# MONTICELLO ECOLOGICAL STUDIES PROGRAM

A Progress Report Covering 1973
Prepared for
Northern States Power Company
Minneapolis, Minnesota

Parameters Studied:

Macroinvertebrates
Adults
Drift
Benthic samples
Fish

by
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## Summary

The 1972 Annual Report of the Monticello Ecological Studies Program included summaries of several data groups collected between 1969 and 1972. Comparisons were made between preoperational (1969 and 1970) and operation years (1971 and 1972), with reference to water quality and fish. A complete report on the effect of heated effluent on colonization rate and growth rate of macroinvertebrates was also given.

The following report for 1973 includes descriptions of work in progress on new studies to further delineate biological responses to effluent from the Monticello Generating Plant.

Work continued on comparison of benthic macroinvertebrate populations in heated and unheated areas of the river near the power plant. At the end of one calendar year of data collection in September 1974, these operational data will be compared to results of the preoperational studies.

In July 1973, a two-year study was initiated to determine reproductive periodicity of river insects near the plant, possible premature emergence, and to obtain a sufficient quantity of adult insects for identification of species. This study has consumed a great amount of time, however, information obtained is essential, since other studies have shown that species may vary widely in response to natural conditions and to added heat.

An important parameter of macroinvertebrates not previously measured in the Mississippi River is drift, i. e., invertebrates which become dislodged or disattached from the bottom and are carried downstream. In July 1973, a sampling program was begun to measure drift in natural and heated areas of the river.

Studies on fish in 1973 concentrated on spawning activities and related spatial distribution near the power plant.

A master's thesis, "Fluorescent dyemarking of cyprinid minnows (family Cyprinidae) and other small fish for population studies in the Mississippi River near Monticello, Minnesota", by John D Ott, was completed in December 1973. A copy of the thesis has been submitted to NSP Engineering Vice Presidential Staff Department, Environmental Science Services Section, which supported the work. Information from the thesis pertaining to influence of the power plant discharge upon minnow population is presented in this report.

Project Title:

Analysis of Flying Aquatic Insects Collected by Light-Trap Samplers

Project objectives:

1. Establish a taxonomic list of insects inhabiting the Mississippi River near NSP's Monticello Nuclear Generating Plant, with emphasis on the orders Trichoptera, Ephemeroptera, and Diptera.

2. Observe daily quantitative samples of flights at three riverside sampling stations for one calendar year.

Methods and materials:

Each sampling station consisted of a 15-watt fluorescent lamp and a pan of 50 percent isopropanol on a wooden supporting structure. From mid-November, catch-pans were filled with a solution of propylene glycol anti-freeze. The stations were located approximately two meters from shore at three sites along the river. Station 1, 0.4 km above the plant intake; Station 2, in the discharge canal; and Station 3, 0.5 km below the end of the discharge canal.

Daily collections were made of samples accumulated the previous night. Collecting began July 17, 1973 and will continue through July 1974. Preserved samples were subsampled in the laboratory and separated according to order. Each month of data was analyzed separately. Identifications were made to the lowest taxa possible. Numbers and weights for each group in the subsample were projected to estimate total taxonomic biomass in the raw sample.

Results:

Samples were collected from July 17, 1973 through November 27, 1973. Operation of the samplers was maintained through the winter months, but insects were not found in traps from November 28, 1973 through early March 1974. Complete identification of Trichoptera for July and August 1973, and of Ephemeroptera for July 1973 are listed in Table A.

Identification of many female species of both orders has not been developed in the literature. For those species requiring detailed clearing techniques, specimens are being held for further study. Table 1 shows monthly total projected number of caddisflies for each station during July and August 1973, the average daily numbers for each station, and the ratio of average daily numbers.

Five-place moving averages of daily numerical data on Trichoptera were calculated to clarify their pattern of abundance during July and August 1973. A comparison of trichopteran numbers trapped at each of the three stations is shown in Figure 1. The same information for the four most abundant families of caddisflies at the site are plotted in Figures 2 through 5. Station 2 was not included in the graphs of families because of the small numbers captured.

Conclusion:

Data from Stations 1 and 3 are comparable, since river habitats are similar at each location. There are several possible explanations for low numbers at Station 2 compared to other sta-

Table A Check list of adult Trichoptera (caddisflies) and Ephemeroptera (mayflies) captured near the Monticello Generating Plant by insect light trap during 1973.

ORDER TRICHOPTERA

Family Hydropsychidae

- Macronemum zebratum
- Cheumatopsyche sp. (female)
- Cheumatopsyche campyla
- Cheumatopsyche speciosa
- Hydropsyche sp. (female)
- Hydropsyche betteni
- H. recurvata
- H. phalerata
- H. bifida
- H. scalaris
- H. vexa
- Potamyia flava
- Arctopsyche sp.

Family Psychomyiidae

- Psychomyia flavida
- Nyctiophylax sp. (female)
- Nyctiophylas vestitus
- Cernotina sp.

Family Rhyacophilidae

- Protoptila sp. (female)
- Protoptila erotica
- Protoptila maculata

Family Leptoceridae

- Athripsodes sp. (female)
- Athripsodes punctatus
- A. transversus
- A. mentieus
- A. cancellatus
- A. flavus
- Oecetis sp. (female)
- Oecetis avara
- Leptocella sp. (female)
- Leptocella candida
- Leptocerus americanus
- Setodes oligia
- Trianodes sp. (female)
- Trianodes baris

Family Philopotamidae

- Chimarra obscura

Family Hydroptilidae

- Hydroptila sp.

Family Helicopsychidae

- Helicopsyche borealis

Table A Check list (cont).

ORDER EPHEMEROPTERA

Family Baetidae

Subfamily Baetinae

Unknown genera

Baetis sp.

Pseudocloeon sp. (female)

Baetis phoebus

Subfamily Caeninae

Tricorythodes sp. (female)

Tricorythodes attratus

T. peridius

Family Heptageniidae

Unknown genera

Family Ephemeridae

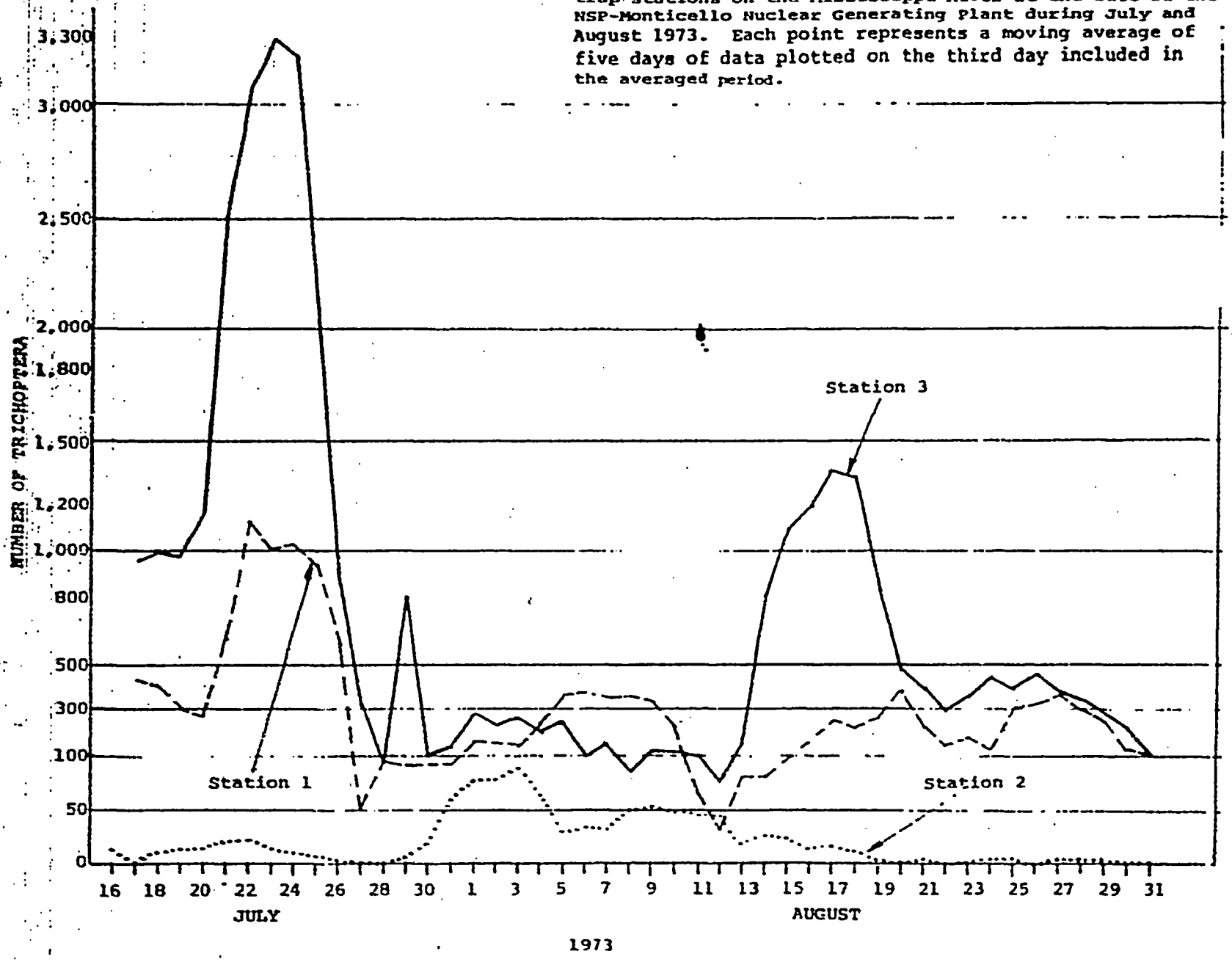
Potamanthus verticis

Ephoron sp.

Table 1. Total projected numbers of trichopterans captured at each station during July and August, 1973. Daily averages were calculated using the total projected numbers and the actual number of samples collected at each station for the month. Ratios were calculated using Station 2 data as a base.

| | July (16-31) 1973 | | | August 1973 | | |
|---|---|---|---|---|---|---|
| Station | 1 | 2 | 3 | 1 | 2 | 3 |
| Number of samples | 17 | 17 | 17 | 26 | 25 | 23 |
| Monthly total projected number | 7,640 | 180 | 22,009 | 5,630 | 678 | 11,030 |
| Daily average | 477.5 | 11.3 | 1,375.6 | 216.5 | 27.1 | 479.6 |
| Ratio | 42.4 | 1 | 122.3 | 7.9 | 1 | 17.7 |

**Figure 1.** Number of trichopterans captured at three light trap stations on the Mississippi River at the site of the NSP-Monticello Nuclear Generating Plant during July and August 1973. Each point represents a moving average of five days of data plotted on the third day included in the averaged period.



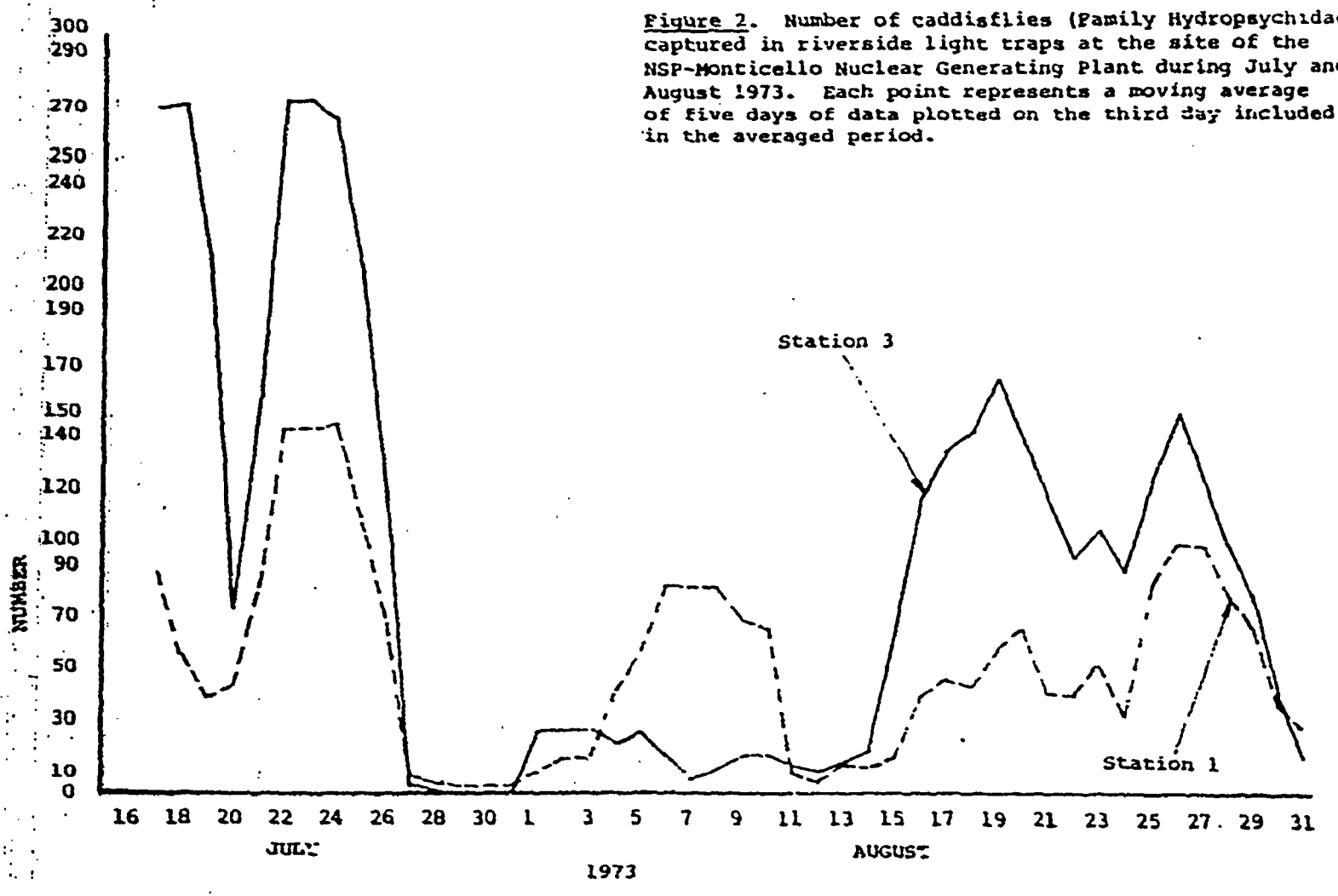



Figure 2. Number of caddisflies (Family Hydropsychidae) captured in riverside light traps at the site of the NSP-Monticello Nuclear Generating Plant during July and August 1973. Each point represents a moving average of five days of data plotted on the third day included in the averaged period.

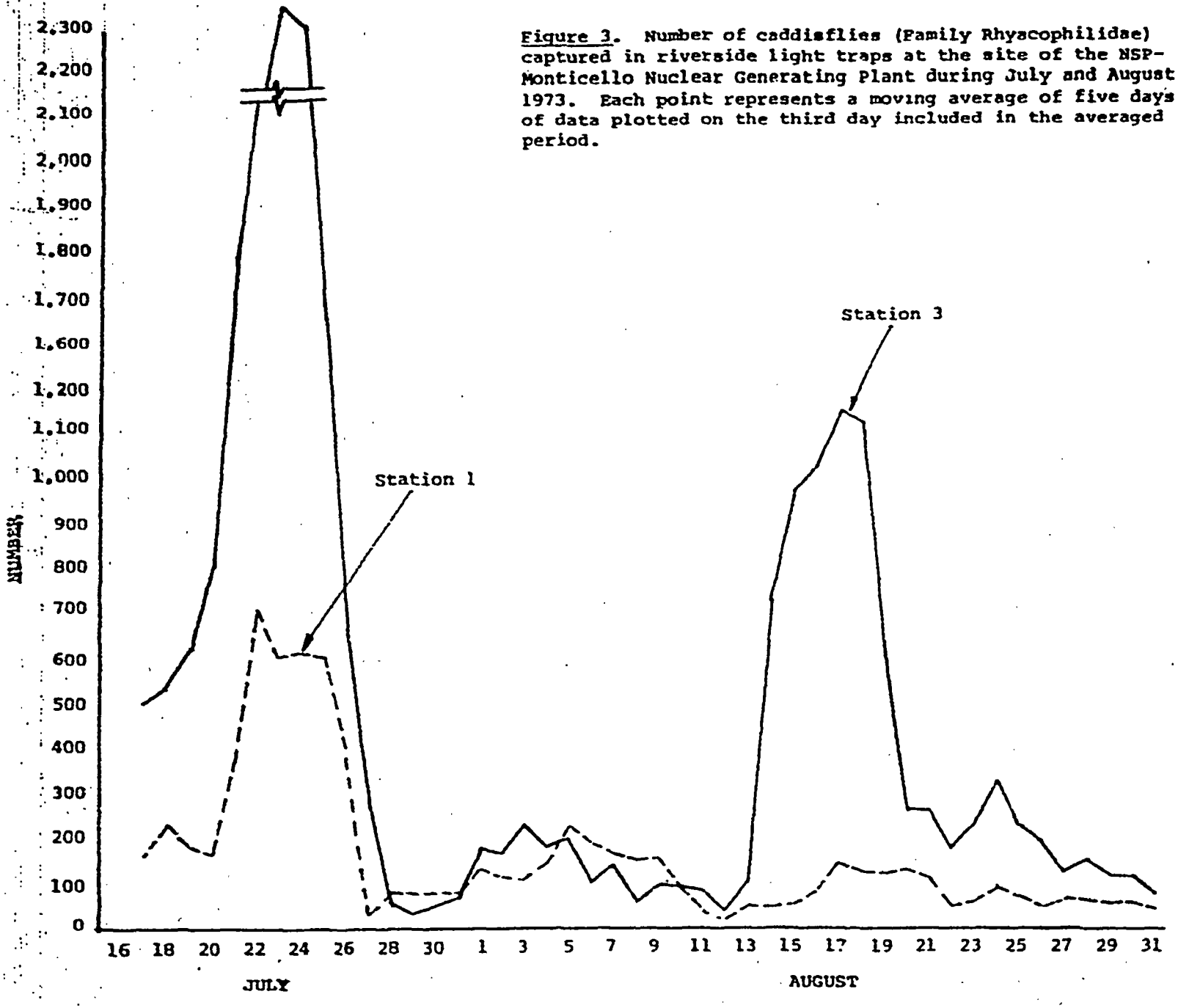



Figure 3. Number of caddisflies (Family Rhyacophilidae) captured in riverside light traps at the site of the NSP-Monticello Nuclear Generating Plant during July and August 1973. Each point represents a moving average of five days of data plotted on the third day included in the averaged period.

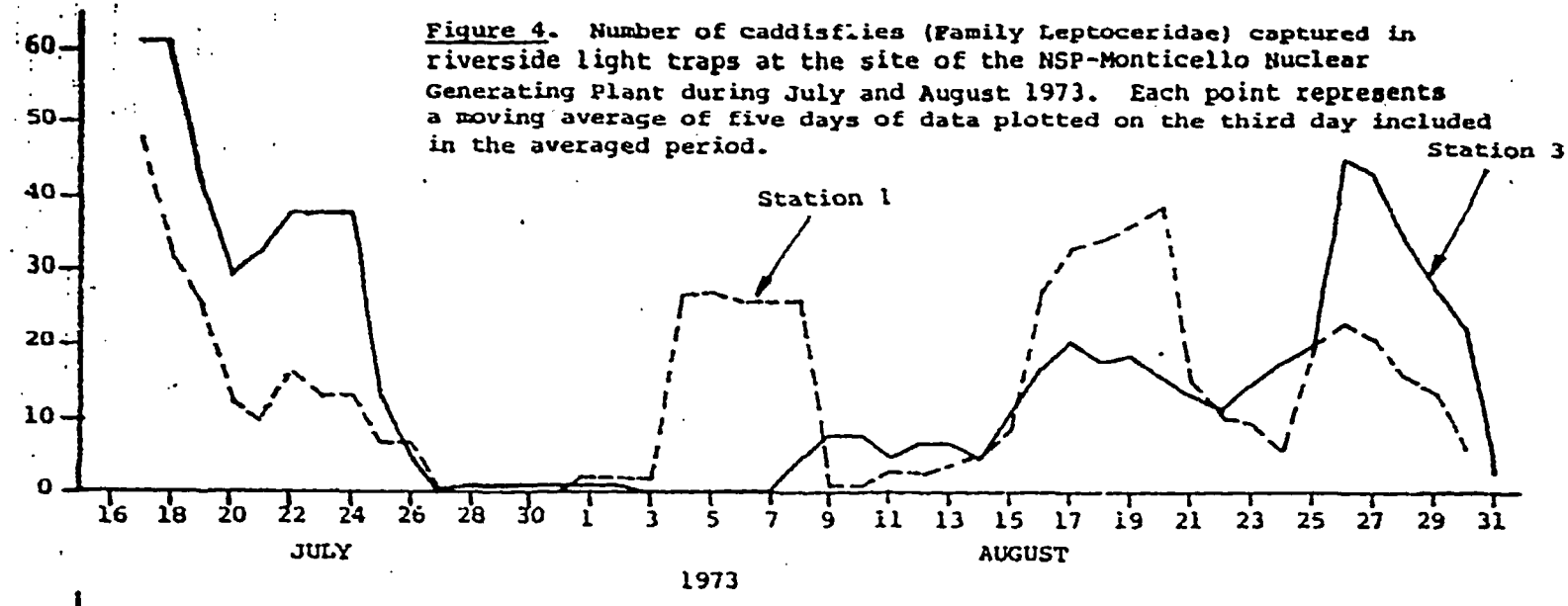



Figure 4. Number of caddisflies (Family Leptoceridae) captured in riverside light traps at the site of the NSP-Monticello Nuclear Generating Plant during July and August 1973. Each point represents a moving average of five days of data plotted on the third day included in the averaged period.

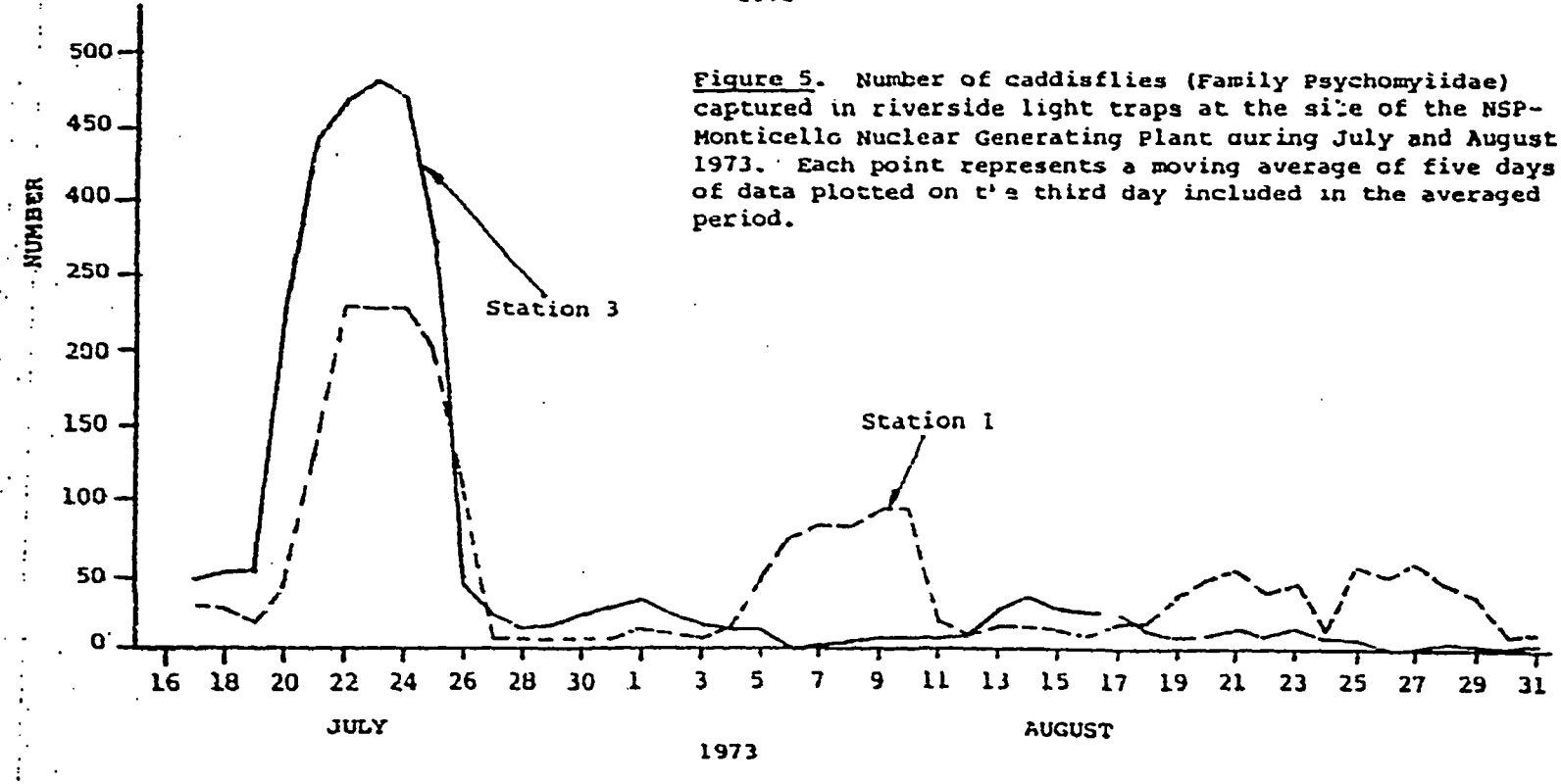



Figure 5. Number of caddisflies (Family Psychomyiidae) captured in riverside light traps at the site of the NSP-Monticello Nuclear Generating Plant during July and August 1973. Each point represents a moving average of five days of data plotted on the third day included in the averaged period.

tions. First, Station 2 is not open to the full width of the river, but is open only to the discharge canal -- a much smaller area. Secondly, substrate in the discharge canal is mostly sand and gravel, whereas that of the main part of the river is rubble and gravel, a more productive substrate for benthic organisms. Lastly, the lights in operation at night on the power plant, and especially the cooling towers, may interfere with the effectiveness of the light trap at Station 2 in that area. Data on each calendar month will be needed to calculate the probability that heated water effluent from the power plant is affecting life cycles of indigenous benthic insects sufficiently to change the abundance or cyclicity of adult emergence.

Estimate of work remaining to complete the project:

Daily collections will be made through July 1974, completing one annual cycle. All samples will be processed taxonomically, numerically, and gravimetrically. Spot-check collections will be made on a few post-July dates in 1974 as necessary. Project completion is expected by July 1, 1975.

Project Title:

Invertebrate Drift in the Mississippi River near the Monticello Plant

Project Objectives:

1. To develop field equipment and techniques for sampling of invertebrate drift in the Mississippi River at Monticello (i.e., a large river).

2. To determine taxonomic composition of drift and its magnitude in water available to the Monticello Generating Plant intake.

3. To determine vertical distribution of drift.

4. To determine the influence of heated water discharge on measured drift parameters.

Methods and materials:

A biweekly sampling schedule was set up for one calendar year. During 1973, samples were taken July 27-28, August 13-14, 28-29, September 11-12, 28-29, November 9-10, and November 30-December 1.

Drift capture nets of 60-inch length with 6-inch square throats were constructed of Nitex 452 (mesh opening approximately 452 microns). Steel frames were used to secure the nets to the river bottom at two stations near the power plant. The upstream station was located near the middle of Control Transect $C_2$ (see Figure 6), and the downstream station was placed near Extra Experimental Station $E_E$.

Nets were placed in stacks with one net resting on the bottom, and the top net was half-submerged beneath the water surface. All nets were cleaned and reset periodically to avoid clogging during each 24-hour sampling period. Samples removed from the nets were preserved in 10 percent formalin and taken to the laboratory for analysis. Approximately 40 samples were taken per sampling period.

Environmental parameters recorded with each sample included air temperature, water temperature, water flow, depth, sky cover, and light conditions, including moonlight, and length of dark and light periods.

An aliquot of each sample was taken in the laboratory. From each aliquot, organisms were separated from the debris, identified taxonomically, enumerated, and weighed. These numerical data are expressed in Table 2 as total drift rate per 24 hours, or as drift density relative to river discharge during the sample.

Results:

Table 2 shows the total number of organisms and total weight of the drift at the upstream and downstream stations as estimates from samples taken at those locations. Conclusions concerning the effect of heated discharge on drift should not be drawn at this time, because only a small portion of the samples has been processed.

Estimate of work remaining to complete the project:

All samples taken to date must be processed, as well as samples that will be taken through July 1974.

Table 2. Estimated total number of drifting organisms and the estimated total drift weight carried in the Mississippi River at stations above and below the Monticello Generator.

| Dates (1973) | Number of Drifting Organisms | | | | Sample Weight (Grams) | | | | 24-Hour River Discharge ($M^3$) |
|---|---|---|---|---|---|---|---|---|---|
| | Peak Number Per 1000 $M^3$ | Peak Drift Period (Hours) | 24-Hour Average Per 1000 $M^3$ | 24-Hour Total | Peak Weight Per 1000 $M^3$ | Peak Drift Period (Hours) | 24-Hour Average Per 1000 $M^3$ | 24-Hour Total | |
| **Upstream Station** | | | | | | | | | |
| July 27-28 | 5138 | 2000 to 1100 | 2625 | $1.09 \times 10^7$ | 10.854 | 2330 to 0230 | 4.909 | $2.04 \times 10^4$ | $4.16 \times 10^6$ (1700 cfs) |
| August 13-14 | 6064 | 1930 to 2230 | 3465 | $4.50 \times 10^7$ | 7.484 | 0230 to 0530 | 4.884 | $6.35 \times 10^4$ | $1.30 \times 10^7$ (5328 cfs) |
| August 28-29 | 1738 | 1730 to 2130 | 1092 | $1.07 \times 10^7$ | --- | --- | --- | --- | $9.82 \times 10^6$ (4016 cfs) |
| **Downstream Station** | | | | | | | | | |
| July 27-28 | 2078 | 2330 to 0230 | 1216 | $5.05 \times 10^6$ | 5.916 | 2000 to 2300 | 2.247 | $9.34 \times 10^3$ | |
| August 13-14 | 8272 | 1930 to 2230 | 5741 | $7.46 \times 10^7$ | 6.712 | 1930 to 2230 | 4.394 | $5.71 \times 10^4$ | |
| August 28-29 | 1932 | 0130 to 0530 | 1176 | $1.15 \times 10^7$ | --- | --- | --- | --- | |

Project Title:

Comparison of Benthic Macroinvertebrate Populations in Heated and Unheated Areas of the Mississippi River near the Monticello Plant.

Project objectives:

1. To determine the effect of heated water on benthic macroinvertebrates below the power plant discharge by drawing correlations between samples from heated and unheated areas in preoperational and postoperational years.

Methods and materials:

Artificial substrates identical to those described in earlier reports (Hopwood, 1970) were placed in the river, as indicated in Figure 6. Stations comprised of four samplers were placed in transects $C_2$, $E_1$, and $E_2$ corresponding to transects used in previous studies. Additional stations not in the preoperational study are shown in Figure 6.

Artificial substrates and resulting samples were handled according to the procedure developed in the preoperational study. Current velocity, temperature, and depth were observed weekly at the stations.

Results:

Sampling began in September, 1973. Through March, 1974, 191 samples were taken, of which approximately 160 were subsampled and sorted for taxonomic distribution. Table 3 shows the placement and retrieval schedule of samplers used during the period of September, 1973 through March, 1974. Some samplers were lost in October, November, and December because of ice damage.

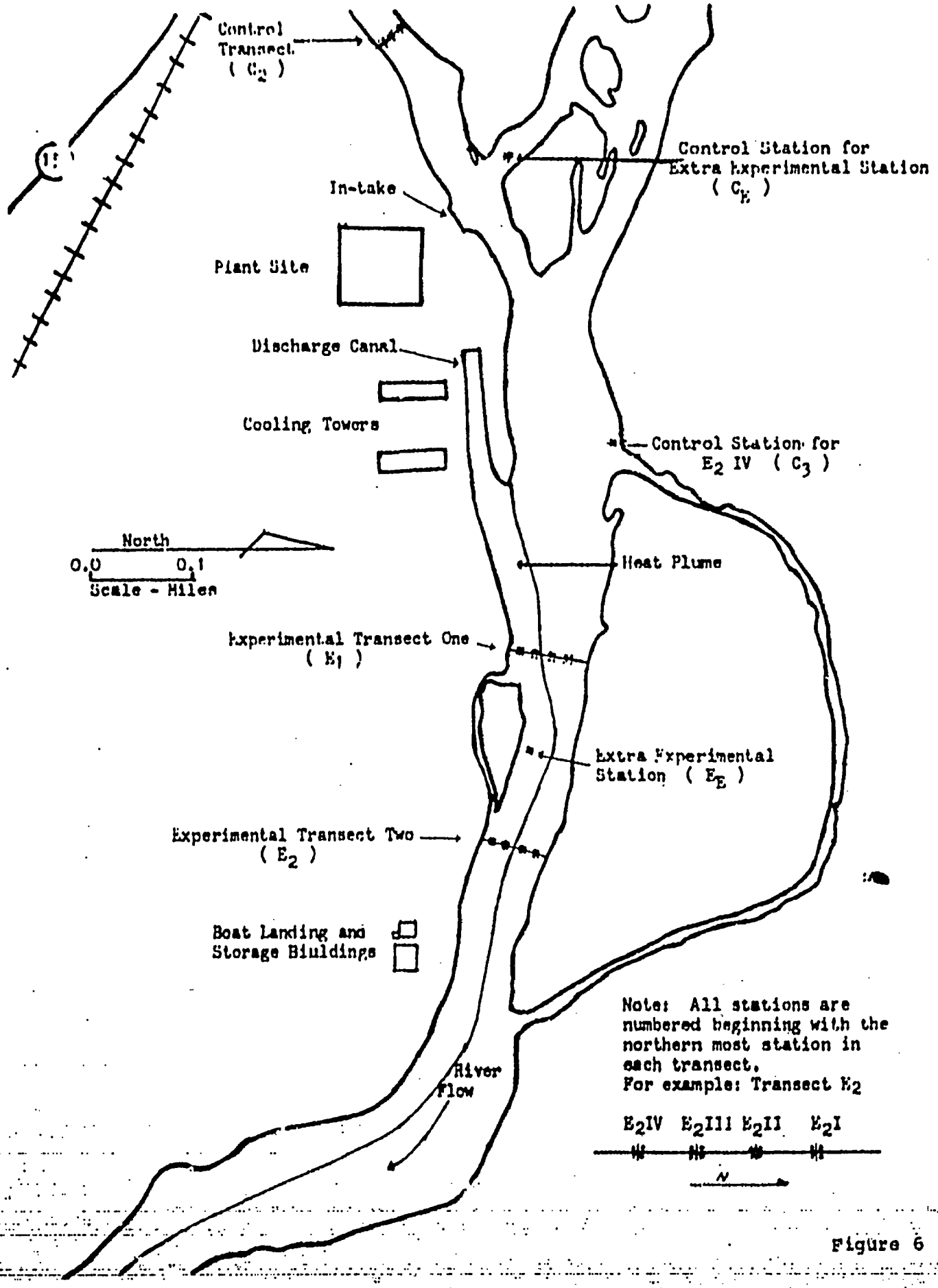

Control Transect ( $C_2$ )
Control Station for Extra Experimental Station ( $C_E$ )
In-take
Plant Site
Discharge Canal
Cooling Towers
Control Station for $E_2$ IV ( $C_3$ )
North
0.0 0.1
Scale - Miles
Heat Plume
Experimental Transect One ( $E_1$ )
Extra Experimental Station ( $E_E$ )
Experimental Transect Two ( $E_2$ )
Boat Landing and Storage Biuldings
River Flow
Note: All stations are numbered beginning with the northern most station in each transect.
For example: Transect $E_2$
$E_2$IV $E_2$III $E_2$II $E_2$I
N

Figure 6

Table 3. Placement-retrieval schedule of artificial substrate samplers used from September 1973 through March 1974. X = 4-block station placed at corresponding dates. -1 = number of blocks lost at each station.

| Date | Station | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_2I$ | $C_2II$ | $C_2III$ | $C_EI$ | $C_3I$ | $E_1I$ | $E_1II$ | $E_1III$ | $E_1IV$ | $E_EI$ | $E_2I$ | $E_2II$ | $E_2III$ | $E_2IV$ |
| September | X | X | X | | | X | X | X | X | | X | X | X | X |
| October | X | X | X | | | X | X | X | X | | X | (-4) X | X | X |
| November | X | X | X | | | X | (-1) X | X | X | | X | X | X | X |
| December | (-4) X | (-2) X | X | (-4) X | (-4) X | (-4) X | X | (-4) X | (-2) X | X | (-2) X | X | X | X |
| January | | | | | | | | | X | X | | | X | X |
| February | X | | | | | | | | X | X | | | X | X |
| March | X | | | | | | | | X | X | | | X | X |

Data on the samples collected in September and October, 1973 are presented in Table 4.

Estimate of work remaining to complete the project:

One complete annual cycle of monthly samples will be finished in September, 1974. All samples must be sorted, identified to the most definitive taxa, counted, and weighed. These procedures are complete for about 20 percent of the samples collected through March, 1974. Statistical comparisons will be made of heated and unheated areas, and of preoperational and post-operational data. Project complation is not expected before January, 1975.

Project Title:

Spatial Distribution and Spawning Activities of Fish in the Mississippi River near the Monticello Plant.

Project objectives:

1. To determine distribution of fish relative to heated discharge from the power plant.

2. To observe spawning time and location of fish living in the area of th power plant.

Methods and materials:

All specimens were collected with the aid of electro-fishing gear. Sampling in 1973 took place on 52 days beginning March 26 and ending December 27. Data recorded for each electro-fishing run included water temperature, duration of the run, and specific location of the run on the river. Each fish was measured, weighed, and tagged. A sample of scales was removed.

Table 4. Number of organisms per 4-block station collected from artificial substrates placed on September 6, 1973 and retrieved October 3, 1973 Mississippi River near the Monticello Generator.

| Stations | Taxa or Group | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hydropsyche and Cheumatopsyche | Chimarra | Psychomyia | Protoptila | Oecetis | Hydroptilidae | Pseudocloeon | Stenonema | Rhithrogena | Potamanthus | Isonychia | Ephemerella | Tricorythodes | Heptagenia |
| $C_2I$ | 1111 | 11 | | 958 | | | 850 | 21 | 3 | | 4 | 149 | | 2 |
| $C_2II$ | 1992 | 12 | | 404 | 24 | 8 | 376 | 72 | | | | 76 | 4 | 4 |
| $C_2III$ | 1796 | 4 | 8 | 516 | 60 | 24 | 316 | 16 | | | | 104 | | 16 |
| $E_1I$ | 3098 | 132 | 24 | 2908 | 8 | 6 | 488 | 96 | 8 | | 16 | 516 | 8 | 6 |
| $E_1II$ | 3320 | 64 | 16 | 4264 | 56 | | 248 | 104 | | 16 | 16 | 520 | | |
| $E_1III$ | 4072 | 112 | | 1312 | 64 | 40 | 264 | 648 | 8 | 16 | 16 | 704 | 8 | |

| | Neoperla | Paragnetina | Phasganophora | Tribe Chironomini Larvae | Pupae | Simulidae Larvae | Ferrissia | Planaria | Small and Damaged Trichoptera | Small and Damaged Ephemeroptera | Small and Damaged Plecoptera | Small and Damaged Diptera | Hydropsyche Cheumatopsyche Damaged |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $C_2I$ | | | | 2258 | 109 | 61 | | 6 | 94 | 109 | | 13 | |
| $C_2II$ | | | | 2584 | 84 | 24 | 8 | 12 | 116 | 52 | 4 | 16 | |
| $C_2III$ | | | | 2496 | 52 | 8 | 12 | 32 | 132 | 36 | | 8 | |
| $E_1I$ | | | | 2020 | 28 | 52 | | | 338 | 62 | 52 | | |
| $E_1II$ | 8 | 8 | | 1344 | 8 | 8 | | 16 | 80 | 32 | 32 | | 112 |
| $E_1III$ | | | 8 | 1352 | 40 | | | | 128 | 32 | 88 | | 96 |

Observation on sex or breeding condition of the fish were recorded according to criteria listed in Table 5.

Results:

Figure 7 shows the relation of spawning activity to date and average water temperature. According to the above criteria for spawning readiness, data were grouped to find the dates of the first and last appearances of M+ and F+ specimens of each species, and the date on which the largest percentage of M++ and F++ specimens occurred.

White suckers probably reached che + spawning condition within the interim between March 26 and April 5. Specimens of carp in the + condition (mostly male) were occasionally caught as late as October 25. Smallmouth bass appeared in samples from June 2 through October 25, however, none were observed in the + or ++ condition.

Figure 8 shows the location of presumptive spawning areas, i.e., areas over which fish in the ++ condition were caught. Black crappies, from which eggs could be stripped, were caught only in Areas 5, 9, and 10. The other species listed were caught in each of the 14 areas in the + condition. Areas used by fish in the ++ condition are listed in Table 6. From these data, it is clear that certain areas were used as spawning grounds by several species. For example, Area 8 was utilized by white suckers in April, by two Moxostoma species in mid-May, and by carp in late May.

Estimate of work remaining to complete the project:

More definitive data of specific environmental conditions, under which fish complete gamete maturation and spawn, are being

collected in 1974. The 1973 and 1974 observations will be analyzed to more fully ascertain the extent of influence of the power plant discharge upon life cycles of fish.

Table 5. Physical characteristics of fish and the corresponding notation codes used to observe spawning activity.

| Designation Code | Characteristic |
|---|---|
| M | Male, determined by the presence of numerous tubercles on the caudal fin (Moxostoma), general body shape (Cyprinus carpio), or the presence of milt (all species). |
| F | Female, determined by the presence of small caudal tubercles, or tubercles absent from large fish, abraded vent and caudal peduncle (Moxostoma), general body shape Cyprinus carpio, or the presence of eggs (all species). |
| M+, F+ | Males liberate milt or eggs with moderate pressure of the hand on the abdomen. |
| M++, F++ | Fish liberate milt or eggs spontaneously upon handling. |

Spawning Times and Temperatures for Selected Species of Fish in the Mississippi River near Monticello Nuclear Generating Plant

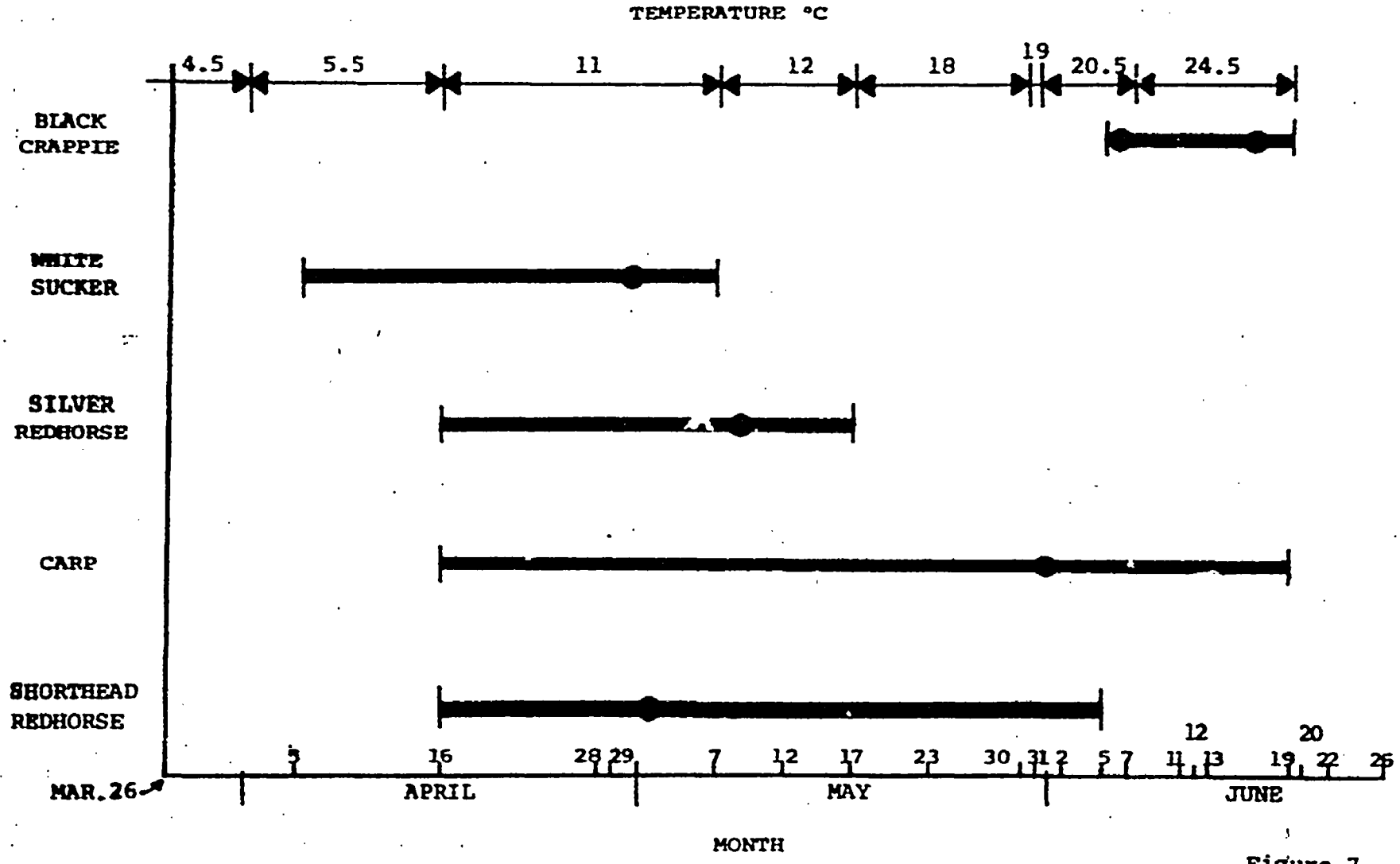



Figure 7

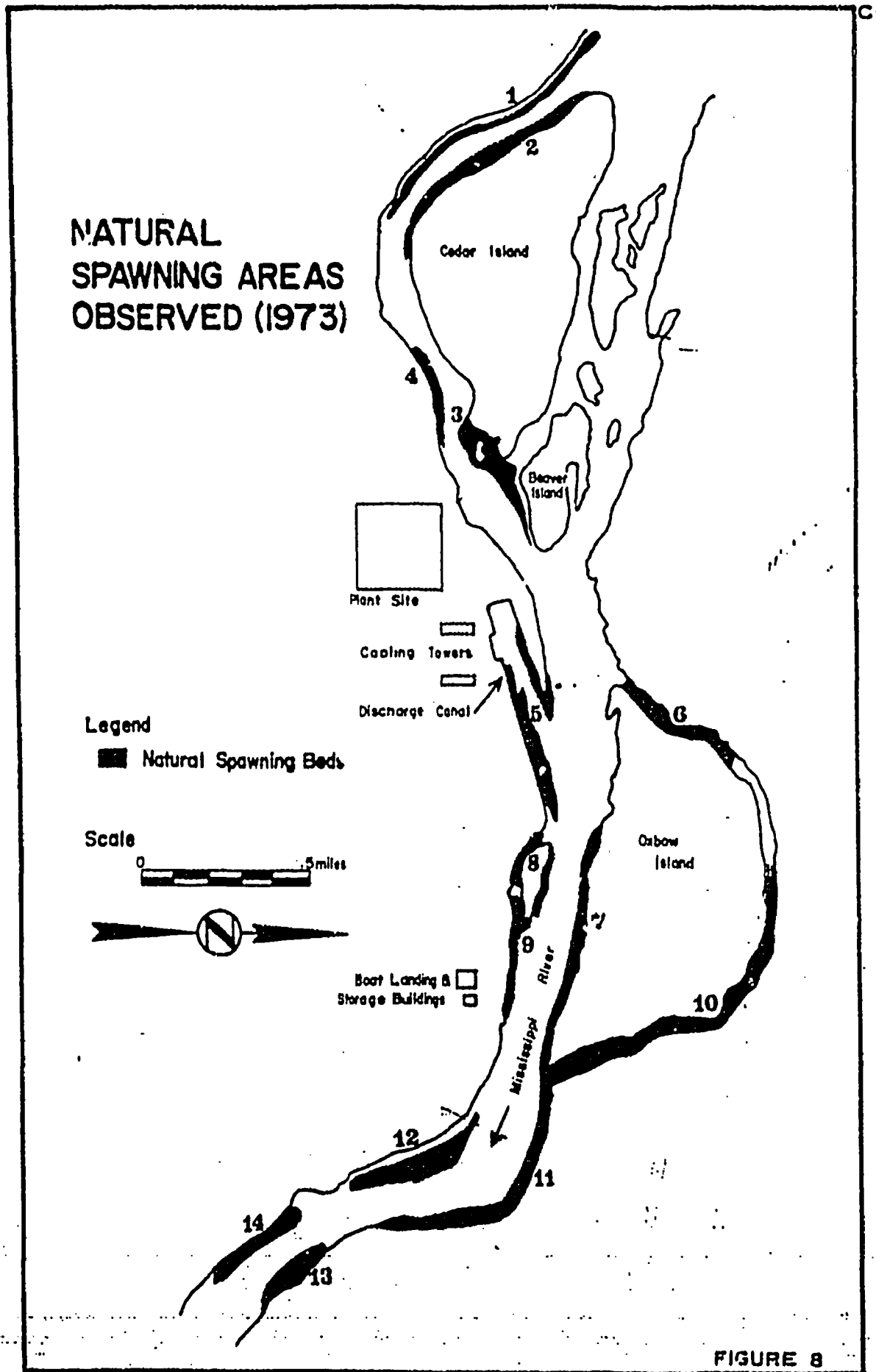

NATURAL
SPAWNING AREAS
OBSERVED (1973)
Cedar Island
Beaver Island
Plant Site
Cooling Towers
Discharge Canal
Legend
Natural Spawning Beds
Scale
0
5 miles
N
Boat Landing &
Storage Buildings
Oxbow Island
Mississippi River
1
2
3
4
5
6
8
9
10
11
12
13
14

FIGURE 8

Table 6. Spawning areas used by ++ fish, and water temperature in the area on the indicated date, Mississippi River near the Monticello Generator in 1973. Areas listed correspond to the map (Figure 8).

| Species | Date | Area | Temperature (C) |
|---|---|---|---|
| White sucker | April 16 | 8 | 6.0 |
| Shorthead redhorse | April 29 | 12 | 11.0 |
| | | 11 | 11.3 |
| | | 14 | 10.5 |
| | | 13 | 11.5 |
| | May 7 | 7 | 12.0 |
| | | 9 | 12.3 |
| | 12 | 7, 8 | 12.0 |
| | 17 | 8 | 13.8 |
| | 23 | 1, 2 | 17.5 |
| Silver redhorse | April 29 | 12 | 11.0 |
| | May 12 | 7, 8, 9 | 12.0 |
| | 17 | 5 | 14.5 |
| | | 7, 8 | 13.8 |
| Carp | May 30 | 5 | 31.0 |
| | | 8 | 21.5 |
| | | 7 | 17.5 |
| | | 9 | 22.0 |
| | 31 | 7 | 19.0 |
| | June 2 | 1 | 20.5 |
| | | 4 | 21.0 |
| | | 3 | 20.8 |
| | 5 | 4 | 20.0 |
| | | 3 | 21.0 |
| | | 6 | 22.0 |
| | 7 | 10 | 20.5 |
| | 11 | 7 | 24.5 |
| | 12 | 6 | 23.8 |
| Black crappie | 7 | 10 | 22.0 |
| | | 9 | 24.8 |
| | 19 | 5 | 21.5 to 24.0 |

Project Title:

Forage Fish Population Studies

Project Objectives:

To determine population size, species composition, and distribution in the power plant area. This report is based on parts of two Master's theses completed at St. Cloud State College (Morgenweck, 1971; Ott, 1973).

Methods and Materials:

Fish were collected with seines at several locations above and below the power plant site. The seines used were 20 feet in length, 3/4 or 1/8 inch mesh, nonbag type. Seining was restricted to areas of sufficiently shallow depth to allow operation by wading, and with slow enough current to permit upstream-to-downstream hauls without having the net turn inside out.

The preoperational survey was made from October 2, 1969 to November 25, 1970, at six stations, two above and four below the power plant discharge (Figure 9). In that period, a total of 7,248 fish were collected. One sample was taken in October 2, 1969. No more samples were taken until May 26, 1970. From May 26, 1970 until September 11, 1970, samples were taken twice each week at each station. From September 20, 1970 until November 1, 1970, weekly samples were taken. The last sample of the preoperational series was taken on November 20, 1970. Environmental conditions, such as air temperature, water temperature, depth current velocity, occurrence of vegetation, and cloud cover affected the sampling efficiency.

The postoperational seining program was conducted from June 19, 1972 to July 25, 1973. Eight sampling sites were used; four

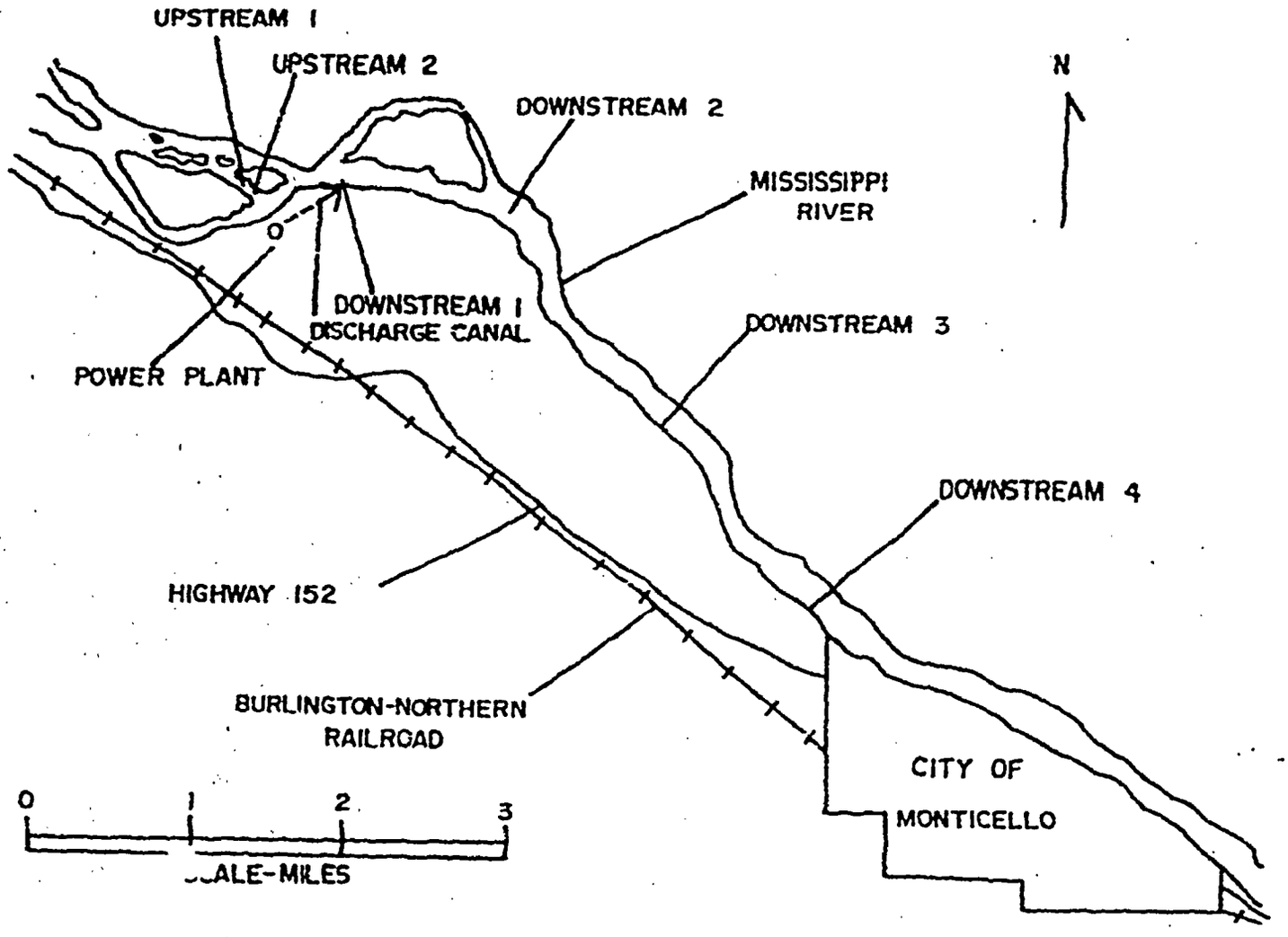



Figure 9. A map showing seining areas used in preoperational studies on fish populations.

above and four below the heated water discharge of the power plant (Figures 10 and 11). Preoperational stations Upstream 1, Downstream 1, and Downstream 2 were identical to postoperational stations Upstream 1, Downstream 1, and Downstream 3, respectively.

Results:

A total of 7,248 fish of 17 species were collected in the preoperational study. The total number of fish collected from all stations and the percent of the total each species represented is given in Table 7. The species composition of the composite of all stations, in order of decreasing abundance was: bigmouth shiner, spotfin shiner, sand shiner, bluntnose minnow, johnny darter, hornyhead chub, longnose dace, common shiner, white sucker, smallmouth bass, spottail shiner, blacknose dace, creek chub, black bullhead, black crappie, golden shiner, and rock bass.

A total of 7,599 fish of 20 species were collected from postoperational seine hauls. The total number of fish collected from all stations and the percent of the total each species represented is given in Table 8. The species composition of the total postoperational collection in decreasing order of abundance was: spotfin shiner, bigmouth shiner, sand shiner, bluntnose minnow, white sucker, common shiner, johnny darter, hornyhead chub, smallmouth bass, fathead minnow, spottail shiner, longnose dace, redhorse spp., trout-perch, blacknose dace, brassy minnow, logperch, largemouth bass, creek chub, and northern redbelly dace. Data on the species composition of fish at each station are given in Table 9. Fathead minnows were probably introduced into the Mississippi River as a result of Berguson's (1973) experiments on entrainment. On five dates from June 1972 through February 1973, a total of 65,820 fathead minnows were introduced into the plant intake water.

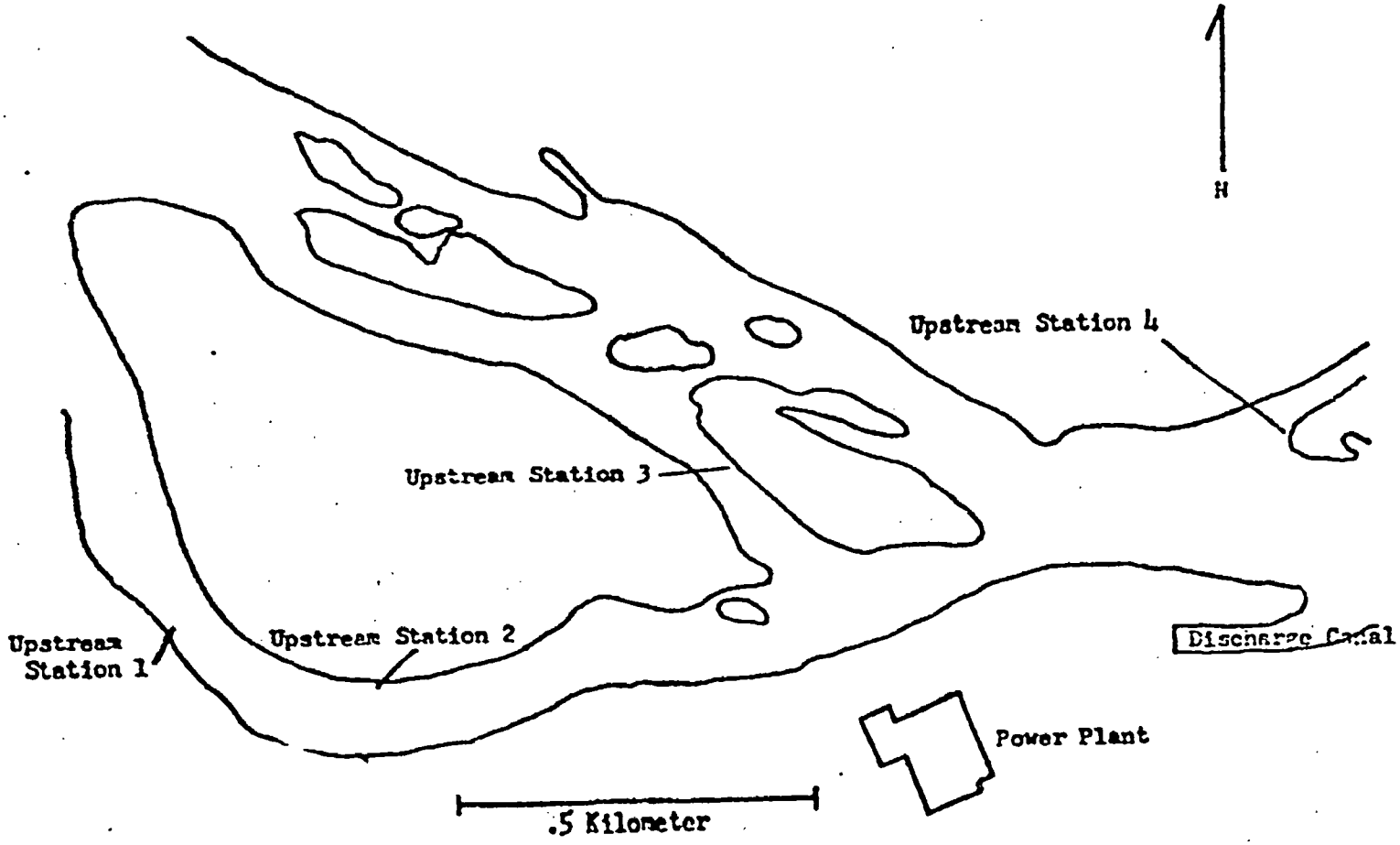



Figure 10. A map showing upstream seining areas used in postoperational studies on fish populations.

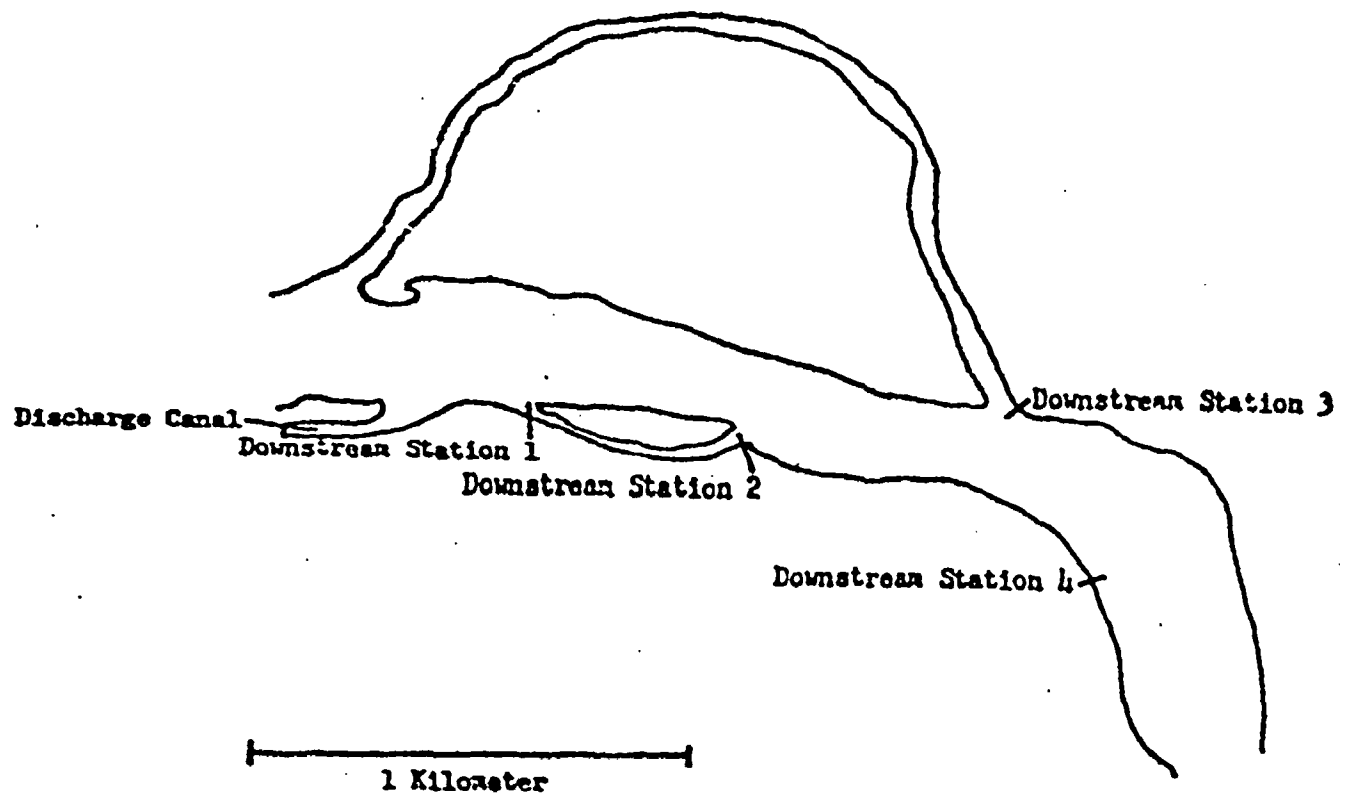



Figure 11. A map showing downstream seining areas used in postoperational studies on fish populations.

Table 7 Total number of fish collected from each seining station in 1970 and the total percent (in parentheses) represented by each species

| Species | Stations | | | | | | |
|---|---|---|---|---|---|---|---|
| | Up-1 | Up-2 | D-1 | D-2 | D-3 | D-4 | Total |
| Emerald shiner | 830 (49.4) | 297 (27.4) | 177 (12.5) | 318 (23.0) | 121 (11.8) | 234 (35.7) | 1977 (27.3) |
| Black bullhead | --- | --- | --- | 1 (.07) | --- | 1 (.1) | 2 (.02) |
| Black crappie | --- | --- | --- | 2 (.1) | --- | --- | 2 (.02) |
| Blacknose dace | --- | 4 (.4) | 11 (.8) | --- | 6 (.6) | 9 (1.4) | 30 (.4) |
| Common shiner | 6 (.4) | 7 (.6) | 84 (6.0) | 19 (1.4) | 29 (2.8) | 64 (9.8) | 209 (2.9) |
| Creek chub | --- | 1 (.09) | 20 (1.4) | --- | 4 (.4) | --- | 25 (.3) |
| Golden shiner | --- | --- | --- | --- | 1 (.1) | --- | 1 (.01) |
| Hornyhead chub | 4 (.2) | 8 (.7) | 57 (4.0) | 7 (.5) | 127 (12.4) | 25 (3.8) | 228 (3.1) |
| Johnny darter | 14 (.8) | 87 (8.0) | 90 (6.4) | 90 (6.5) | 26 (2.5) | 56 (8.5) | 363 (5.0) |
| Longnose dace | 53 (3.2) | 4 (.4) | 14 (1.0) | --- | 152 (14.8) | 1 (.1) | 224 (3.1) |
| Redhorse sucker | 1 (.05) | --- | 6 (.4) | 2 (.14) | 10 (1.0) | 1 (.1) | 20 (.3) |
| Rock bass | --- | --- | --- | 1 (.07) | --- | --- | 1 (.01) |
| Sand shiner | 614 (36.5) | 303 (27.7) | 96 (6.8) | 253 (18.3) | 33 (3.2) | 34 (5.2) | 1333 (18.4) |
| Smallmouth bass | 34 (2.0) | 32 (2.9) | 17 (1.2) | 3 (.2) | 4 (.4) | 31 (4.7) | 121 (1.7) |

Table 7 (cont'd.)

| Species | Stations | | | | | | |
|---|---|---|---|---|---|---|---|
| | Up-1 | Up-2 | D-1 | D-2 | D-3 | D-4 | Total |
| Spotfin shiner | 48 (2.9) | 231 (21.1) | 429 (30.4) | 461 (33.3) | 264 (25.8) | 95 (14.5) | 1528 (21.1) |
| Spottail shiner | 4 (.2) | 3 (.3) | 23 (1.6) | 3 (.2) | 34 (3.3) | 8 (1.2) | 75 (1.0) |
| White sucker | 20 (1.2) | 27 (2.5) | 66 (4.7) | 37 (2.7) | 14 (1.4) | 20 (3.1) | 184 (2.5) |
| Bluntnose minnow | 53 (3.2) | 89 (8.1) | 321 (22.7) | 187 (13.5) | 199 (19.4) | 76 (11.6) | 925 (12.7) |
| Total Number | 1681 | 1093 | 1411 | 1384 | 1024 | 655 | 7248 |
| % Total | (23.2) | (15.1) | (19.5) | (19.1) | (14.1) | (9.0) | |

Table 8 Total number of each species collected in 1972 and 1973 from each station for species composition and the percent of the total that they represent (in parentheses).

| Species | Stations | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Up-1 | Up-2 | Up-3 | Up-4 | D-1 | D-2 | D-3 | D-4 | |
| Spotfin shiner | 42 (15.8) | 106 (38.4) | 193 (9.8) | 129 (30.2) | 830 (33.6) | 168 (36.9) | 271 (17.5) | 47 (26.3) | 1786 (23.5) |
| Bigmouth shiner | 107 (40.1) | 4 (1.4) | 612 (30.9) | 19 (4.5) | 274 (11.0) | 20 (4.4) | 608 (39.3) | 12 (6.7) | 1656 (21.8) |
| Sand shiner | 45 (16.9) | 94 (34.1) | 754 (38.0) | 12 (2.8) | 404 (16.4) | 69 (15.2) | 249 (16.1) | 14 (7.8) | 1641 (21.6) |
| Bluntnose minnow | 21 (7.9) | 31 (11.2) | 117 (5.9) | 73 (17.1) | 506 (20.5) | 137 (30.1) | 320 (20.7) | 24 (13.4) | 1229 (16.2) |
| Common shiner | 21 (7.9) | 2 (.7) | 52 (2.6) | 5 (1.2) | 122 (4.9) | 18 (4.0) | 26 (1.7) | 9 (5.0) | 255 (3.4) |
| Hornyhead chub | 10 (3.7) | 14 (5.1) | 22 (1.1) | 5 (1.2) | 43 (1.7) | 2 (.4) | 23 (1.5) | 7 (3.9) | 126 (1.7) |
| Johnny darter | 8 (3.0) | 2 (.7) | 49 (2.5) | 8 (1.9) | 84 (3.4) | 7 (1.6) | 24 (1.6) | 14 (7.8) | 196 (2.6) |
| Fathead minnow | 1 (.4) | -- -- | 2 (.1) | 17 (4.0) | 34 (1.4) | 1 (.2) | 6 (.4) | 5 (2.8) | 66 (.9) |
| Spottail shiner | 1 (.4) | 1 (.4) | 20 (1.0) | 1 (.2) | 24 (1.0) | 10 (2.2) | 4 (.3) | 1 (.6) | 62 (.8) |
| Creek chub | 3 (1.1) | -- -- | -- -- | -- -- | 3 (.1) | -- -- | -- -- | -- -- | 6 (.1) |

Table 8 Continued.

| Species | Stations | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Up-1 | Up-2 | Up-3 | Up-4 | D-1 | D-2 | D-3 | D-4 | |
| Longnose dace | -- | -- | 42 | -- | 3 | -- | -- | 11 | 56 |
| | -- | -- | (2.1) | -- | (.1) | -- | -- | (6.1) | (.7) |
| Blacknose dace | 1 | -- | 19 | 1 | 4 | -- | -- | -- | 25 |
| | (.4) | -- | (1.0) | (.2) | (.2) | -- | -- | --- | (.3) |
| Redhorse sucker spp. | 2 | 21 | 4 | 1 | 7 | 2 | 5 | 7 | 49 |
| | (.8) | (7.6) | (.2) | (.2) | (.3) | (.4) | (.3) | (3.9) | (.6) |
| White sucker | -- | 1 | 33 | 121 | 105 | 8 | 9 | 18 | 295 |
| | -- | (.4) | (1.7) | (28.3) | (4.2) | (1.8) | (.6) | (10.1) | (3.9) |
| Smallmouth bass | 1 | -- | 41 | 9 | 17 | 2 | -- | 9 | 79 |
| | (.4) | -- | (2.1) | (2.1) | (.7) | (.4) | -- | (5.0) | (1.0) |
| Largemouth bass | -- | -- | -- | 2 | 3 | 2 | -- | -- | 7 |
| | -- | -- | -- | (.5) | (.1) | (.4) | -- | -- | (.1) |
| Logperch | 2 | -- | -- | 6 | 4 | -- | -- | -- | 12 |
| | (.8) | -- | -- | (1.4) | (.2) | -- | -- | -- | (.2) |
| Trout-perch | 1 | -- | 12 | 2 | 4 | 9 | -- | -- | 28 |
| | (.4) | -- | (.6) | (.5) | (.2) | (2.0) | -- | -- | (.4) |
| Brassy minnow | -- | -- | 8 | 15 | -- | -- | -- | 1 | 24 |
| | -- | -- | (.4) | (3.5) | -- | -- | -- | (.6) | (.3) |
| N. Redbelly dace | -- | -- | -- | 1 | -- | -- | -- | -- | 1 |
| | -- | -- | -- | (.2) | -- | -- | -- | -- | (nil) |
| Total | 266 | 276 | 1980 | 427 | 2471 | 455 | 1545 | 179 | 7599 |

Table 9 Occurrence of fish species at each station in the order of their abundance during 1972 and 1973. The most numerous fish are coded 1, second most abundant as 2, etc.

| Species | Stations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Up-1 | Up-2 | Up-3 | Up-4 | D-1 | D-2 | D-3 | D-4 |
| Spotfin shiner | 3 | 1 | 3 | 1 | 1 | 1 | 3 | 1 |
| Bigmouth shiner | 1 | 6 | 2 | 4 | 4 | 4 | 1 | 6 |
| Sand shiner | 2 | 2 | 1 | 7 | 3 | 3 | 4 | 4 |
| Bluntnose minnow | 4 | 3 | 4 | 3 | 2 | 2 | 2 | 2 |
| White sucker | - | 10 | 9 | 2 | 6 | 8 | 8 | 3 |
| Common shiner | 5 | 7 | 5 | 12 | 5 | 5 | 5 | 8 |
| Johnny darter | 7 | 8 | 6 | 9 | 7 | 9 | 6 | 5 |
| Hornyhead chub | 6 | 5 | 10 | 11 | 8 | 10 | 7 | 10 |
| Smallmouth bass | 14 | - | 8 | 8 | 11 | 12 | - | 9 |
| Fathead minnow | 11 | - | 16 | 5 | 9 | 14 | 9 | 12 |
| Spottail shiner | 12 | 9 | 11 | 15 | 10 | 6 | 11 | 13 |
| Longnose dace | - | - | 7 | - | 17 | - | - | 7 |
| Redhorse sucker | 9 | 4 | 15 | 17 | 12 | 11 | 10 | 11 |
| Trout-perch | 15 | - | 13 | 14 | 15 | 7 | - | - |
| Blacknose dace | 13 | - | 12 | 16 | 13 | - | - | - |
| Brassy minnow | - | - | 14 | 6 | - | - | - | 14 |
| Logperch | 10 | - | - | 10 | 14 | - | - | - |
| Largemouth bass | - | - | - | 13 | 18 | 13 | - | - |
| Creek chub | 8 | - | - | - | 16 | - | - | - |
| N. Redbelly dace | - | - | - | 18 | - | - | - | - |

A small portion (9,471) of these were recovered from the discharge water. Of the 9,471 fish recovered, 349 were alive after 168 hours. Thus, a sufficient number of the introduced fathead minnows could have survived entrainment and become part of the postoperational species composition.

The species composition (by percentage) of preoperational and postoperational samples are compared in Table 10. A rank correlation calculation was performed on these two sets of data, resulting in the values shown in Table 11. The correlation coefficients were: Upstream Station 3 = 0.873, Downstream Station 1 = 0.926, and Downstream Station 3 = 0.930.

The high correlation of the data from preoperational and postoperational seining studies shows that the changes in species composition have been minor. The lower correlation of the data from Upstream Station 3 indicates that more change occurred at this station than at Downstream Station 1, which shows a higher correlation, despite the fact that Downstream Station 1 was subject to the heated water. Other than added heat, possible causes of the minor changes in species composition observed at the three stations compared could be natural population fluctuation, sampling error, or alterations in the habitat. From these data it is possible to conclude that the addition of the heated water effluent had no significant effect on minnow population in the study area.

Changes in habitat at each station generally resulted in changes in population size. When current velocity was low, population size was large, and when dropping water level constricted flow into a channel with high current velocity, minnow population was reduced, probably by dispersal downstream.

Table 10 Comparison of species composition, by percentage, of preoperational and postoperational fish populations sampled by seining in the Mississippi River.

| Species | Stations | | | | | |
|---|---|---|---|---|---|---|
| | Pre Up-1 | Post Up-1 | Pre D-1 | Post D-1 | Pre D-2 | Post D-3 |
| Spotfin shiner | 2.9 | 9.8 | 30.4 | 33.6 | 33.3 | 17.5 |
| Bigmouth shiner | 49.4 | 30.9 | 12.5 | 11.0 | 23.0 | 39.3 |
| Sand shiner | 36.5 | 38.0 | 6.8 | 16.4 | 18.3 | 16.1 |
| Bluntnose minnow | 3.2 | 5.9 | 22.7 | 20.5 | 13.5 | 20.7 |
| Common shiner | 0.4 | 2.6 | 6.0 | 4.9 | 1.4 | 1.7 |
| Hornyhead chub | 0.2 | 1.1 | 4.0 | 1.7 | 0.5 | 1.5 |
| Johnny darter | 0.8 | 2.5 | 6.4 | 3.4 | 6.5 | 1.6 |
| Spottail shiner | 0.2 | 1.0 | 1.6 | 1.0 | 0.2 | 0.3 |
| Creek chub | - | - | 1.4 | 0.1 | - | - |
| Longnose dace | 3.2 | 2.1 | 1.0 | 0.1 | - | - |
| Blacknose dace | - | 1.0 | 0.8 | 0.2 | - | - |
| Redhorse sp. | .06 | 0.2 | 0.4 | 0.3 | .14 | 0.3 |
| White sucker | 1.2 | 1.7 | 4.7 | 4.2 | 2.7 | 0.6 |
| Smallmouth bass | 2.0 | 2.1 | 1.2 | 0.7 | 0.2 | - |

Table 11 Results of a rank correlation calculation performed on the abundance of the various species collected in preoperational and postoperational seining operations. Species are coded most abundant as 1 and least abundant as 14. The formula (Freund, 1970) used to calculate the correlation is:

$$r' = 1 - 6(\ d^2)/n(n^2 - 1)$$

where (d) is the difference between the rank of the species and (n) is the number of species being compared.

| | Upstream Station 3 | | | | Downstream Station 1 | | | | Downstream Station 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Past Rank | Present Rank | d | $d^2$ | Past Rank | Present Rank | d | $d^2$ | Past Rank | Present Rank | d | $d^2$ |
| Spotfin shiner | 5 | 3 | 2 | 4 | 1 | 1 | 0 | 0 | 1 | 3 | 2 | 4 |
| Bigmouth shiner | 1 | 2 | 1 | 1 | 3 | 4 | 1 | 1 | 2 | 1 | 1 | 1 |
| Sand shiner | 2 | 1 | 1 | 1 | 4 | 3 | 1 | 1 | 3 | 4 | 1 | 1 |
| Bluntnose minnow | 3.5 | 4 | .5 | .25 | 2 | 2 | 0 | 0 | 4 | 2 | 2 | 4 |
| Common shiner | 9 | 5 | 4 | 16 | 6 | 5 | 1 | 1 | 7 | 5 | 2 | 4 |
| Hornyhead chub | 10.5 | 10 | .5 | .25 | 8 | 8 | 0 | 0 | 8 | 7 | 1 | 1 |
| Johnny darter | 8 | 6 | 2 | 4 | 5 | 7 | 2 | 4 | 5 | 6 | 1 | 1 |
| Spottail shiner | 10.5 | 11.5 | 1 | 1 | 9 | 9 | 0 | 0 | 9.5 | 9.5 | 0 | 0 |
| Creek chub | 13.5 | 14 | .5 | .25 | 10 | 13.5 | 3.5 | 12.25 | 13 | 12.5 | .5 | .25 |
| Longnose dace | 3.5 | 7.5 | 4 | 16 | 12 | 13.5 | 1.5 | 2.25 | 13 | 12.5 | .5 | .25 |
| Blacknose dace | 13.5 | 11.5 | 2 | 4 | 13 | 12 | 1 | 1 | 13 | 12.5 | .5 | .25 |
| Redhorse sucker | 12 | 13 | 2 | 4 | 14 | 11 | 3 | 9 | 11 | 9.5 | 1.5 | 2.25 |
| White sucker | 7 | 9 | 2 | 4 | 7 | 6 | 1 | 1 | 6 | 8 | 2 | 4 |
| Smallmouth bass | 6 | 7.5 | 1.5 | 2.25 | 11 | 10 | 1 | 1 | 9.5 | 12.5 | 3 | 9 |
| | | $r' = .873$ | | | | $r' = .926$ | | | | $r' = .930$ | | |

Water standing in pools attracted large numbers of minnows. The standing water was often warmed by the sun and had a higher temperature than the flowing water nearby. It was not possible to determine whether the minnows were attracted to quiet areas, because the pool water was warmer or because the current was slower.

Seine hauls on cloudly days yielded relatively smaller catches than on sunny days. Afternoon samples were usually larger than morning samples at the same station. Thus, it does seem clear that the effect of sunlight on minnow population movements occurs more by heating than by light intensity, since pools would have less light on the bottom than shallow areas with low current. It seems reasonable that the minnows select microhabitats by response to separate thresholds for current and temperature. Small fish may remain in deeper, swifter water early in the day and on cloudy days, because the shallows may be relatively cooler. As the day advances, the temperature in shallow areas may increase just enough to cause movement of the school, or aggregation of a dispersed school. Conversely, the fish may disperse out of shallow areas at times when the low temperature there may be less desirable than the higher current of waters near the middle of the river.