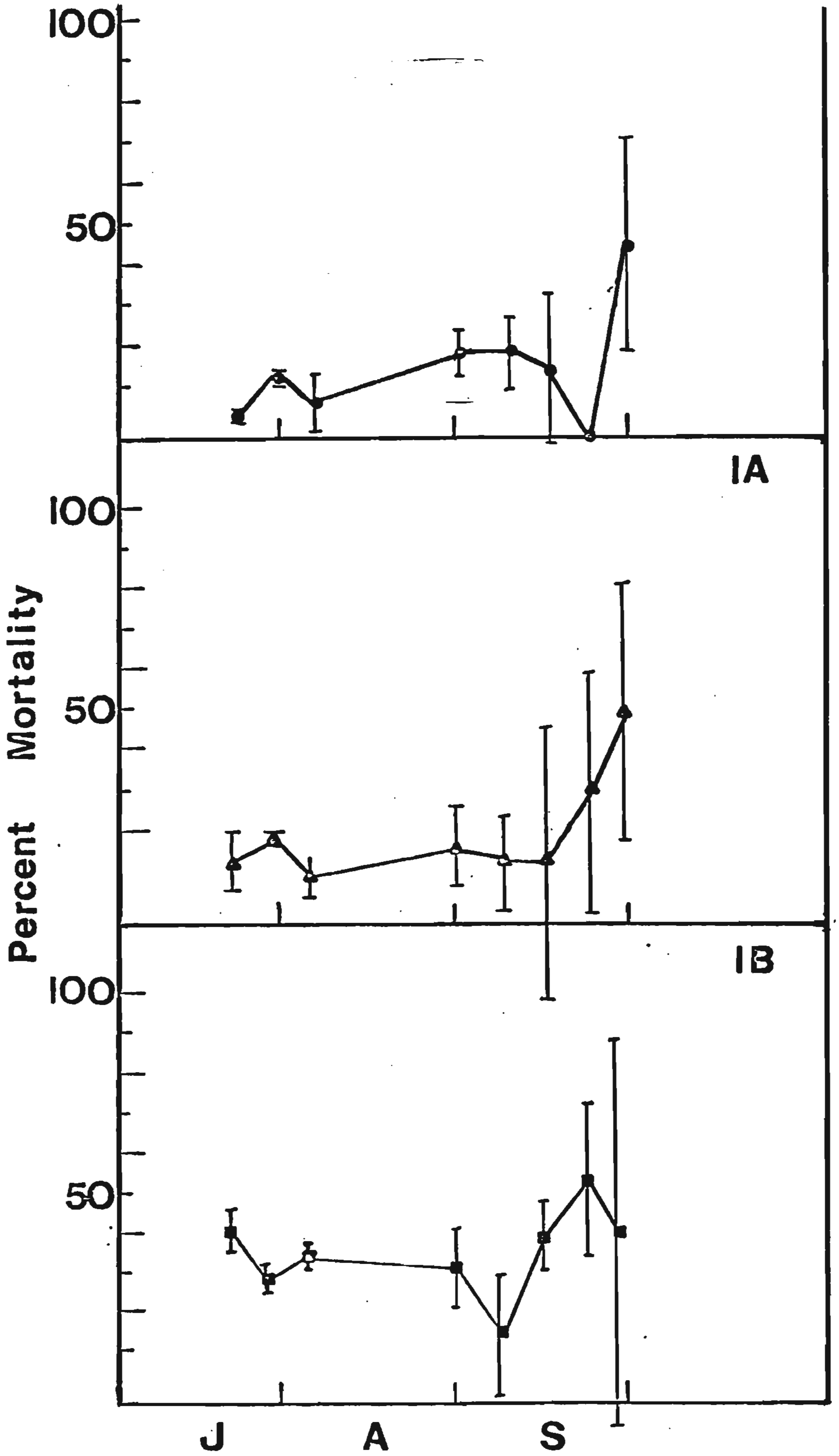

FIGURE V-9 Percentage zooplankton mortality in the Ohio River (Station II) and discharge channel (Stations IA and IB) at the J. M. Stuart Station during July-September, 1974 (from Miller et al., 1975).

Legend

A. Little-Three-Mile Creek

B. Kennedy Creek

C. Bull Fork Creek

D. J. M. Stuart Electrical Generating Station

E. River navagational signals

F. Weir

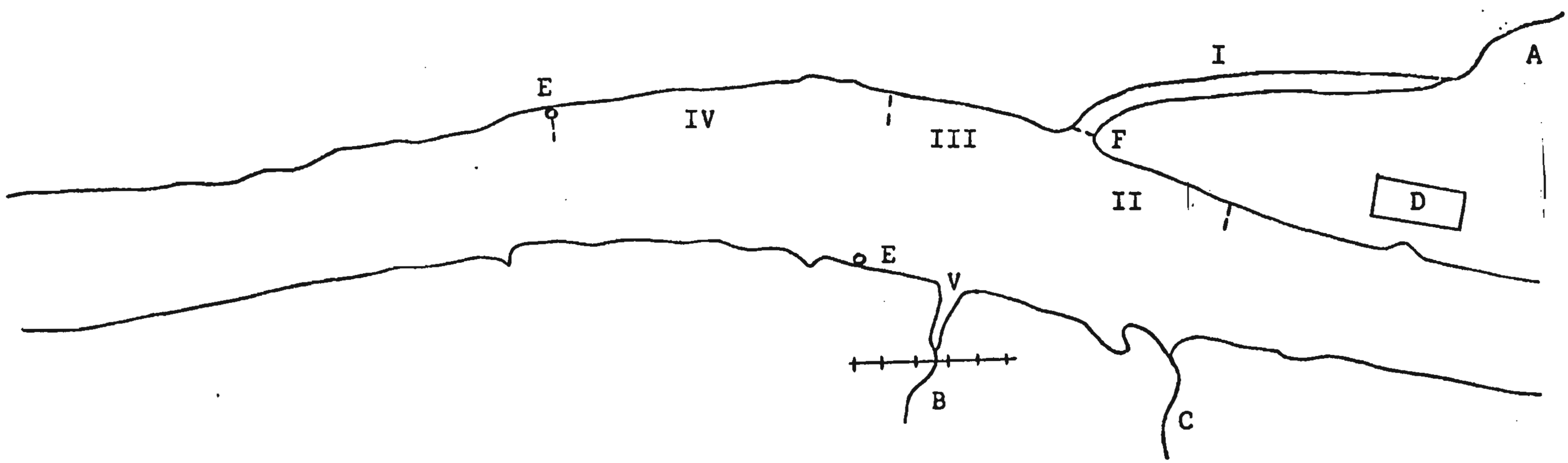

FIGURE V-10 Location of sampling zones (I through V) at the J. M. Stuart Station, 1970 (from Norris and Gammon, no date).

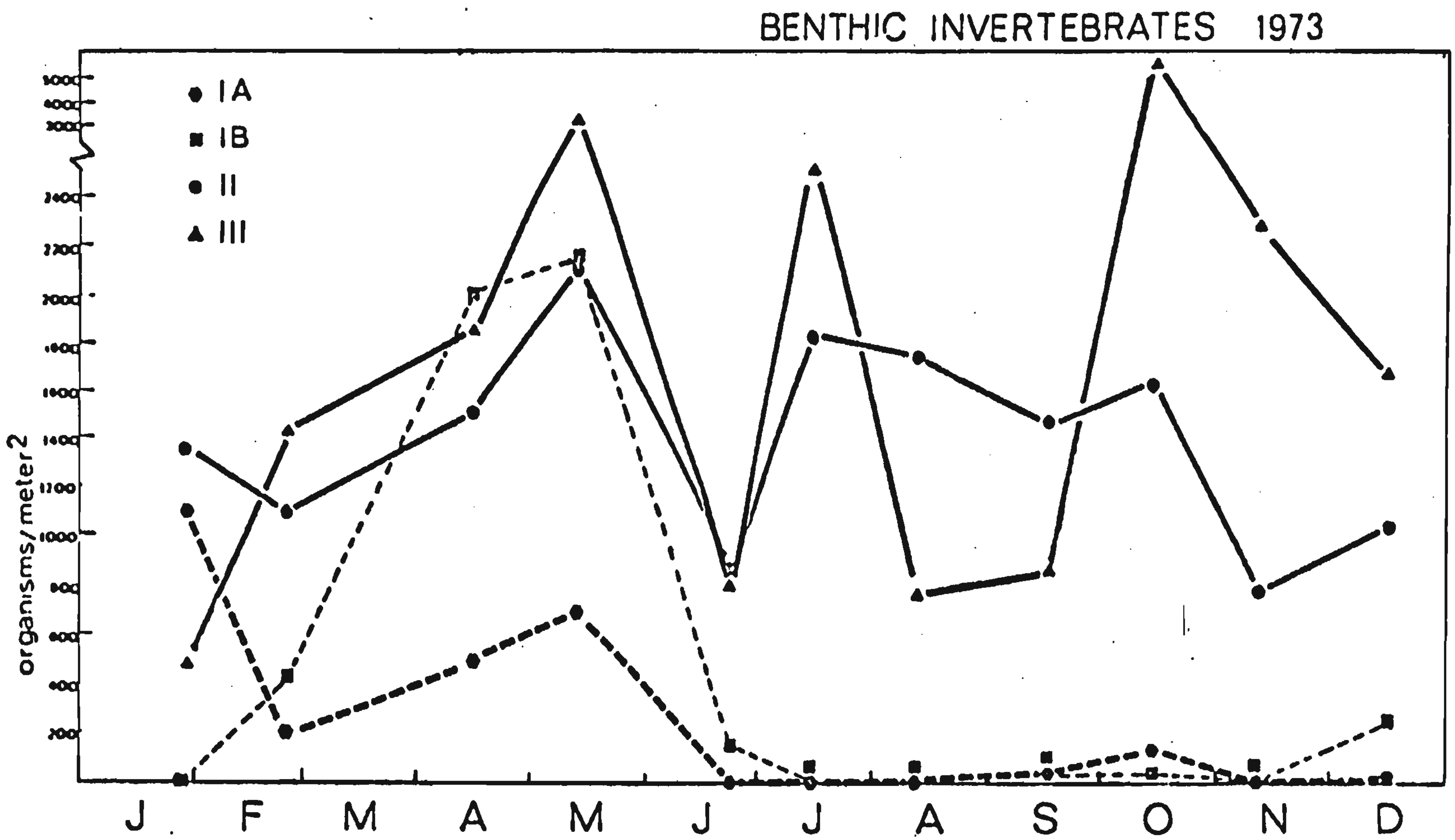

FIGURE V-11 Density of macroinvertebrates collected from natural substrates of LTMC and the Ohio River, 1973 (from Reed et al., 1974).

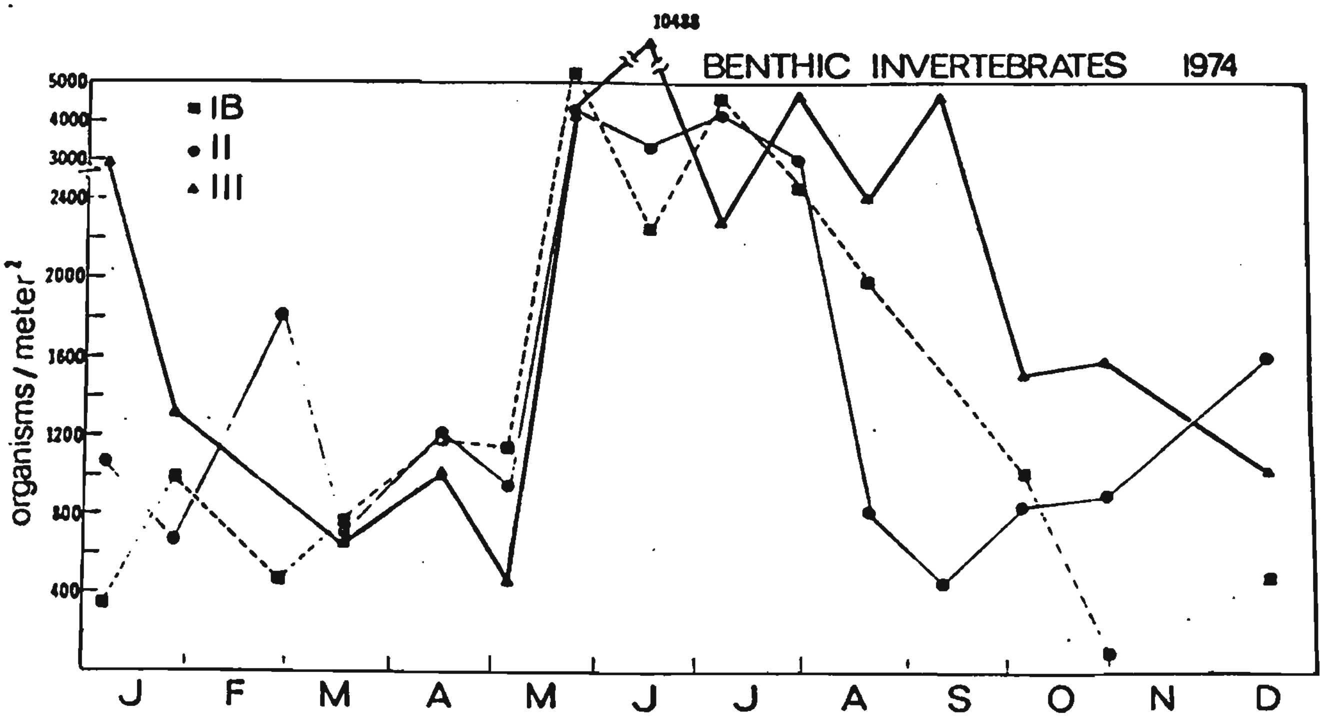

FIGURE V-12 Density of macroinvertebrates collected from natural substrates of LTMC (Station IB) and the Ohio River (Stations II and III), 1974 (from Miller et al., 1975).

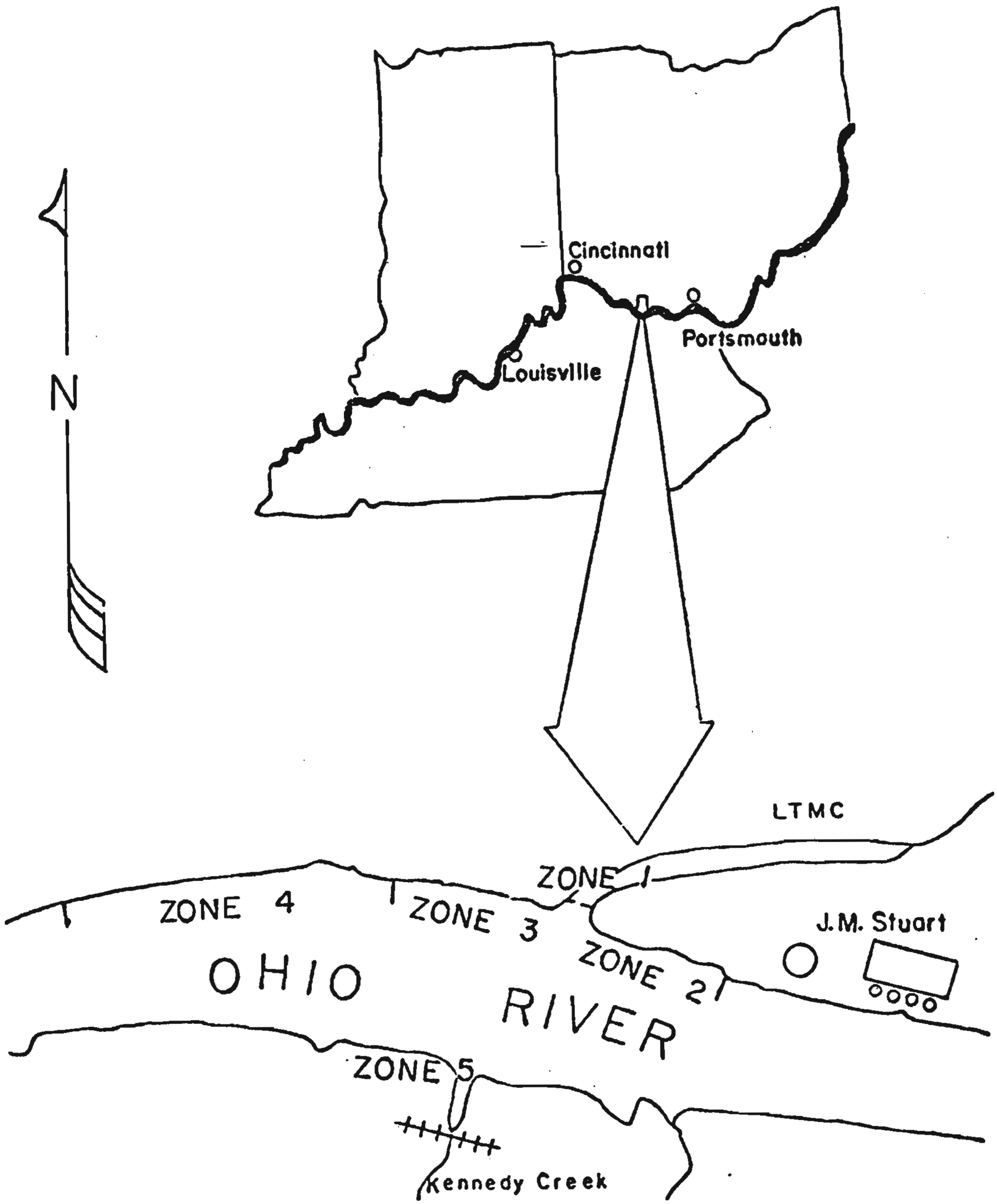

FIGURE V-13 Location of the J. M. Stuart Station and Sampling Zones 1 through 5 (from Hatch and Gammon, 1973).

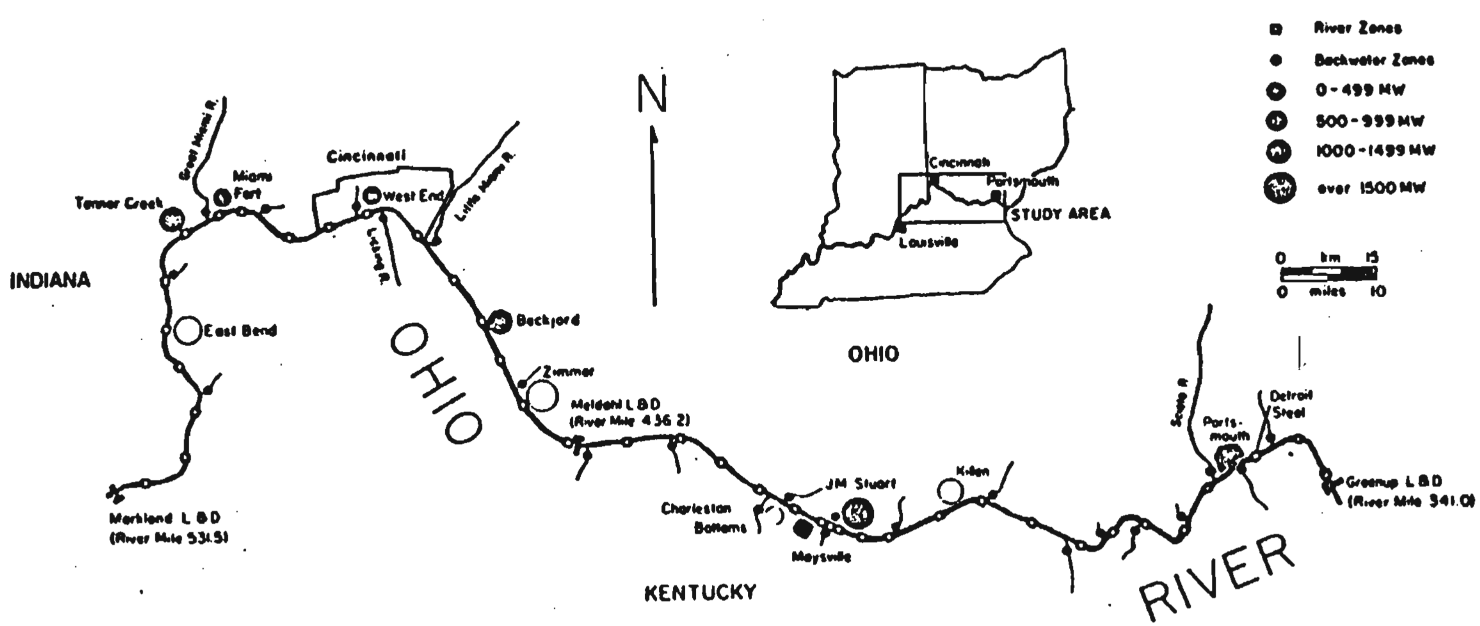

FIGURE V-14 Map of the 301 km study area showing regional location and the locations of the major municipal areas, locks and dams, and thermal sources in relation to the 39 river and 23 backwater zones studied July-October 1975(closed circles = operational plants, open circles = plants under construction) (from Yoder and Gammon, 1976).

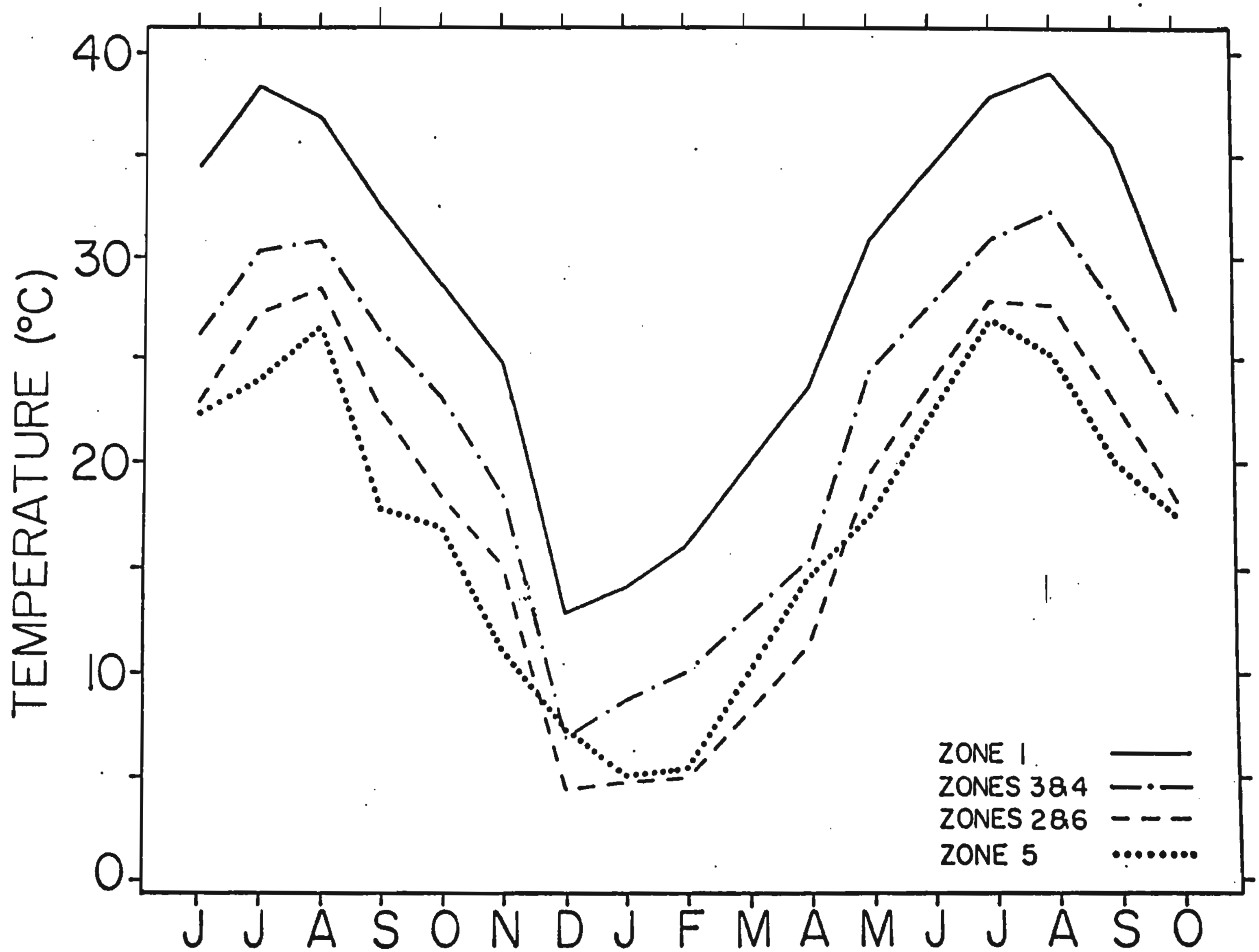

FIGURE V-15 Seasonal temperature variations in degrees C; June 1974 through October 1975, in zone 1 (———), zones 3 and 4 (—·—·), zones 2 and 6 (------), and zone 5 (......) (from Yoder and Gammon, 1976).

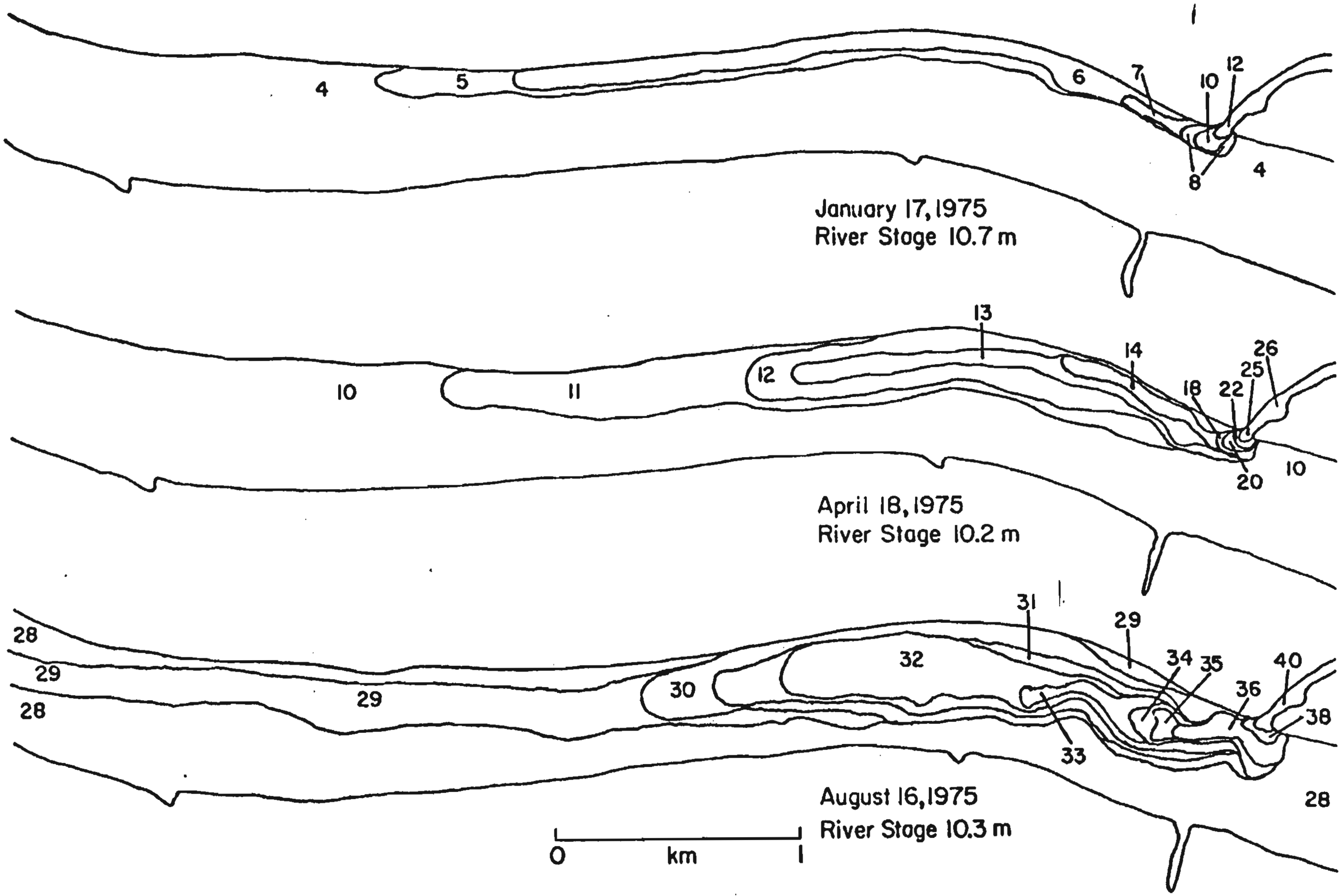

FIGURE V-16 Thermal plume configuration in °C downriver from the J. M. Stuart discharge canal during January, April, and August 1975 (from Yoder and Gammon, 1976).

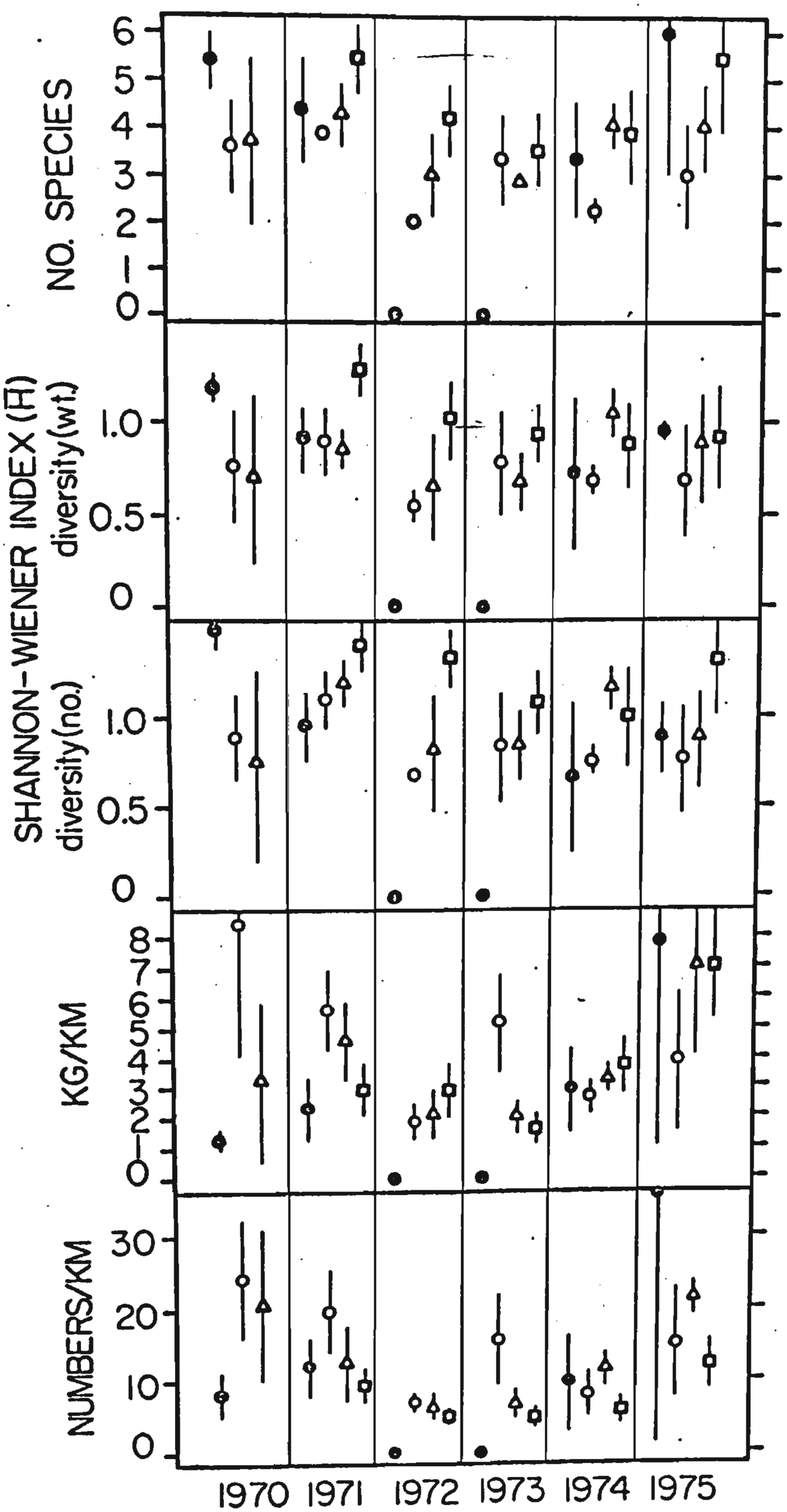

FIGURE V-17 Annual variations of five community indices (+ std. err) in zone 1 (•), zone 2 (o), zone 3 (Δ), and zone 4 (□) for electrofishing catches, July-October 1970-1975 (from Yoder and Gammon, 1976).

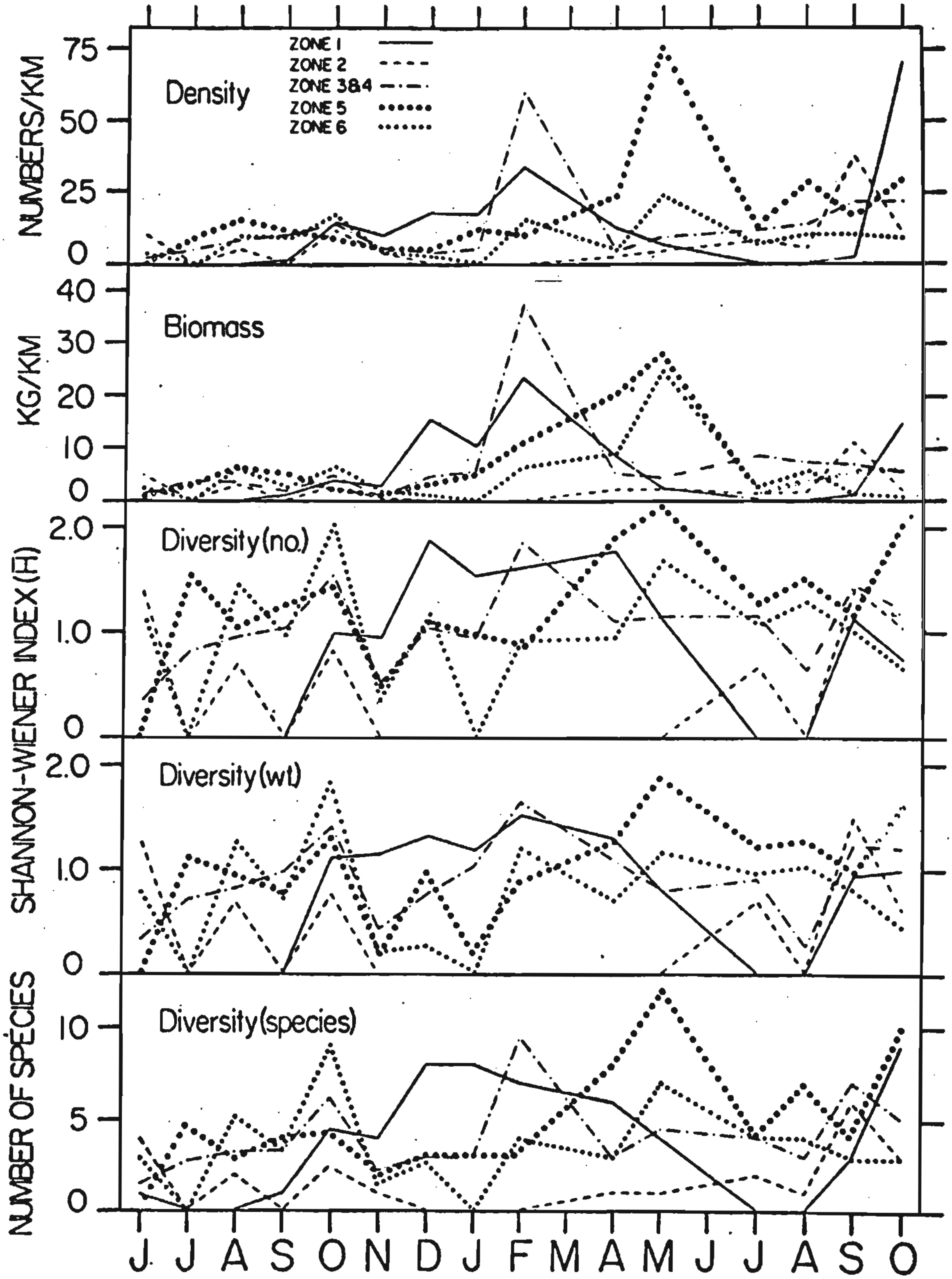

FIGURE V-18 Seasonal variations of five community indices for electrofishing catches in the J. M. Stuart segment, June 1974-October 1975 (from Yoder and Gammon, 1976).

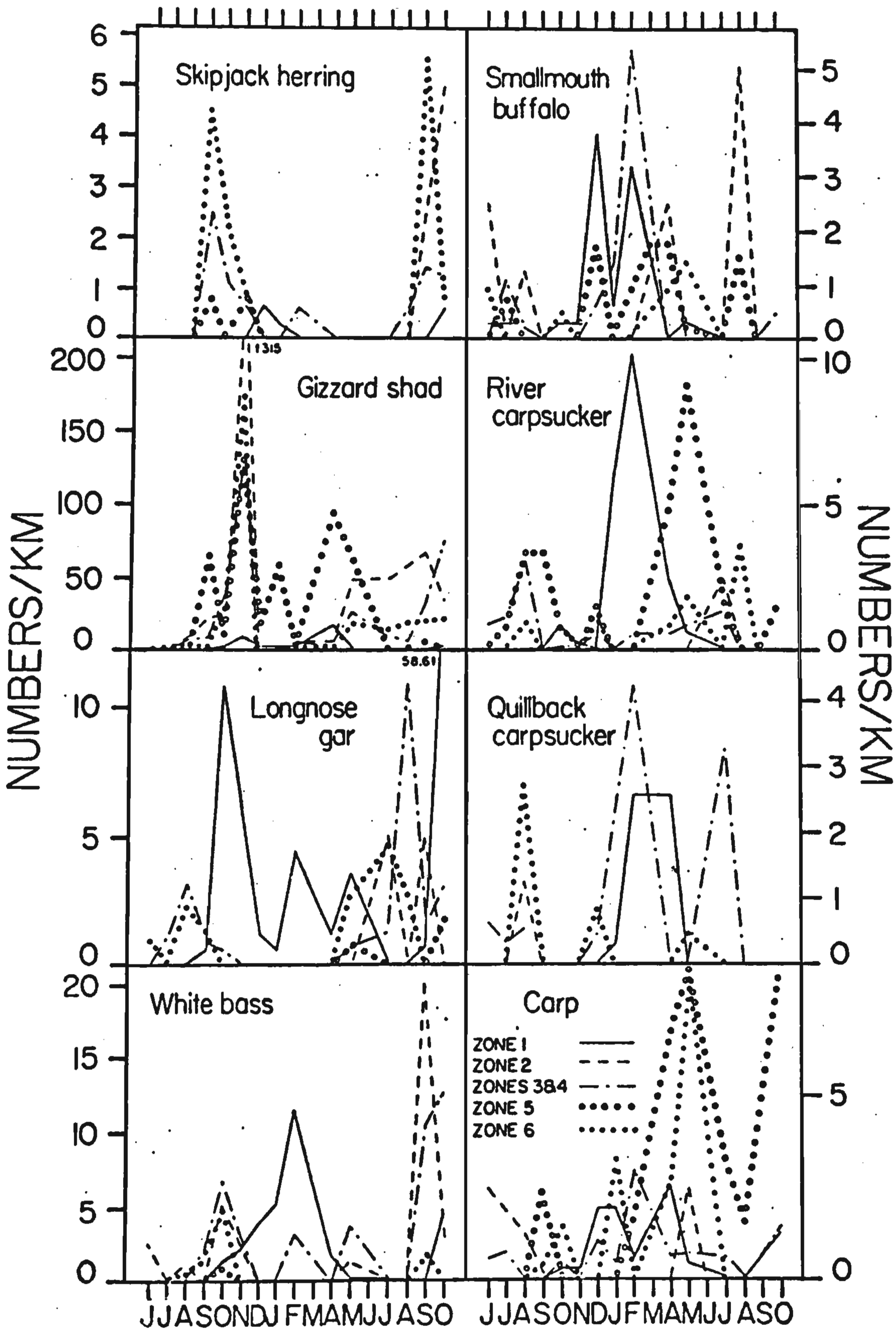

FIGURE V-19 Seasonal abundance of eight species collected by electrofishing in the J. M. Stuart segment, June 1974-October 1975 (from Yoder and Gammon, 1976).

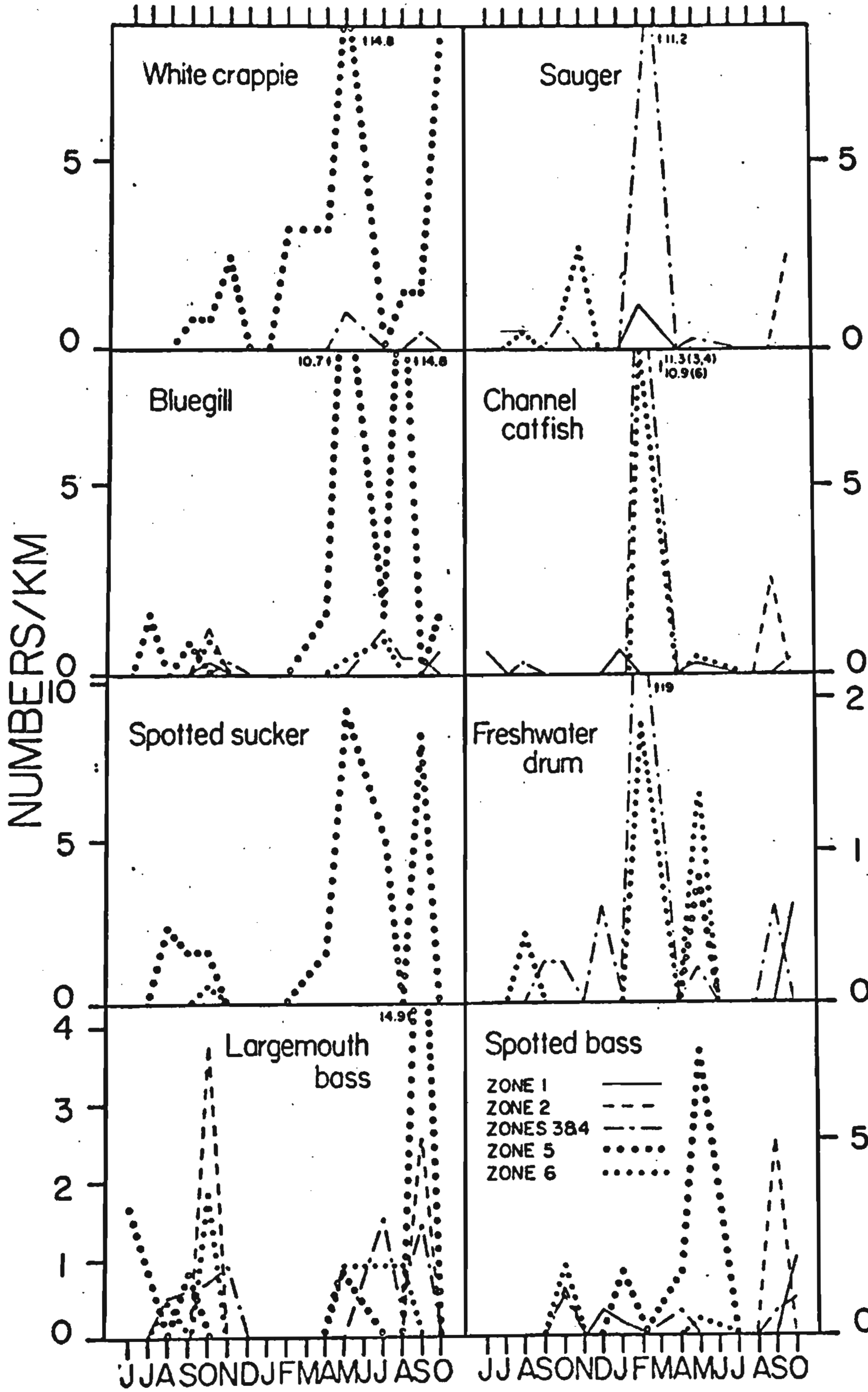

FIGURE V-20 Seasonal abundance of eight species collected by electrofishing in the J. M. Stuart segment, June 1974-October 1975 (from Yoder and Gammon, 1976).

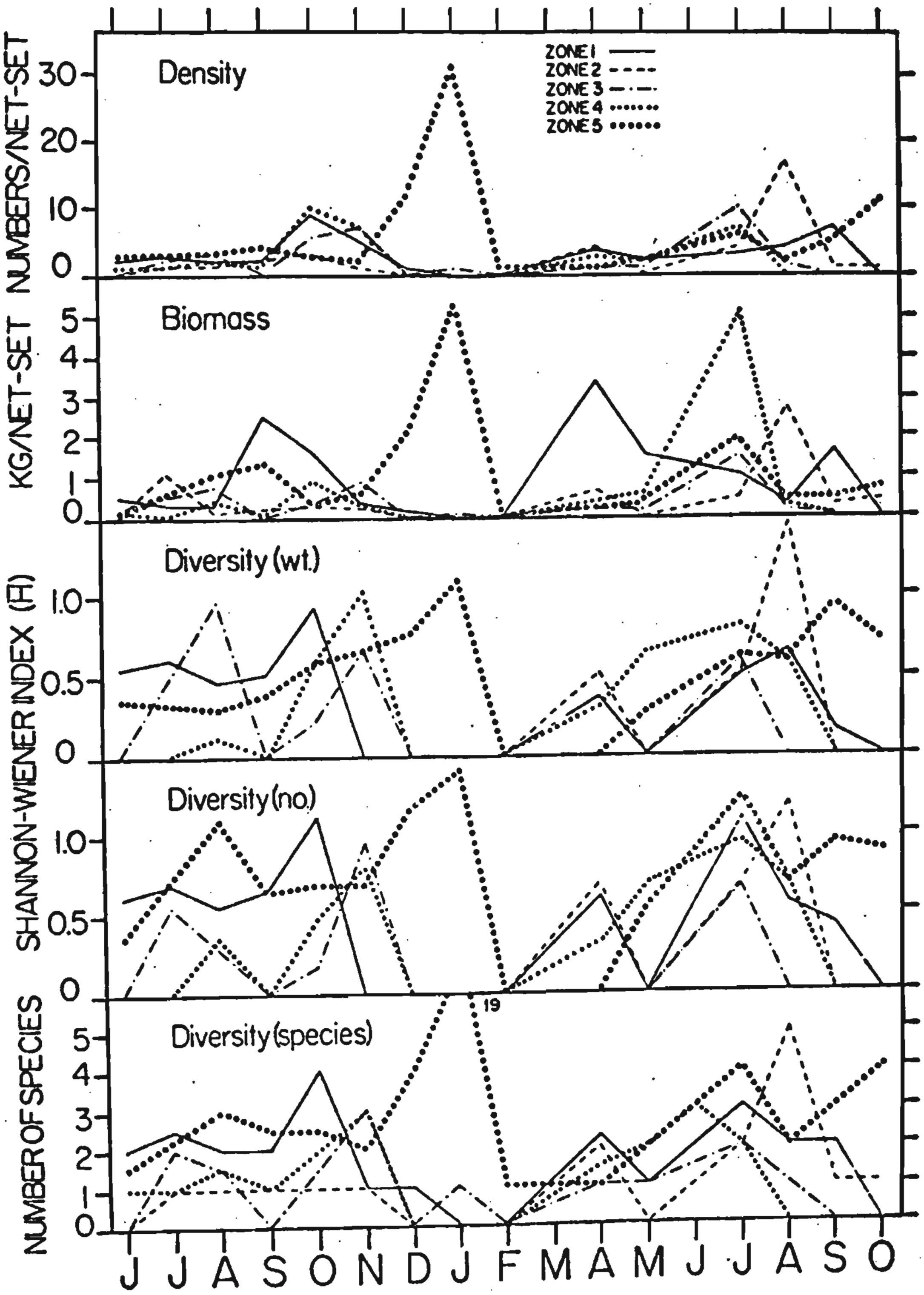

FIGURE V-21 Seasonal variations of the five community indices for D-net catches in the J. M. Stuart segment, June 1974-October 1975 (from Yoder and Gammon, 1976).

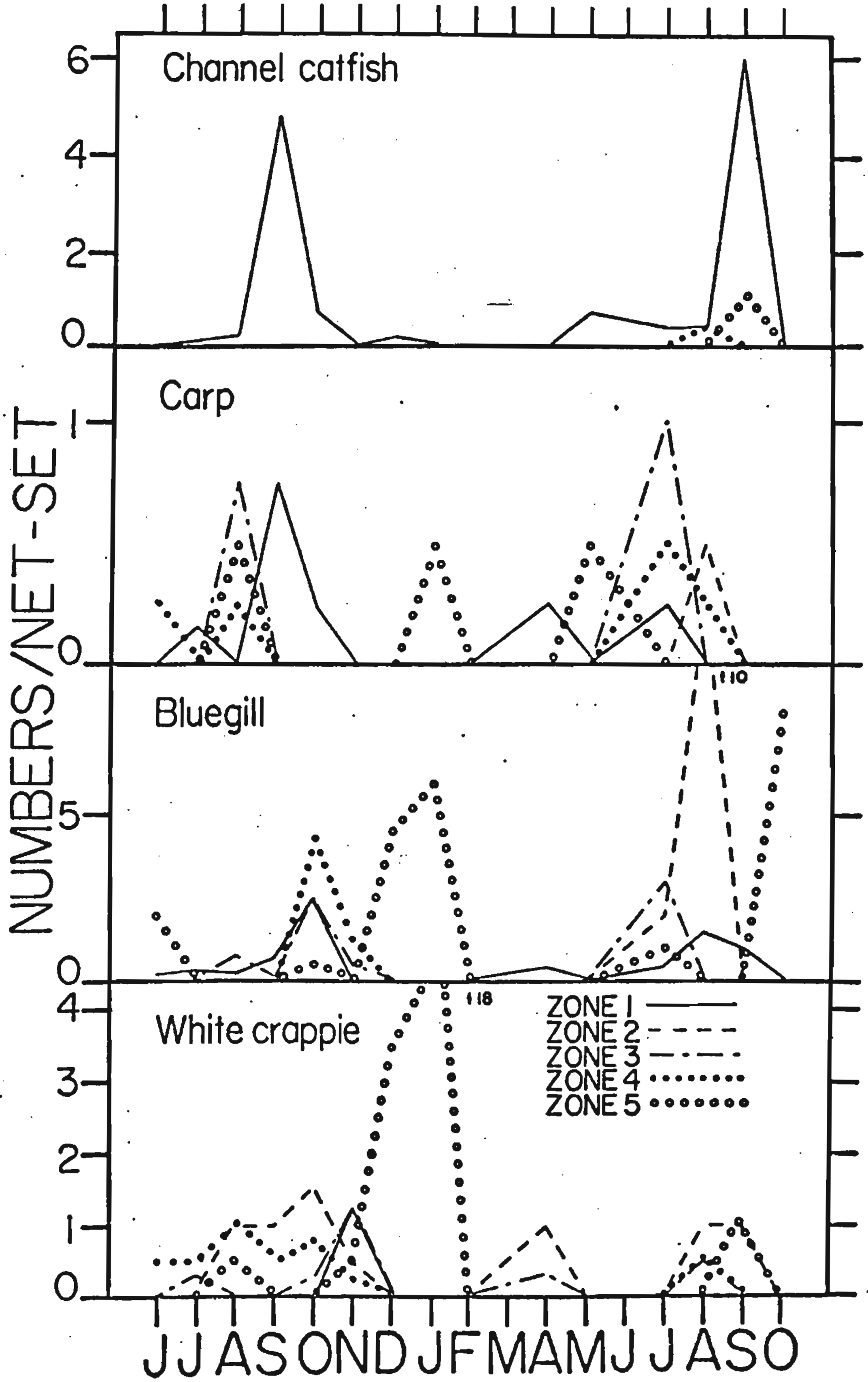

FIGURE V-22 Seasonal abundance of four species collected in D-nets in the J. M. Stuart segment, June 1974-October 1975 (from Yoder and Gammon, 1976).

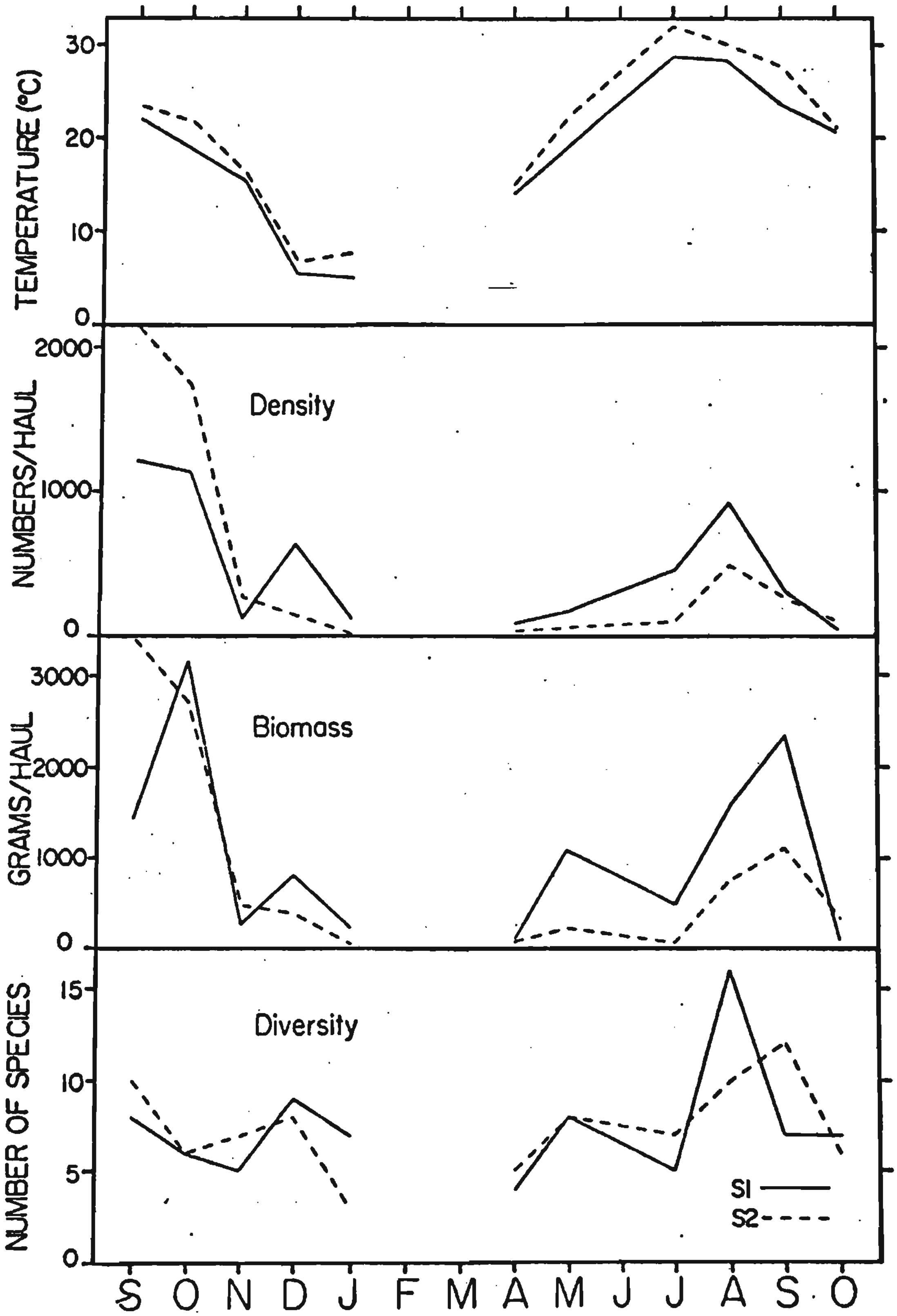

FIGURE V-23 Seasonal variations in temperature (°C), density, biomass, and diversity at S1 (——) and S2 (--) for seining catches, September 1974-October 1975 (from Yoder and Gammon, 1976).

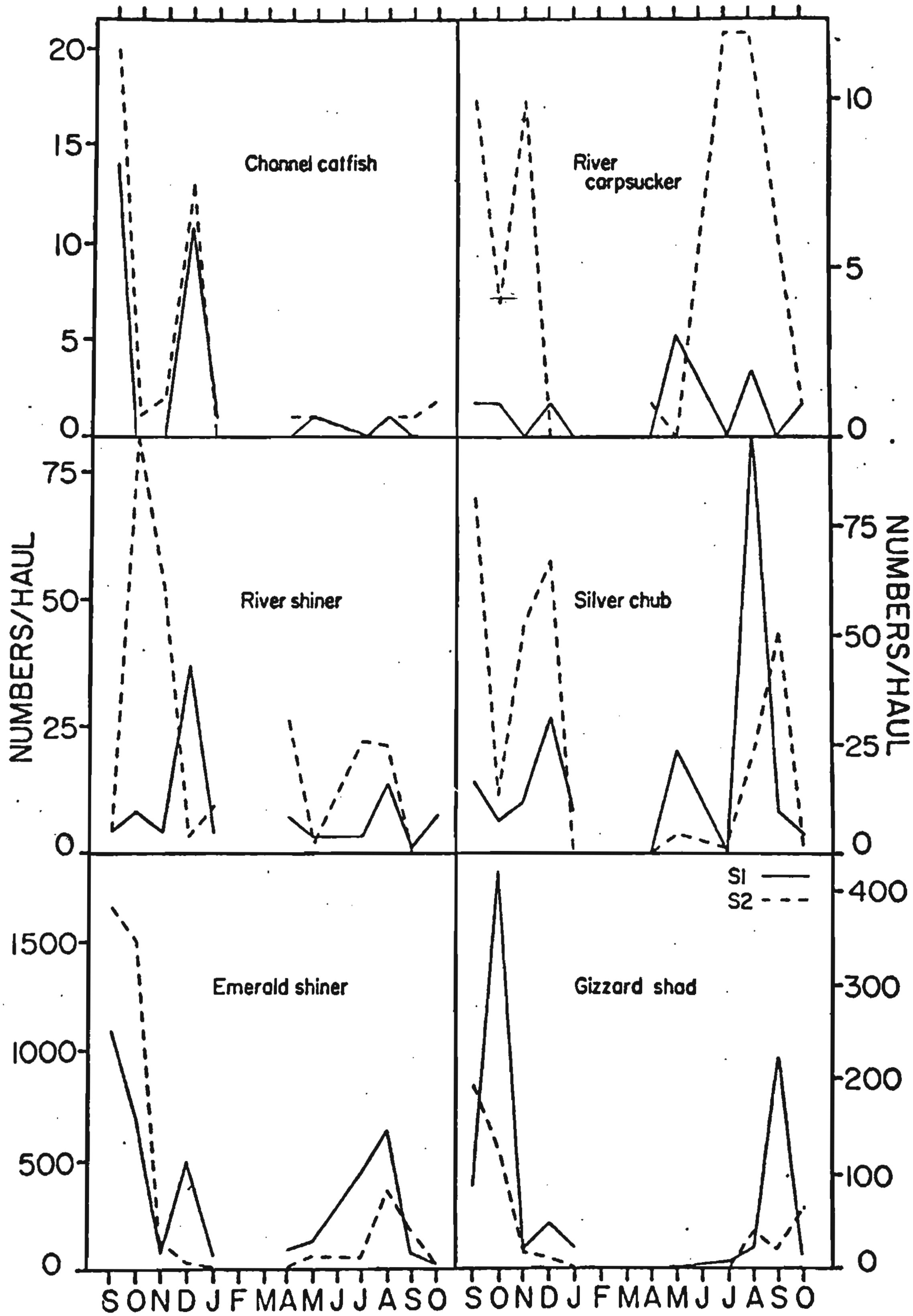

FIGURE V-24 Seasonal abundance of six species collected by seining at S1 (——) and S2 (--), September 1974-October 1975 (from Yoder and Gammon, 1976).

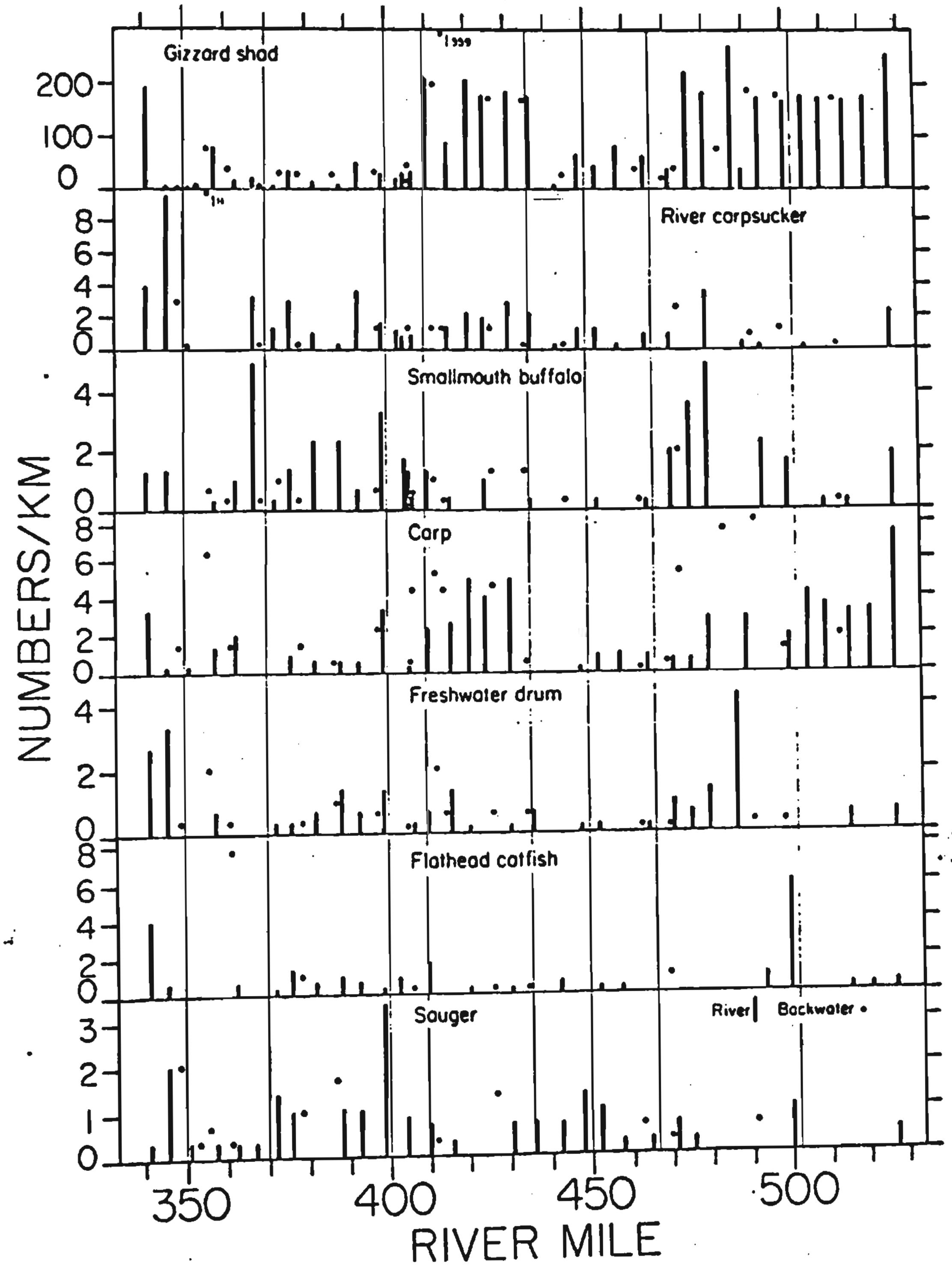

FIGURE V-25 Distribution and relative abundance of seven intermediate species in the 301 km study area, July-October 1975 (from Yoder and Gammon, 1976).

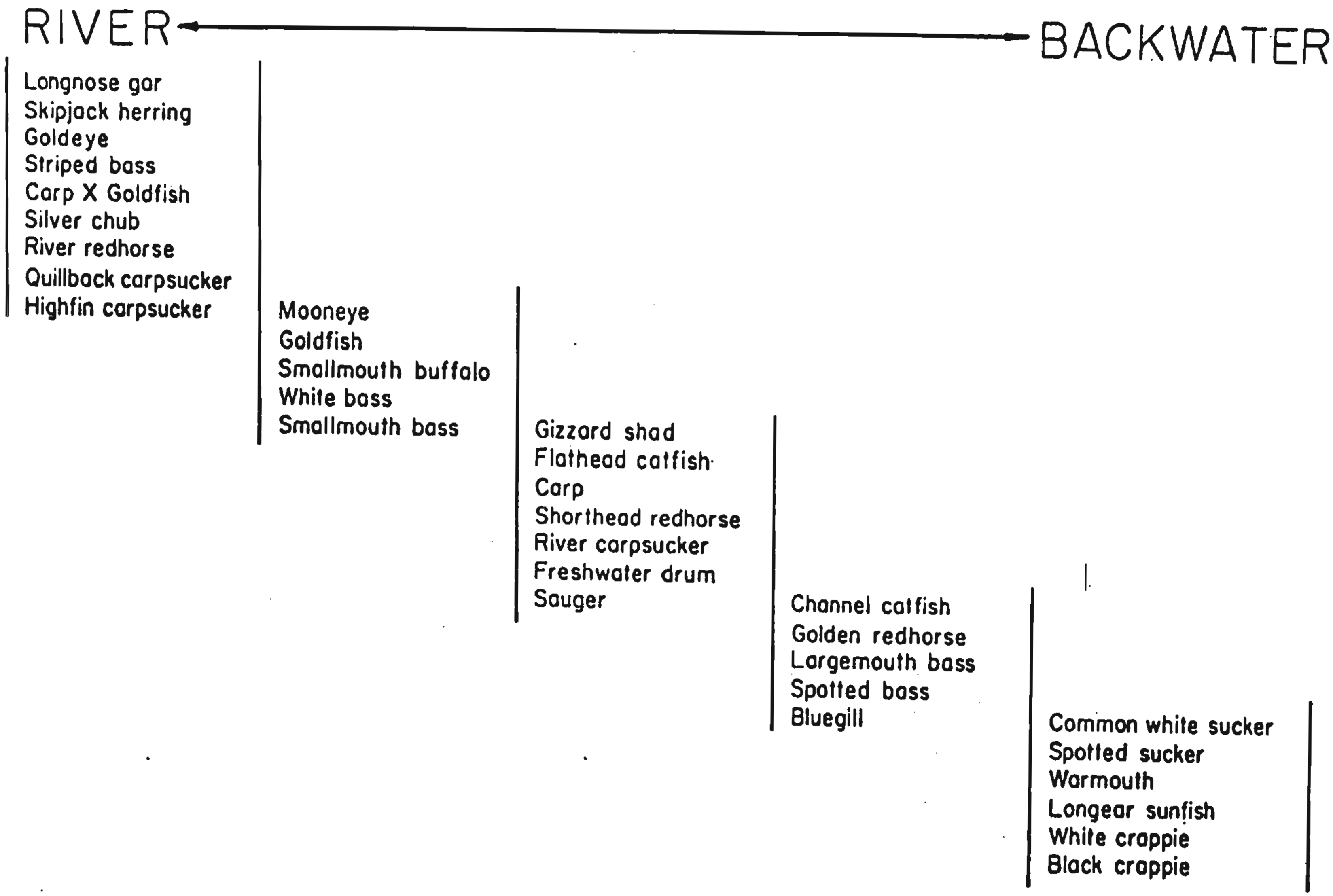

FIGURE V-26 Relative frequencies of occurrence in the river and backwaters by the major species collected by electrofishing in the 301 km study area, July-October 1975 (from Yoder and Gammon, 1976).

SYNERGISTIC EFFECTS

VI. SYNERGISTIC EFFECTS

A. Existing Pollutants

The water quality of this section of the Ohio River is relatively good. This has been demonstrated by the diversity of aquatic fauna reported from this area and is further indicated by the water quality monitoring results of the ORSANCO monitor system.

A recent review of the scientific literature by Cairns, Heath, and Parker (1975) indicates that temperature may or may not affect the toxicity of other materials, depending on the species of test organism and the water temperature and concentration of material present. It is reasonable to assume that synergistic effects would be most likely present in heavily polluted waters and would be least likely present in "clean" or slightly polluted waters. A review of the ORSANCO water quality data indicates that synergistic effects with temperature are not likely.

B. Dissolved Oxygen

The introduction of a thermal effluent can generally cause a reduction of dissolved oxygen in two ways. One way is by reducing the saturation level of dissolved oxygen by increasing the water temperatures. The other is by stimulating biological and chemical oxygen demand by in-increasing water temperatures. Studies by Smiddy (1974) and Miller et al. (1975) have found dissolved oxygen concentrations in unheated and heated waters in the vicinity of the J. M. Stuart Station to be adequate for supporting aquatic life (considered to be not less than a daily average of 5.0 mg/l nor less than 4.0 mg/l at any time, by the Ohio EPA) (Figures VI-1 and VI-2).

C. Gas Bubble Disease

If supersaturation of dissolved oxygen occurs to any great extent "gas bubble disease" may result. Supersaturation can be caused by a rapid rise in the temperature of the water, resulting in a rapid decrease in the saturation level of dissolved oxygen. Supersaturation may also be caused by conditions other than a rapid rise in temperatures. Photosynthetic aquatic plants (photoplankton, periphyton, and aquatic macrophytes) may cause supersaturation by oxygen production during photosynthesis.

In fish, gas bubble disease may be indicated by several features, including bubbles in the fin, "popeye" (eye forced from its socket), gas bubbles beneath the cornea of the eye, bubbles beneath the mucous membrances lining the mouth and gill arches, and bubbles along the lateral line causing scales to be raised.

During the field studies by Norris and Gammon (no date), Hatch and Gammon (1973), Lesniak and Gammon (1974) and Yoder and Gammon (1976), no fish were reported to possess gas bubble disease symptoms. Because of these extensive fisheries investigations involving the examination of hundreds of fish, it would seem reasonable to conclude that any significant occurrence of these symptoms would have been detected and reported.

D. Chlorine

The Amertap (sponge ball) antifouling system is utilized to clean the condenser tubes of once-through Units 1, 2, and 3 at the J. M. Stuart Station, rather than a biocide such as chlorine. Chlorine is used, however, to prevent fouling in the cooling tower for Unit 4, primarily during the summer. Blowdown from the cooling tower is, in part, used to sluice bottom ash to the ash pond; the remaining blowdown goes directly to the ash pond. Several tests have been made by The Dayton Power and Light Company personnel at the outfall of the ash pond at times of chlorination and no residual chlorine was detected. This effectively eliminates the consideration of any synergistic effects of temperature and chlorine at the J. M. Stuart Station.

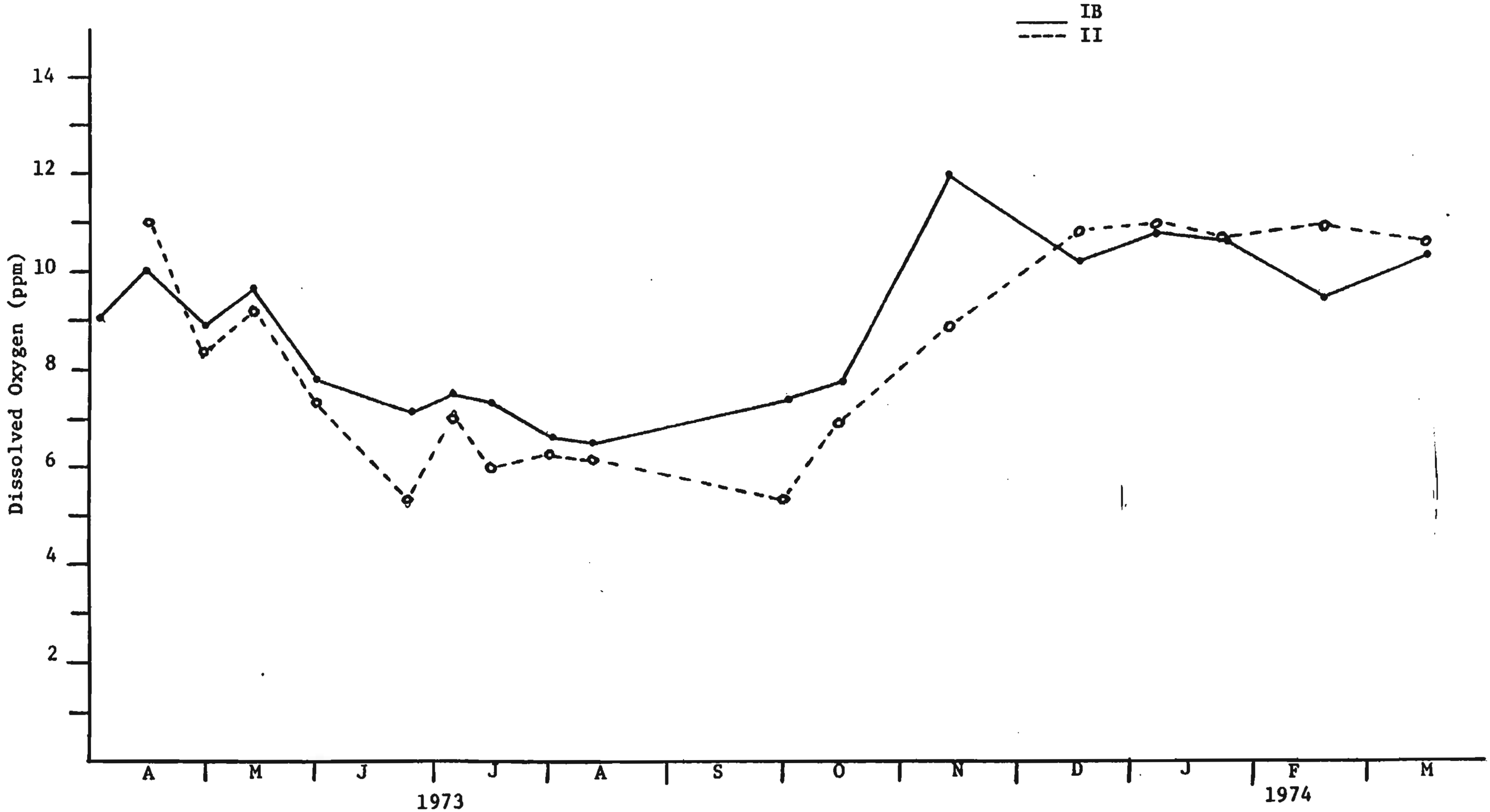

FIGURE VI-1 Dissolved oxygen concentration at Stations IB and II, J. M. Stuart Station, 1973-1974 (from Smiddy, 1974).

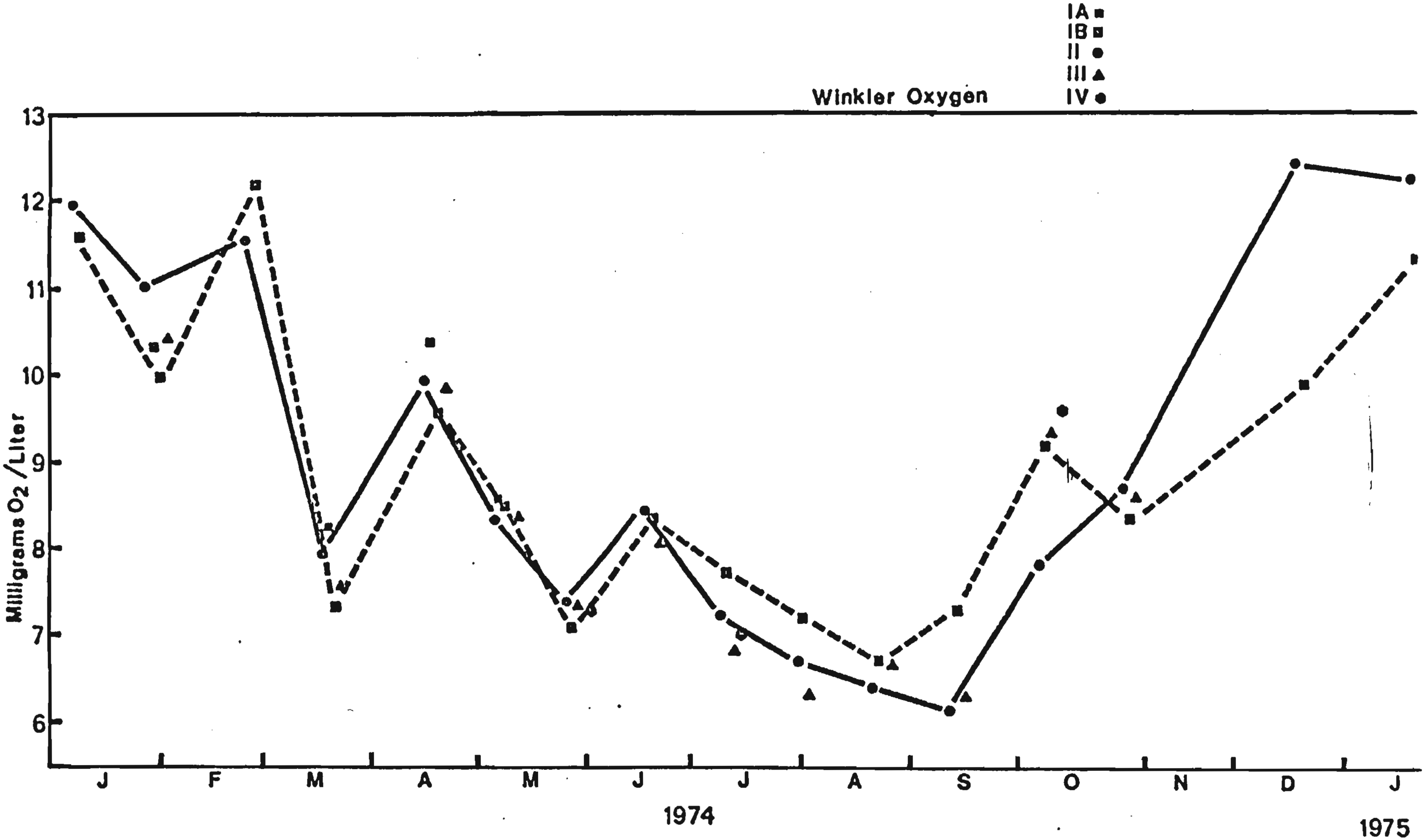

FIGURE VI-2 Dissolved oxygen concentration determinations at the J. M. Stuart Station 1974-75 (from Miller *et al.*, 1975).

ECONOMIC AND RECREATIONAL EFFECTS

VII. ECONOMIC AND RECREATIONAL EFFECTS

The Ohio River serves a variety of functions over its course through this area. It provides a source of municipal and industrial water supply, a medium for disposing of domestic and industrial waste, a recreational resource, as well as a transportation route.

The City of Maysville, Kentucky, in 1974, utilized approximately 1.3 mgd for their municipal water supply (WAPORA, 1976a).

Currently, water-oriented recreation consists primarily of boating, sightseeing, picnicking, and fishing. Primary contact recreation (swimming) is slight on this portion of the Ohio River, although there may be some water skiing. Data about the total number of people using this area recreationally are not available. The number of recreational craft that passed the Greenup and Meldahl Lock and Dam from January through October 1973 was 2,085 and 4,184, respectively (WAPORA, 1976a). These numbers do not reflect recreational boating that is confined within the Meldahl pool and therefore, underestimate the amount of such boating by an unknown amount. The effect of the thermal effluent on recreational fishing in Little Three Mile Creek and the adjacent Ohio River is discussed in Section V-F of this document. It was concluded that recreational fishing has been altered by the thermal effluent, and that overall recreational usage may now be greater than prior to plant start-up. While summer LTMC fishing has been degraded, winter fishing has been enhanced, providing what we believe is, on balance, an acceptable trade-off.

The cost-benefit aspects of alternative cooling systems at the J. M. Stuart Station will be submitted as a separate document (appended under separate cover) which will discuss the engineering, ecological and economic implications of selected feasible alternatives to the present once-through discharge system.

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VIII. LITERATURE CITED

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Yoder, C. O. and J. R. Gammon. 1975. Seasonal distribution and abundance of Ohio River fishes at the J. M. Stuart Electric Generating Station. Manuscript for publication; submitted to The Dayton Power and Light Company, April 10, 1975.

APPENDIX

IX. APPENDIX

The following is a list of the reports appended to, and hereby made a part of, this 316(a) demonstration.

Gammon, J.R. and S. Norris. 1970. The effect of the heated water effluent on the aquatic biota of Little Three Mile Creek. First Annual Progress Report, 1970 for The Dayton Power and Light Company. 39 p.

Hatch, J.T. and J.R. Gammon. 1973. The responses of the fish fauna of Little Three Mile Creek and the Ohio River to a thermal effluent. 1973 summary report for The Dayton Power and Light Company. 91 p.

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Yoder, C.O. and J.R. Gammon. 1976. Spatial and temporal distributions and abundance of fishes in the middle Ohio River. 1976 Report for The Dayton Power and Light Company. 113 p.

Yoder, C.O. and J.R. Gammon. 1975. Seasonal distribution and abundance of Ohio River fishes at the J. M. Stuart Electric Generating Station. Manuscript for publication; submitted to The Dayton Power and Light Company, April 10, 1975.

Project No. 160 February 2, 1977

ERRATA

(Pages 85 and ~~115~~)

J. M. STUART STATION
316(A) DEMONSTRATION

SEPTEMBER 28, 1976

SUBMITTED TO:

THE DAYTON POWER AND LIGHT COMPANY

DAYTON, OHIO

SUBMITTED BY:

WAPORA, INC.

CINCINNATI, OHIO

Bernard L. Huff

BERNARD L. HUFF, MANAGER

CINCINNATI OFFICD

tions. The plume, as measured, is shown in Figure IV-24. At the time of the field study, the ambient temperature was 23°C (73.4°F). There were high winds blowing from the west, the sky was completely overcast, and the air temperature was between 22 and 25°C (71 and 77°F). Only two once-through cooling units were operating; however, all of the circulating pumps were in operation.

As Figure IV-24 shows, the plume observed is very complex. The complexity is increased by the apparent upstream movement of the plume after it hits the bank of the Kentucky side. This effect is probably due to the reflection of the plume from the bank. The apparent upstream movement of the plume on the Kentucky side may be partially confused by the entrance of small quantities of water from Bull Fork Creek. As Figure IV-22 shows, the influent from Sleepy Hollow Creek caused a small plume by itself. This was apparently due to solar radiation falling on the relatively shallow creek and causing a slightly elevated temperature. It is suspected that the same effect may have occurred at Bull Fork Creek on both survey days.

In addition to the major discharge of heated water through Little Three Mile Creek, the plant discharges small quantities of warm water from outfalls along the Ohio bank above Little Three Mile Creek. These discharges cause a small plume which hugs the Ohio bank as shown in Figure IV-24. The temperature rise in the small plume along the Ohio bank is only about 1°C (1.8°F).

The cross-sectional distribution of the plume on September 20, 1976 is shown in Figures IV-25, IV-26, and IV-27. These figures show that the plume is entirely confined to the top ten to twelve feet of the river.

Measurements of the effluent from the operating units indicated that the water was being discharged at 38°C (100.4°F) at the upstream end of LTMC. This was mixed with discharges from the circulating pump on the non-operating unit which was being discharged at 25°C (77°F). The two flows mixed thoroughly in LTMC and had a resulting temperature of 36°C (96.8°F). In traveling down LTMC, the temperature of the outflow decreased until it was 34°C (93.2°F) at the mouth of the creek.

Measurements of the plume inside the 5°F isotherm (2.8°C) ΔT indicated a surface plume of approximately 265 acres. This area extended all the way across the river; however, it remained at all times less than twelve feet deep. Since the average depth of the river is 35 feet, the plume covered less than one-third of the transverse area of the river at all times. The 5°F plume extended on the surface, from the mouth of LTMC (RM 405.5) to approximately RM 406.3, thus yielding a total length of 0.8 miles.

B. Water Quality Compliance

Copies of all water quality related communications (which indicate possible harmful effects) between the applicant (The Dayton Power and Light Company) and any agency other than the EPA during the last five years are presented separately as an appendix to this document. The 316(a) guidelines (U.S. EPA, September 30, 1974, page 28) further state:

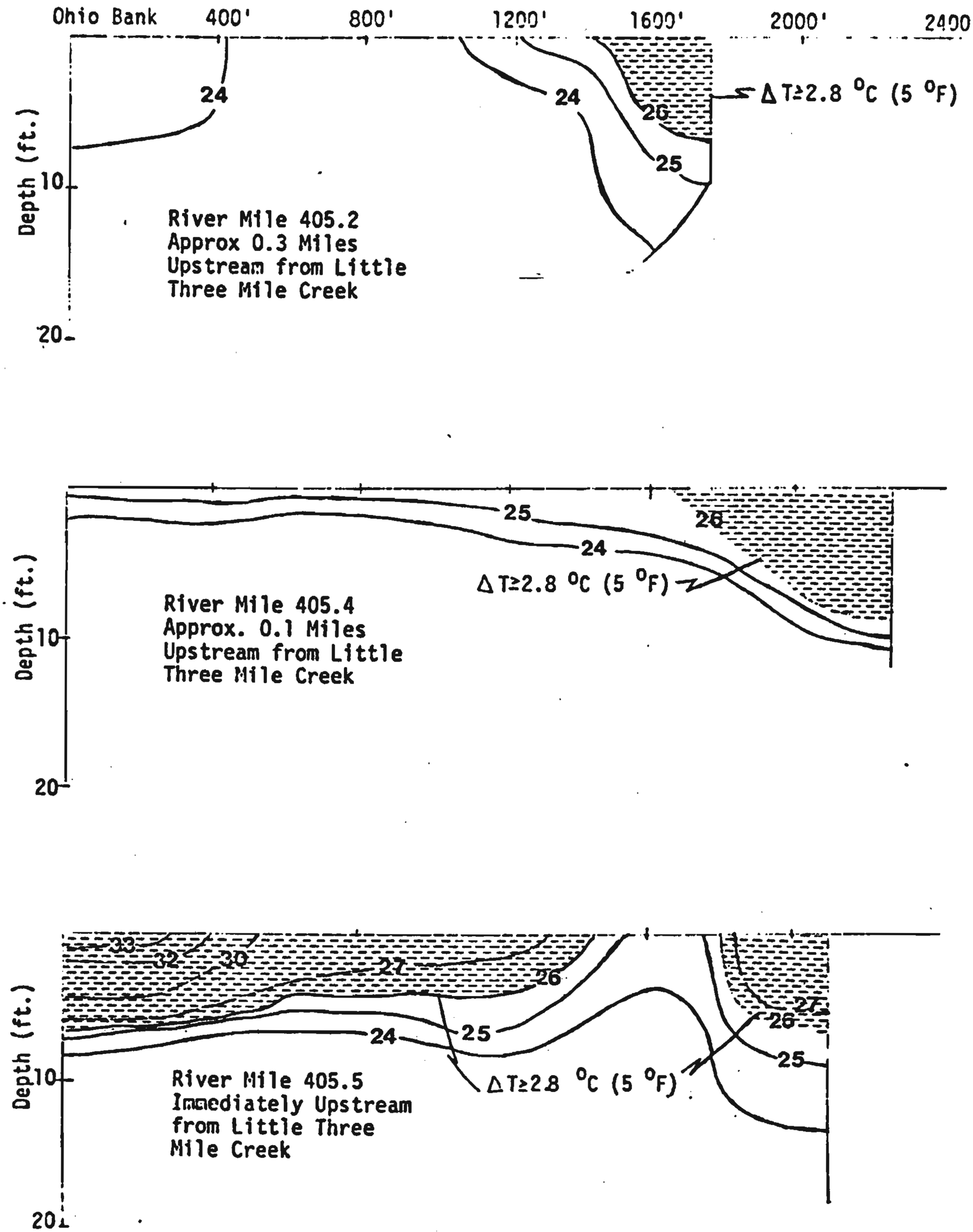

FIGURE IV-25 Temperature (°C) cross sections observed at designated mile points on the Ohio River at the J. M. Stuart Station, September 20, 1976.

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