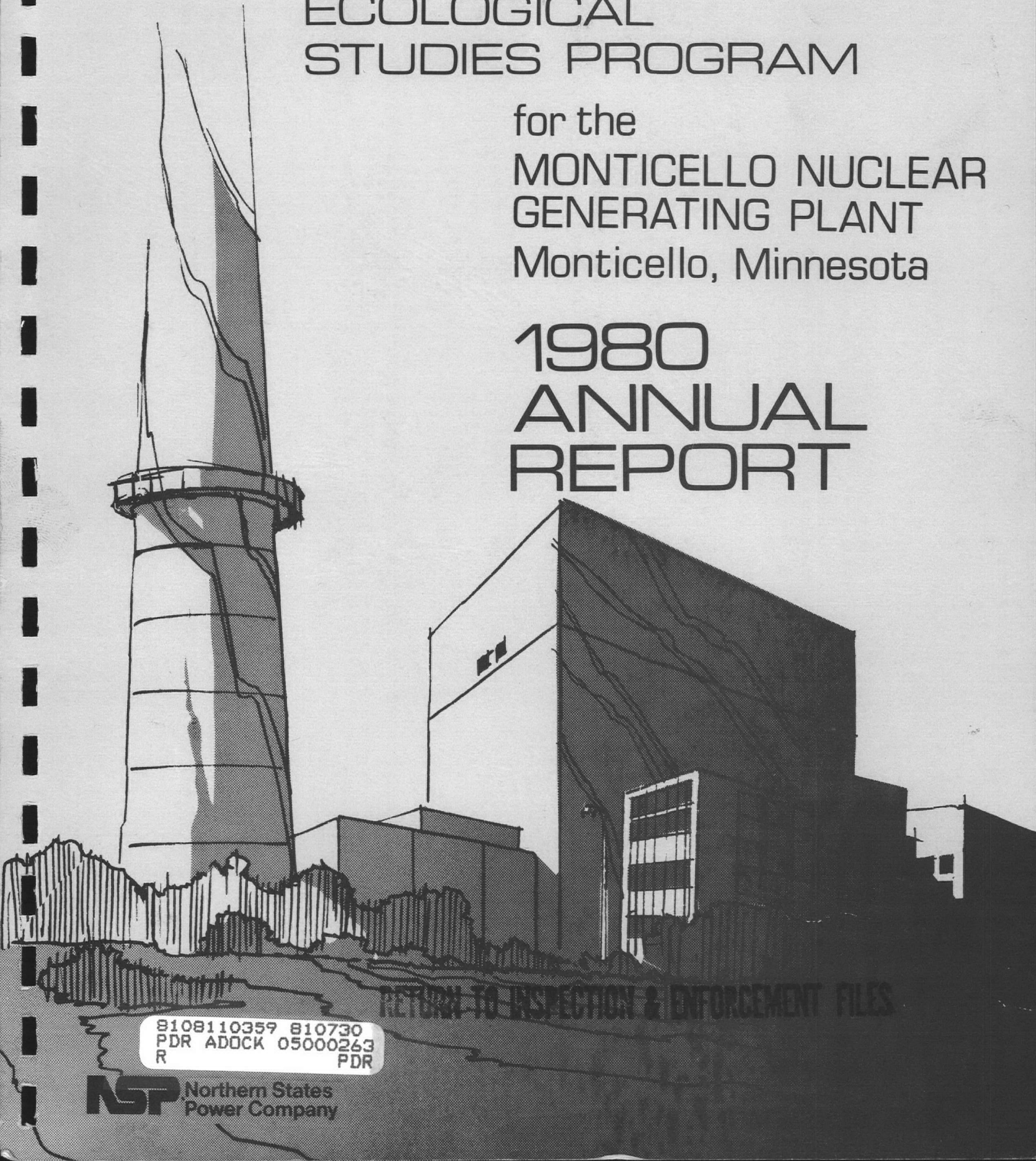
ENVIRONMENTAL MONITORING AND ECOLOGICAL STUDIES PROGRAM

for the MONTICELLO NUCLEAR GENERATING PLANT
Monticello, Minnesota

1980 ANNUAL REPORT



NSP Northern States Power Company

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INTRODUCTION

Two areas of ecological monitoring were conducted in 1980: Water Quality and Fishery Studies. The objectives of the water quality study were to determine if plant operation was altering certain chemical parameters within the river and to determine if these changes (if any) had any effect on the fishery. Because the Mississippi River near Monticello is a large, turbulent stream with a boulder substrate, many conventional fish sampling methods are impractical. Two techniques that have worked well for capturing specimens are electrofishing and seining. Large fishes are efficiently sampled by electrofishing, and small species and young fishes are captured by seining. The objective of the electrofishing and seining studies was to assess the relative abundance and seasonal distribution of fish in response to the plant discharge plume. A paper assessing the influence of several parameters on fish year-class strength is also presented.

This is the thirteenth consecutive report (tenth operational) summarizing environmental monitoring activities for the Monticello Nuclear Generating Plant (MNGP).

Science Services Section
Environmental and Regulatory Activities Department
Northern States Power Company (NSP)
July 15, 1981

MONTICELLO NUCLEAR GENERATING PLANT
ENVIRONMENTAL MONITORING PROGRAM
1980 ANNUAL REPORT

WATER MONITORING SUMMARY

(1.1)

(Physical Parameters)

Prepared for

Northern States Power Company
Minneapolis, Minnesota

by

Science Services Section
Environmental and Regulatory
Activities Department
Northern States Power Company

1.1 1980 MONTICELLO WATER MONITORING SUMMARY (PHYSICAL PARAMETERS)

The Monticello Nuclear Generating Plant (MNGP) had four outages during 1980 (Table 1.1-1). These outages accumulated to slightly more than 75 days. The outage of greatest duration began on February 23 and terminated on April 5. MNGP's on-line performance for 1980 was 79 percent.

Data are collected hourly by the plant computer on the circulating water system at MNGP. These data were transformed into weekly averages and are listed in Table 1.1-2.

Total precipitation in 1980 for central Minnesota (St. Cloud Weather Bureau data) was very close to the 40-year average (26.48 inches). However, April, May, July, October, and November were exceptionally dry months, which resulted in below average river discharge (4,400 cfs) for much of the year (Table 1.1-3). Maximum river discharge occurred in mid-April during a moderate spring run-off (Figure 1.1-1). Minimum river discharge occurred in July and August, just prior to periods of extensive precipitation during August and September.

The rate of water withdrawal from the Mississippi River by MNGP was quite consistent and generally ranged between 500 and 600 cfs (Figure 1.1-2). The only deviations from this pumping rate occurred during plant outages and intake icing conditions.

Ambient river water temperatures are illustrated in Figure 1.1-3. Winter temperatures were consistently at 32°F; warming did not begin until early April. Maximum weekly mean temperature of 81°F occurred in mid-July during the low water period. Temperatures gradually declined in the fall, reaching 32°F in early December.

Winter discharge canal water temperatures generally ranged between 65°F and 75°F (Figure 1.1-4). Maximum discharge canal temperatures, slightly exceeding 92°F, occurred in late-May and mid-July. Discharge temperatures throughout the summer were generally near 85°F, due to "helper mode" plant operation (once-through cooling tower operation) from late-May to September.

Table 1.1-1

1980 MONTICELLO OFF-LINE TIME

Date Off	Date On	Outage Time (Hrs)
2/23 (1800 hrs)	4/5 (2000 hrs)	1010
4/19 (2000 hrs)	4/28 (1400 hrs)	210
4/29 (0200 hrs)	5/15 (1100 hrs)	393
11/5 (2200 hrs)	11/14 (0300 hrs)	197
	Total	1810 hrs (75.4 Day)

Table 1.1-2

1980 MONTICELLO WATER SYSTEM SUMMARIES

Week Of	River Discharge	Plant Intake (cfs)	Ambient River Temp °F	Discharge Canal Temp °F
1/4/80	4167	543	32.0	65.1
1/11	3604	543	32.0	64.4
1/18	4049	658	32.0	63.8
1/25	4979	431	32.0	68.0
2/1	5879	277	32.4	79.3
2/8	4960	215	32.5	64.2
2/15	5082	432	32.1	63.5
2/22	4583	411	32.3	56.6
2/29	4782	7	32.1	36.9
3/7	4645	9	32.1	34.4
3/14	4569	6	32.1	34.3
3/21	4212	5	32.5	34.9
3/28	4683	5	32.7	34.4
4/4	7189	39	33.0	35.0
4/11	11571	520	37.0	63.1
4/18	10844	536	42.3	72.2
4/25	7645	181	55.4	61.0
5/2	6044	131	59.1	62.9
5/9	4758	57	61.5	64.3
5/16	3550	259	57.9	64.8
5/23	3083	574	64.5	92.3
5/30	2458	550	71.7	87.8
6/6	3076	557	69.9	84.8
6/13	4053	549	69.0	83.4
6/20	4201	545	70.8	84.2
6/27	3582	549	74.2	88.4
7/4	2582	539	72.1	85.8
7/11	2013	545	78.3	91.5
7/18	1772	541	80.7	92.5
7/25	2211	541	76.3	88.9
8/1	1848	537	76.7	85.7
8/8	1696	565	75.1	75.2
8/15	2008	560	73.5	73.5
8/22	2045	558	70.7	70.7
8/29	2342	568	71.9	72.7
9/5	2666	552	69.1	80.3
9/12	3382	562	69.0	86.4
9/19	5408	569	60.9	88.6
9/26	4471	573	56.7	85.7

Table 1.1-2 (Continued)

Week Of	River Discharge	Plant Intake (cfs)	Ambient River Temp °F	Discharge Canal Temp °F
10/3/80	4001	584	55.0	85.1
10/10	3317	578	59.5	85.1
10/17	3185	552	48.0	78.8
10/24	3427	550	45.1	77.2
10/31	3922	545	39.8	73.1
11/7	4004	442	40.8	64.2
11/14	3950	194	39.4	45.4
11/21	3683	418	35.7	64.7
11/28	3384	446	33.4	68.4
12/5	2693	474	32.7	74.0
12/12	3132	440	32.4	76.9
12/19	3399	481	32.7	76.3
12/26	2836	470	32.3	75.6
12/31	3352	522	32.1	75.2

Table 1.1-3

MISSISSIPPI RIVER AT MONTICELLO, MINNESOTA
Monthly Average River Discharge (cfs)

	1973	1974	1975	1976	1977	1978	1979	1980
January	3755	3787	6908	3459	1295	5800	4830	4557
February	3644	3875	6297	3763	1754	4800	5469	4856
March	11132	3796	5620	7796	3341	7500	6352	4653
April	6361	11513	18122	11700	3350	10500	17161	9138
May	6678	16387	26355	3815	2202	7000	17550	3611
June	4038	12370	9323	1903	2475	6500	9028	3698
July	2189	3918	12137	1852	2323	5500	9313	2008
August	4340	3458	3654	1203	1275	6000	4818	2036
September	2771	1616	3325	1052	3420	6500	3919	4105
October	12289	1719	3133	1151	5617	4700	2967	3522
November	7418	4171	3625	1331	6783	3996	6974	3755
December	4723	2572	3340	1286	6046	3376	4228	3080
Average	5778	5765	8395	3359	3323	6014	7717	4085

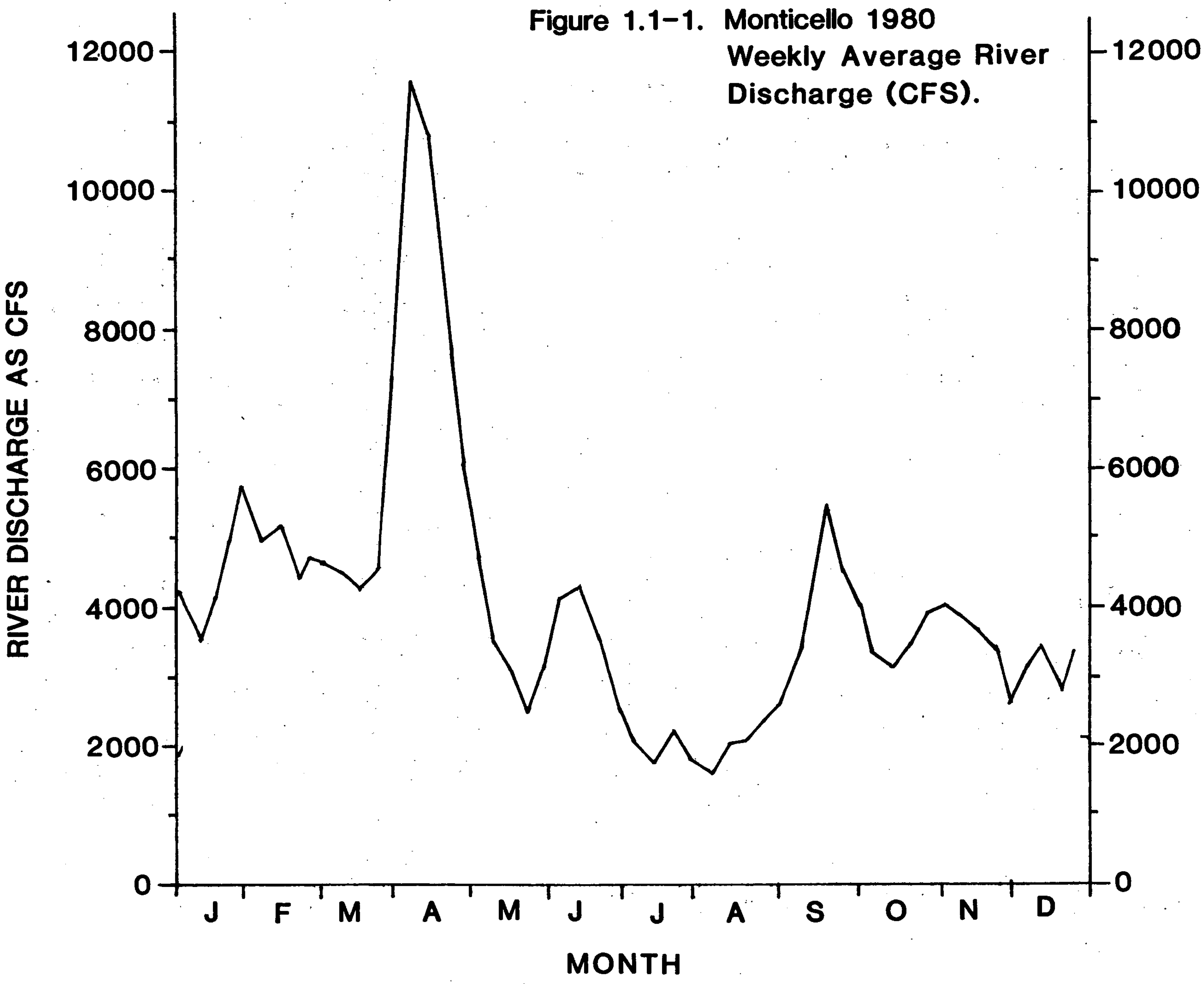


Figure 1.1-1. Monticello 1980 Weekly Average River Discharge (CFS).

Figure 1.1-2. Monticello 1980 Weekly Average Plant Intake Withdrawal Rate (CFS)

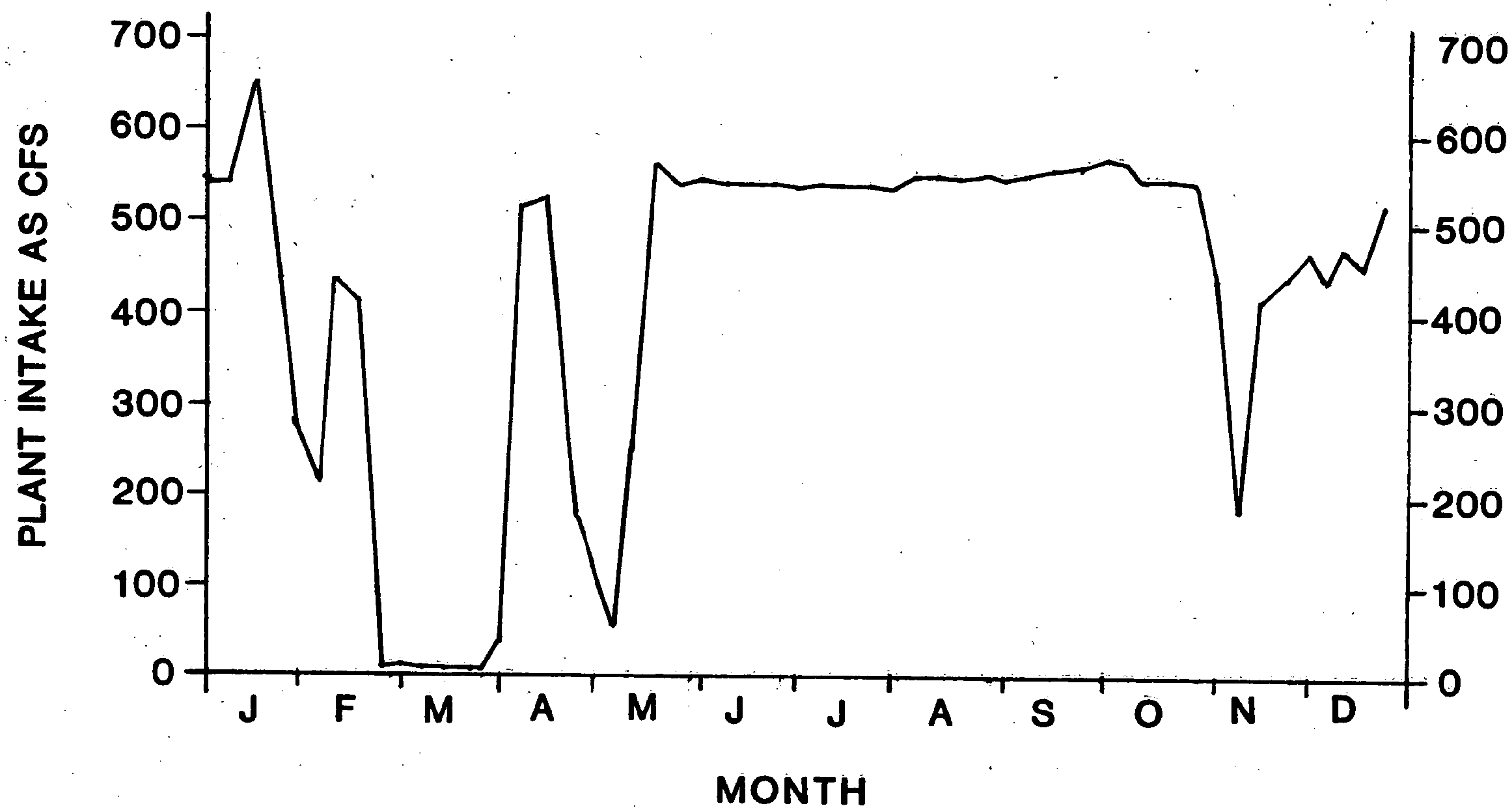


Figure 1.1-3. Monticello Weekly Average River Temperature (°F).

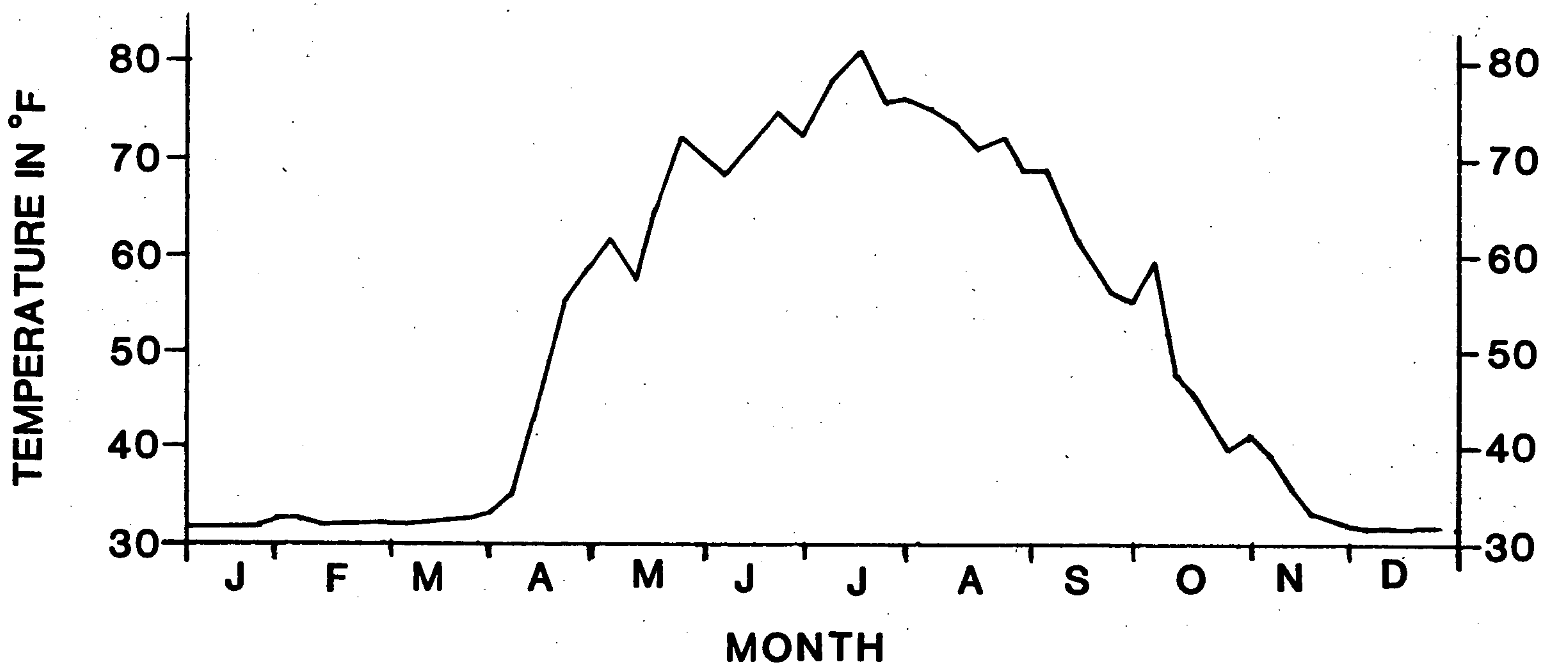
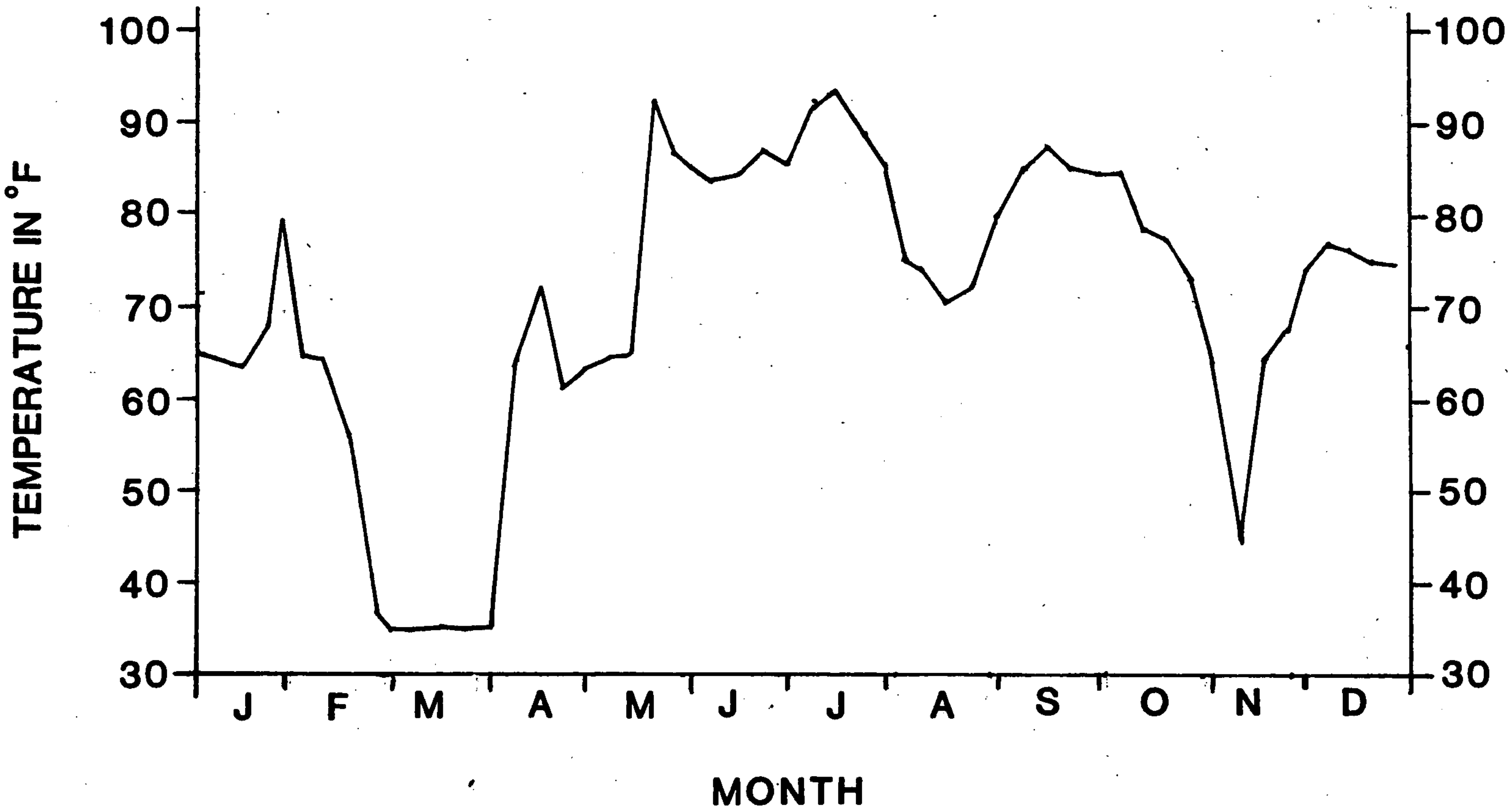


Figure 1.1-4. Monticello 1980 Weekly Average Discharge Canal Water Temperature (°F).



MONTICELLO NUCLEAR GENERATING PLANT

ENVIRONMENTAL MONITORING PROGRAM

1980 ANNUAL REPORT

WATER MONITORING SUMMARY

(1.2)

(Chemical Parameters)

Prepared for

Northern States Power Company

Minneapolis, Minnesota

by

Sciences Services Section

Environmental and Regulatory
Activities Department

Northern States Power Company

1.2 MISSISSIPPI RIVER WATER MONITORING SAMPLE

1.2.1 SUMMARY

The 1980 Mississippi River water monitoring program was identical to the programs of 1972 through 1979. Three sampling sites were used in the acquisition of water quality data used in assessing the impact of the discharge from the Monticello Plant on the river.

The three sampling sites used were the discharge outfall, 1,000 feet upstream of the outfall, and 1,000 feet downstream of the outfall. Samples were taken during the last week of the month from January through December. Sample collection analyses were done by NSP personnel. The NSP Chestnut Street Testing Laboratory was used for the analyses. Procedures for collection and analyses were as outlined in US EPA Manual of Methods for Chemical Analyses of Water Wastes and APHA-AWWA-WPCF Standard Methods for the Examination of Water and Wastewater (14 Editions 1975).

Results of the analyses are presented in Table 1.2-1. A comparison of the discharge outfall and downstream transect values showed a significant difference only in the temperature values. This variation was apparent both on a monthly and an annual average comparison. The most significant variation for an extended portion of the year occurred during the months of September through January. Differences in temperature during this period ranged from 8.0°C in September to 22°C in January.

As in past years of monitoring, impact exerted by plant effluent discharge is observed on the significant elevation of the physical water quality temperature. This impact is, as expected, most evident at the discharge outfall. However, any attempt to extrapolate concern for the river system, based on the impact seen at the outfall, should dissipate when consideration is given to the impact of downstream transect, which is 1,000 feet from the discharge outfall.

Monticello Environmental Monitoring

Table 1.2-1 Mississippi River Water

1980	Temp °C Upstream	Temp °C Downstream	Temp °C Discharge	Dissolved Oxygen mg/1 O_2 Upstream	Dissolved Oxygen mg/1 O_2 Downstream	Dissolved Oxygen mg/1 O_2 Discharge	Specific Conductance µmhos/cm 25°C Upstream	Specific Conductance µmhos/cm 25°C Downstream	Specific Conductance µmhos/cm 25°C Discharge
January	0	4	22	11.8	10.2	8.4	248	250	282
February	0	0	0	12.9	12.5	12.5	231	225	221
March	0	0	0	12.0	13.0	11.8	232	262	268
April	14	16	24	10.3	10.0	9.6	237	230	230
May	26	28	35.5	10.1	9.2	7.5	325	380	425
June	24	27	31	10.4	11.0	7.9	350	350	360
July	23.5	25.5	27.5	8.4	7.8	7.4	340	340	340
August	19	24	25	8.0	8.4	7.6	350	360	360
September	12	16.5	20	10.6	9.3	9.6	240	280	280
October	9	12	18	12.8	11.8	12.5	250	255	320
November	0	4	17	13.5	12.1	12.4	250	250	255
December	0	5	19	13.0	12.0	10.2	220	220	355
Average	10.6	13.5	19.9	11	11	10	273	306	305

	pH Upstream	pH Downstream	pH Discharge	Total Dissolved Solids mg/1 Upstream	Total Dissolved Solids mg/1 Downstream	Total Dissolved Solids mg/1 Discharge	Sulfate mg/1 SO_4 Upstream	Sulfate mg/1 SO_4 Downstream	Sulfate mg/1 SO_4 Discharge
January	7.3	7.4	7.4	210	210	220	9	10	9
February	7.7	7.6	7.7	220	220	220	11	10	7
March	7.7	7.9	7.7	210	210	210	8	8	9
April	8.1	8.0	8.2	150	150	150	8	8	8
May	7.9	7.8	7.4	190	180	170	9	10	8
June	8.4	8.4	8.4	200	210	200	8	9	9
July	8.6	8.6	8.7	210	200	210	-	-	-
August	8.6	8.6	8.7	200	220	190	-	-	-
September	8.5	8.5	8.4	200	200	200	13	13	12
October	7.9	7.9	8.0	180	180	210	13	13	12
November	8.0	7.9	7.8	200	200	190	12	12	12
December	8.5	8.5	8.4	250	240	240	15	14	15
Average	8.1	8.1	8.1	202	202	201	11	10	10

	P Alkalinity mg/1 CaCo3 Upstream	P Alkalinity mg/1 CaCo3 Downstream	P Alkalinity mg/1 CaCo3 Discharge	M Alkalinity mg/1 $CaCO_3$ Upstream	M Alkalinity mg/1 $CaCO_3$ Downstream	M Alkalinity mg/1 $CaCO_3$ Discharge	Ammonia Nitrogen mg/1 Upstream	Ammonia Nitrogen mg/1 Downstream	Ammonia Nitrogen mg/1 Discharge
January	0	0	0	174	177	173	.09	.08	.12
February	0	0	0	176	176	175	.11	.13	.14
March	0	0	0	168	169	170	.34	.28	.22
April	0	0	0	133	133	133	.01	.01	.01
May	6	6	5	157	157	158	.01	.01	.01
June	6	8	7	169	170	172	.04	.01	.01
July	5	5	7	161	164	164	.04	.09	.05
August	5	6	6	159	163	162	.14	.08	.11
September	4	4	3	154	153	154	.04	.06	.03
October	6	6	5	159	161	160	.03	.02	.02
November	4	3	4	156	163	157	.01	.01	.01
December	0	0	0	180	188	185	.06	.08	.12
Average	3	3	3	162	165	164	.08	.07	.07

- = Sample lost

Table 1.2-1 (Continued)

Monticello Environmental Monitoring

1980	Nitrate Nitrogen mg/l N Upstream	Nitrate Nitrogen mg/l N Downstream	Nitrate Nitrogen mg/l N Discharge	Nitrite Nitrogen mg/l N Upstream	Nitrite Nitrogen mg/l N Downstream	Nitrite Nitrogen mg/l N Discharge	Total Dissolved Phosphorus mg/l P Upstream	Total Dissolved Phosphorus mg/l P Downstream	Total Dissolved Phosphorus mg/l P Discharge
January	.45	.48	.43	.008	.010	.010	.05	.03	.04
February	.54	.47	.43	.010	.007	.006	.02	.01	.05
March	.65	.60	.66	.010	.010	.013	.14	.08	.09
April	.10	.05	.03	.005	.006	.005	.02	.09	.03
May	.17	.11	.11	.008	.007	.008	.02	.03	.06
June	.11	.01	.01	.004	.005	.005	.06	.04	.05
July	.01	.03	.03	.003	.003	.003	.09	.09	.13
August	.16	.09	.09	.007	.006	.007	.06	.06	.06
September	.21	.19	.20	.004	.007	.008	.03	.03	.03
October	.09	.08	.06	.007	.008	.007	.02	.02	.01
November	.10	.09	.10	.007	.005	.006	.01	.02	.02
December	.50	.42	.42	.010	.009	.013	.03	.02	.02
Average	.26	.22	.21	.007	.007	.008	.05	.04	.05

1980	Biochemical Oxygen Demand mg/l Upstream	Biochemical Oxygen Demand mg/l Downstream	Biochemical Oxygen Demand mg/l Discharge	Chloride mg/l Cl Upstream	Chloride mg/l Cl Downstream	Chloride mg/l Cl Discharge
January	.9	1.0	1.3	10	11	11
February	.9	1.0	1.0	5	5	5
March	3.0	2.1	2.7	8	7	8
April	4.4	4.0	4.4	5	6	5
May	3.1	3.0	2.8	6	6	7
June	4.0	2.9	3.4	8	7	8
July	3.6	3.6	3.6	8	9	8
August	-	-	-	10	14	10
September	2.0	2.0	2.0	19	15	16
October	2.1	1.9	2.0	9	11	12
November	1.0	1.8	1.9	11	11	10
December	3.7	1.4	1.3	8	6	7
Average	2.4	2.1	2.2	8.9	9	8.9

- = Sample lost

MONTICELLO NUCLEAR GENERATING PLANT

ENVIRONMENTAL MONITORING PROGRAM

1980 ANNUAL REPORT

A SUMMARY OF THE 1980 MONTICELLO ELECTROFISHING SURVEY

(2.1)

Prepared for

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Minneapolis, Minnesota

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2.1 A SUMMARY OF THE 1980 MONTICELLO ELECTROFISHING SURVEY

2.1.1 INTRODUCTION

Electrofishing studies were conducted in 1980 to assess relative abundance and seasonal distribution of fish in response to the Monticello Nuclear Generating Plant's (MNGP) thermal plume. Study areas (Figure 2.1-1) were sampled eight times between April 11 and October 24. Sector A encompasses an area of 21.6 ha and extends from the discharge canal outlet upstream 1.7 km to the top of Cedar Island. Sector B extends 1.5 km downstream from the discharge canal to the bottom of Boy Scout Rapids and includes an area of 27.1 ha. The thermal plume covered less than one-half the area of Sector B throughout most of the sampling season.

Although total annual precipitation for central Minnesota was near the forty-year average, dry weather throughout much of the summer resulted in below average river discharge for most of the sampling season (see Section 1.1). River discharges near 2,000 cfs in July and August had a tendency to concentrate fish closer to the main river channel.

Percentage composition, catch per unit effort, condition factors, and length-weight relationships were determined for predominant species in each sector. Comparisons with 1968-1979 data were also made.

2.1.2 MATERIALS AND METHODS

Equipment, sampling frequency, technique, and data computation were the same as the 1976-1979 studies. Sampling was conducted with pulsed direct-current electrofishing equipment (Figure 2.1-2). A five-meter, flat bottom boat equipped with a railing, one anode, and ten cathodes was utilized.

The power source was a 230-volt revolving field portable alternator. Current was maintained at five amperes at a rate of 60 pulses/second with a commercial transforming unit.

Paired shocking runs were conducted along opposing shorelines, as described in the 1975 report. Stunned fish were captured with one-inch mesh landing nets equipped with eight-foot insulated handles and placed in holding basins until completion of each sampling run. Elapsed shocking time was recorded for each run by a clock, which only tallied the seconds that the electrical field was energized.

Fish were measured to the nearest millimeter and weighed to the nearest 10 grams. Scales were collected from key scale areas from specimens over the entire length range for future age and rate of growth analysis.

Species catch per unit effort (cpe) was computed for both sectors on each sample date. Cpe's were determined for number (fish/hr.) and weight (kg/hr.) by dividing the total number and weight of fish collected per area by the elapsed shocking time for that area.

Fish were grouped into twenty-millimeter intervals, and mean total lengths and weights were computed for each group. Using these averages, condition factors were computed for the most abundant species with the formula:

$$K = \frac{W \times 10^5}{L^3},$$

where K is the condition factor, W is weight in grams, and L is total length in millimeters.

Individual fish measurements were used to compute length-weight relationships for the five dominant species. Data from both sectors were combined in this analysis. As with condition factors, all data were grouped and not segregated by sex. Metric measurements were transformed into logarithms, and simple linear regressions were computed. Length-weight formulas used to describe the data are presented in the following form:

$$\log W = \log a + b \log L,$$

where W is the weight in grams, L is the total length in millimeters, a is the W axis intercept, and b is the slope of the length-weight regression line.

2.1.3 RESULTS

A total of 3,154 fish was collected in the 1980 survey, 1,307 from Sector A and 1,847 from Sector B. Seventeen species from eight families were identified. Most of these species have been common components of previous electrofishing surveys (Table 2.1-1).

Percentage contribution to the total catch by number was computed for each species from 1968 through 1980 (Table 2.1-2 and Figures 2.1-2 through 2.1-5). Monthly catch per unit effort statistics were computed by number (fish/hr.) and weight (kg/hr.) for each species (Tables 2.1-3 and 2.1-4). Seasonal abundance patterns for the prominent species are presented in Figures 2.1-6 through 2.1-10. Comparisons of annual cpe are presented as fish/hr. and kg/hr. in Tables 2.1-5 and 2.1-6.

Length frequency distributions are presented at twenty-millimeter intervals in Figures 2.1-11 through 2.1-15. Condition factors were determined using these twenty-millimeter interval statistics for the five predominant

species (Table 2.1-7). A comparison of mean annual fish condition is presented in Table 2.1-8. Length-weight relationships were also computed for these species and are presented in Table 2.1-9.

2.1.4 DISCUSSION

Stream conditions throughout much of the 1980 sampling season were low, which tended to concentrate fish toward the center of the river. This concentrating factor may have contributed to high 1980 catch statistics.

Carp, shorthead redhorse, silver redhorse, white sucker, and smallmouth bass collectively comprised 96 percent of the total catch. Bowfin, green sunfish, and pumpkinseed were new additions to the species list since 1976.

Sector A had the following fish dominance ranking: shorthead redhorse, silver redhorse, carp, white sucker, and smallmouth bass. In Sector B the dominance ranking was shorthead redhorse, silver redhorse, carp, smallmouth bass, and white sucker.

Carp

Carp constituted 11.4 percent of the total catch by number in Sector A and 8.7 percent in Sector B. Mean annual abundance for carp was 38.0 fish/hr. in Sector A and 49.4 fish/hr. in Sector B (Table 2.1-5). These averages are extremely close to the 1979 figures, which were the lowest recorded during the five-year study period. Figure 2.1-6 illustrates that carp were attracted to the heated area of Sector B only during July. Catch rates for the two sectors were similar for the remainder of the year.

Mean condition factors for Sectors A and B fish were 1.25 and 1.36, respectively. Condition for this species was greater during 1976 through 1978. Competition from the increasingly abundant catostomid groups may be stressing the carp population and contributing to their abundance and condition decline.

The length-weight relationship for carp was:

$$\log W = -4.282 + 2.769 \log L.$$

This formula compares well with other North American studies cited in Carlander (1969), where similar regressions ranged from:

$$\log W = -3.982 + 2.664 \log L \text{ to}$$
$$\log W = -6.226 + 3.477 \log L.$$

Shorthead redhorse

Shorthead redhorse composed 51.0 percent of the catch by number in Sector A and 50.8 percent in Sector B. This species was more abundant in 1980 than in previous studies (Table 2.1-5). Mean annual abundance for shorthead redhorse was 168.7 fish/hr. for Sector A and 293.2 fish/hr. for Sector B. The strong 1976 year class, which contributed to the high cpe's in 1977 through 1979, was the major component in the 1979 catch. Fish from this year class had a length range of 350 to 400 mm (Figure 2.1-12). This cohort exhibited considerable growth since 1979, with an average length of 325 to 350 mm.

Shorthead redhorse were attracted to the thermally influenced area during April, May, and October (Figure 2.1-4). Catch rates for both sectors were similar throughout the summer months.

Average condition factors for shorthead redhorse were 1.11 for Sector A and 1.12 for Sector B. These means are higher than those computed for 1978 and 1979, but similar to 1976 and 1977 data.

The following length-weight relationship was developed for shorthead redhorse:

$$\log W = -4.545 + 2.836 \log L.$$

This regression compares well with those cited in Carlander (1969), which range from:

$$\log W - -3.20 + 2.83 \log L \text{ to}$$
$$\log W = -4.042 + 3.021 \log L.$$

Silver redhorse

Silver redhorse constituted 26.2 percent of the catch by number in Sector A and 29.2 percent in Sector B. These figures are similar to 1978 and 1979 data, but are several times greater than previous studies (Table 2.1-2).

Fish were collected at the rate of 84.0 fish/hr. in Sector A and 164.5 fish/hr. in Sector B. Figure 2.1-8 reveals that catch rates in Sector B were substantially higher than those in Sector A during all months except May and late July. Increased cpe's in 1978, 1979, and 1980 are attributed to the 1976 year class, which comprised a majority of the silver redhorse catch.

Condition factors for Sector A and Sector B fish compared well. Mean condition factors for Sector A and B fish were 1.14 and 1.15, respectively. These means are higher than those computed in 1978 and 1979.

Silver redhorse had a length-weight relationship:

$$\log W = -4.634 + 2.878 \log L.$$

This regression closely approximates the formula reported in Carlander (1969), which was:

$$\log W = -4.263 + 3.124 \log L.$$

White sucker

White sucker comprised 4.8 percent of the catch by number in Sector A and 2.9 percent in Sector B (Table 2.1-2). Catch per unit effort statistics (Table 2.1-5) have been quite stable since 1978. White sucker was collected at the rate of 16.1 fish/hr. in Sector A and 15.5 fish per hour in Sector B. The 1976 year class comprised a majority of the white sucker catch. Figure 2.1-9 indicates that white sucker had a preference for warm water in April and May, but avoided this area in August, September, and October.

Mean condition factors for Sector A and Sector B were 1.15 and 1.18, respectively. These indicies are similar to those computed since 1977. They do, however, show some increase over 1978 data but not nearly as high as 1976. As with other catostomid members, white sucker had excellent reproductive success in 1976 and subsequent high survival rates, which have imposed slight limitations on the population through competition for food and habitat.

White sucker had a length-weight relationship of:

$$\log W = -5.012 + 3.034 \log L.$$

This regression compares well with the range reported in Carlander (1969) of:

$$\log W = -2.822 + 2.2303 \log L \text{ to}$$
$$\log W = -5.395 + 3.223 \log L.$$

Smallmouth bass

Smallmouth bass composed 1.6 percent of the total catch by number in Sector A and 4.8 percent in Sector B (Table 2.1-2). Annual cpe data (Table 2.1-5) indicate a substantial abundance decrease in the upstream sector. Fish were collected at a rate of 5.3 fish/hr. in Sector A and 29.4 fish/hr. in Sector B. Natural attrition and increased avoidance to the electrofishing equipment (due to age) by the strong 1976 year class fish are believed to be responsible for the abundance decline of this species. Catch rates for this species now approximate those of 1976, prior to recruitment of the dominant 1976 year class.

Seasonal abundance, illustrated in Figure 2.1-10, reveals a preference for the warm water of Sector B in May, June, September, and October. During the remainder of the study similar catch rates were obtained in both sectors.

The mean condition factor for smallmouth bass was 1.48 for Sector A and 1.43 for Sector B. Average condition of these fish was higher than those of 1978 and 1979. However, these fish were leaner for a given length than those collected during 1976 and 1977.

The length-weight relationship for smallmouth bass was:

$$\log W = -5.005 + 3.069 \log L.$$

This formula compares well with the range of regressions reported in Carlander (1977):

$$\log W = -4.177 + 2.701 \log L \text{ to}$$
$$\log W = -5.841 + 3.372 \log L.$$

Walleye

As in most years, walleye comprised a very small portion of the 1980 catch. Their percentage contribution by number was 0.6 percent in Sector A and 0.3 percent in Sector B.

Catch per unit effort for walleye was 2.3 fish/hr. in Sector A and 2.1 fish/hr. in Sector B (Table 2.1-5). This species' preference for deeper water, which is not efficiently electrofished, contributes to the paucity of walleye in this and previous studies. Insufficient numbers of walleye were collected in 1980 to warrant computation of condition factors or length-weight regressions.

Miscellaneous Species

Miscellaneous species comprised 4.4 Percent of the total catch in Sector A and 3.3 percent in Sector B (Table 2.1-2). Their mean annual catch rate was 14.8 fish/hr. in Sector A and 23.7 fish/hr. in Sector B (Table 2.1-5). The numerical dominance ranking for the miscellaneous catch in Sector A was: northern Pike, northern hogsucker, black crappie, rock bass, greater redhorse, burbot, and black bullhead. Sector B had the following dominance ranking: northern hogsucker, rock bass, black bullhead, black crappie, northern pike, greater redhorse, largemouth bass, bowfin, pumpkinseed, and green sunfish. As in earlier studies, the warm water of Sector B attracted uncommon species, especially centrachids and ictalurids.

2.1.5 SUMMARY

1. The 1980 electrofishing study was conducted with a pulsed DC unit at four-week intervals from April through October.

2. A total of 3,154 fish were collected from 17 species and 8 families.

3. Sector A had the following dominance ranking: shorthead redhorse, silver redhorse, carp, white sucker, and smallmouth bass. In Sector B the dominance ranking was: shorthead redhorse, silver redhorse, carp, smallmouth bass, and white sucker.

4. Catch per unit effort was high-similar to 1978 and 1979. Abundance for all major species, except shorthead redhorse, has declined since 1978. These reductions are primarily a result of the natural attrition of the exceptionally strong 1976 year classes.

5. Catch rates (cpe) were generally higher for the dominant species in Sector B. This condition also occurred in 1976 through 1979, suggesting a preference for warmer water by most species. This would be expected, because throughout most of the year, ambient temperatures are below the optimum or desired temperature range of most area species.

6. Condition factors were computed for the five dominant species. These indices indicate that:

   a. In general, 1980 fish in both sectors have the same weight for a given length.

b. All species showed improved physical condition over 1979.

7. Length-weight relationships computed for the five dominant species compared well with regressions reported by Carlander (1969 and 1977).

2.1.6 LITERATURE CITED

Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology, Volume I, 752 pp. The Iowa State University Press, Ames, Iowa.

Carlander, K.D. 1977. Handbook of Freshwater Fishery Biology, Volume II, 421 pp. The Iowa State University Press, Ames, Iowa.

Figure 2.1-1. 1980 Monticello Electrofishing Areas.

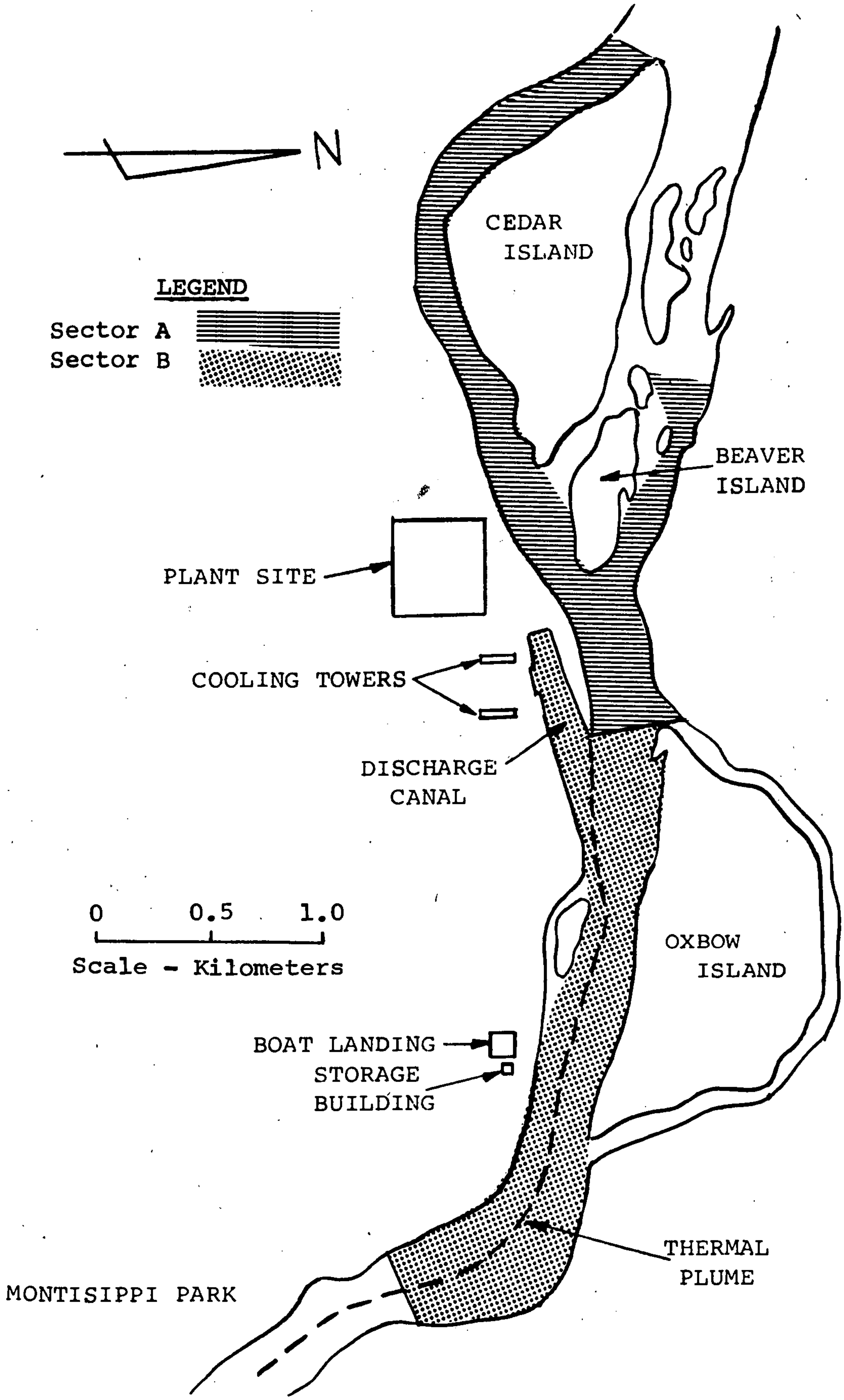


Figure 2.1-2

ELECTROFISHING BOAT (5m.)

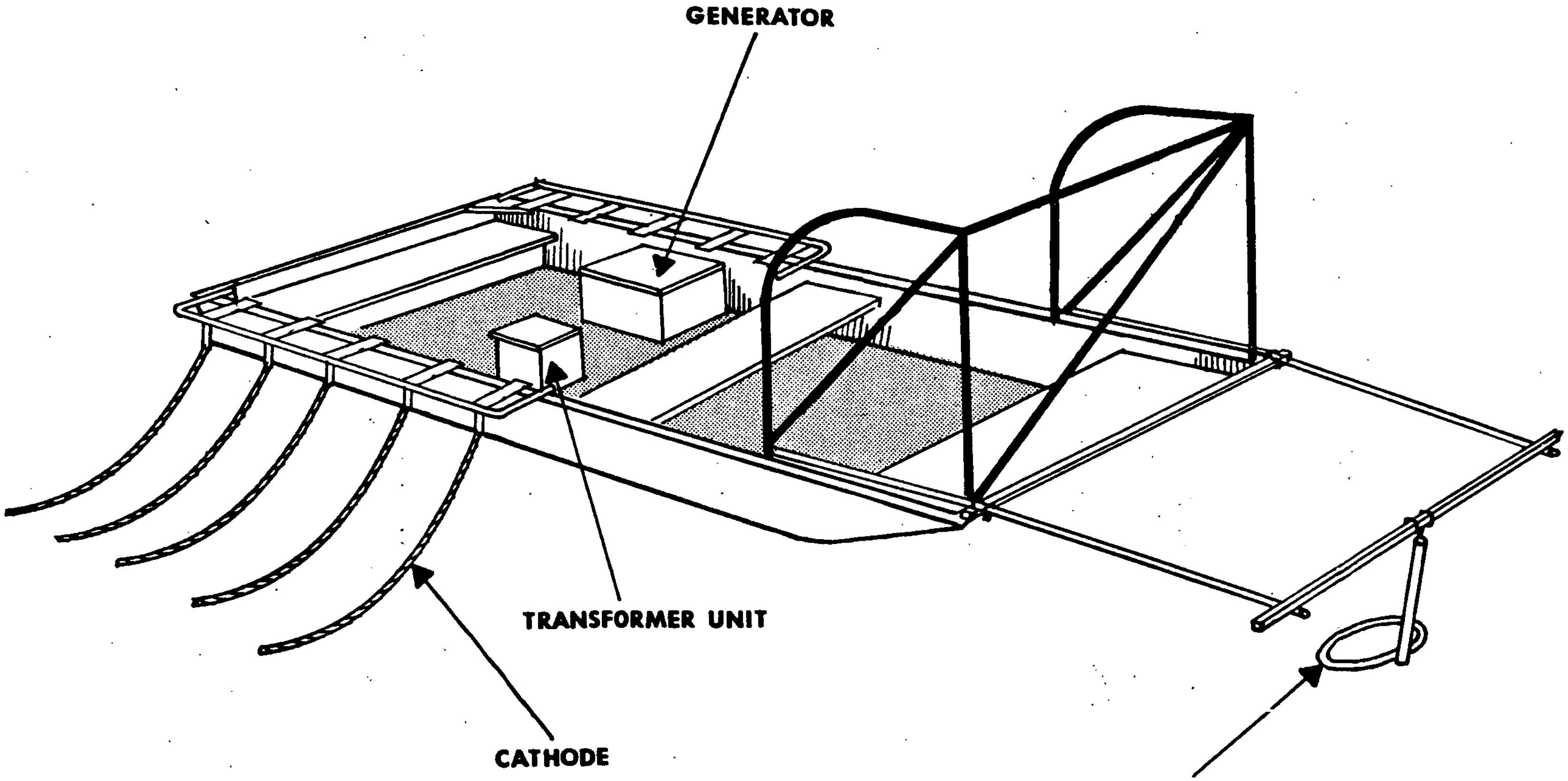


Figure 2.1-3

OVERALL FISH CATCH

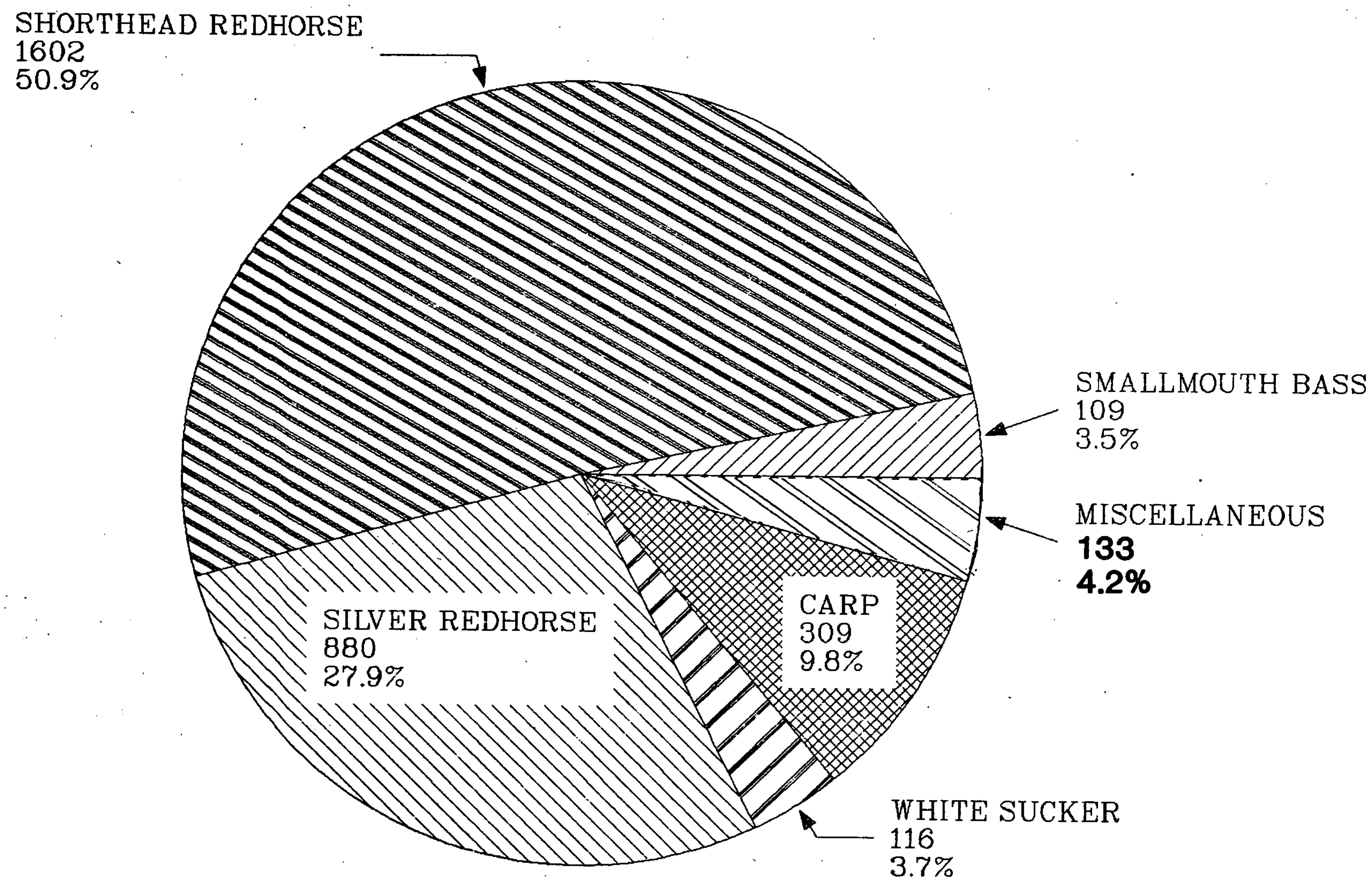


Figure 2.1-4

SECTOR 1 FISH CATCH

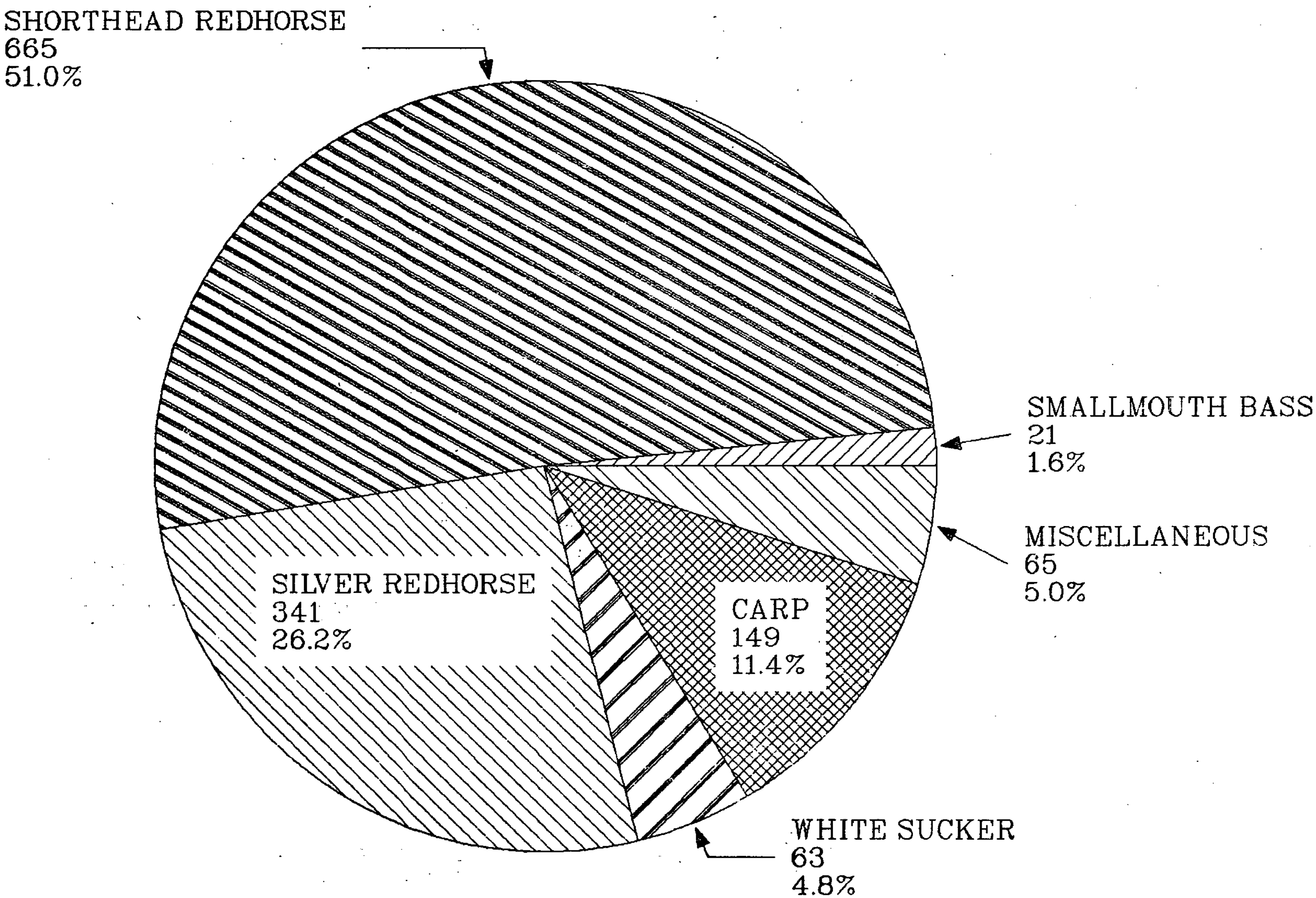
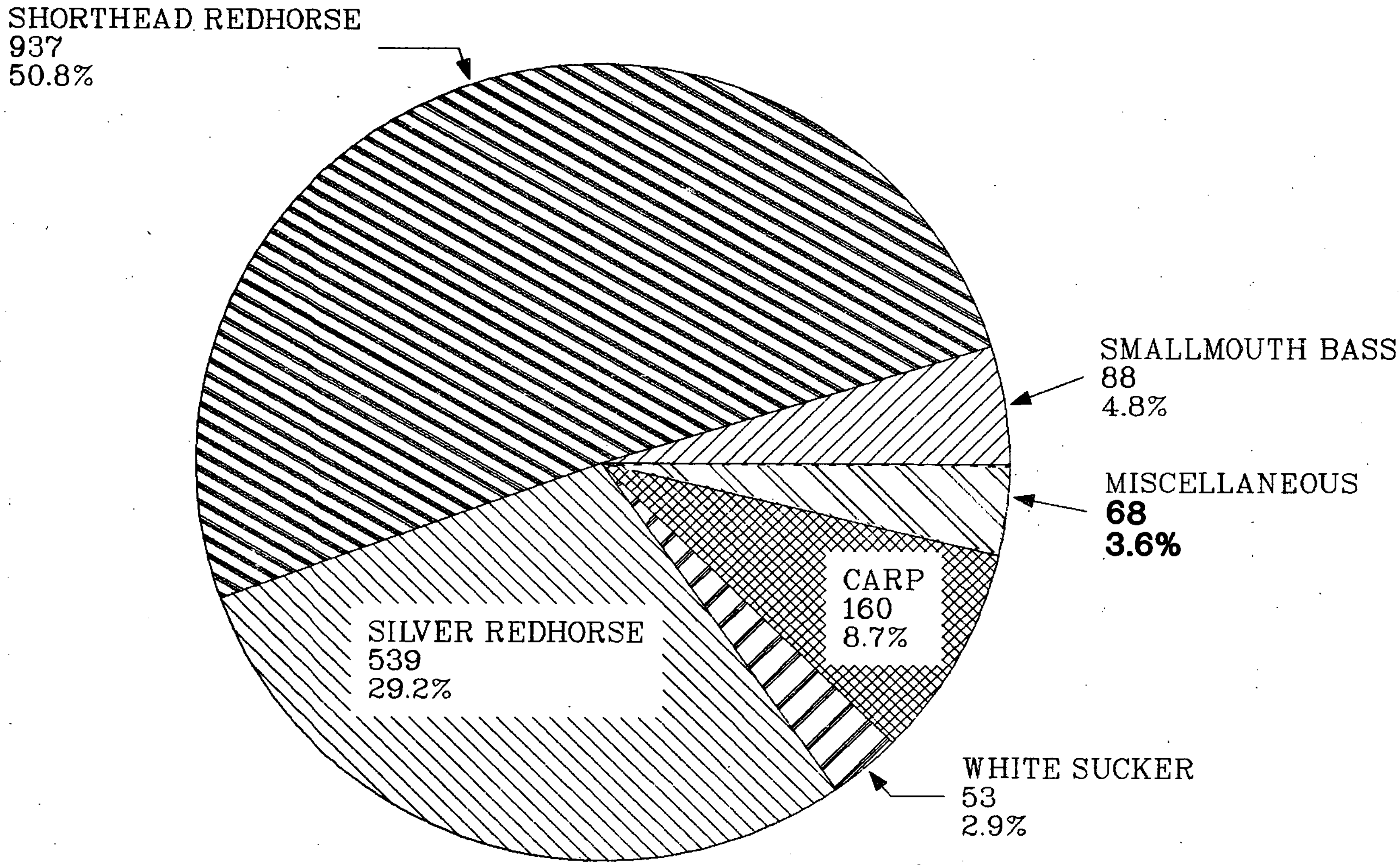
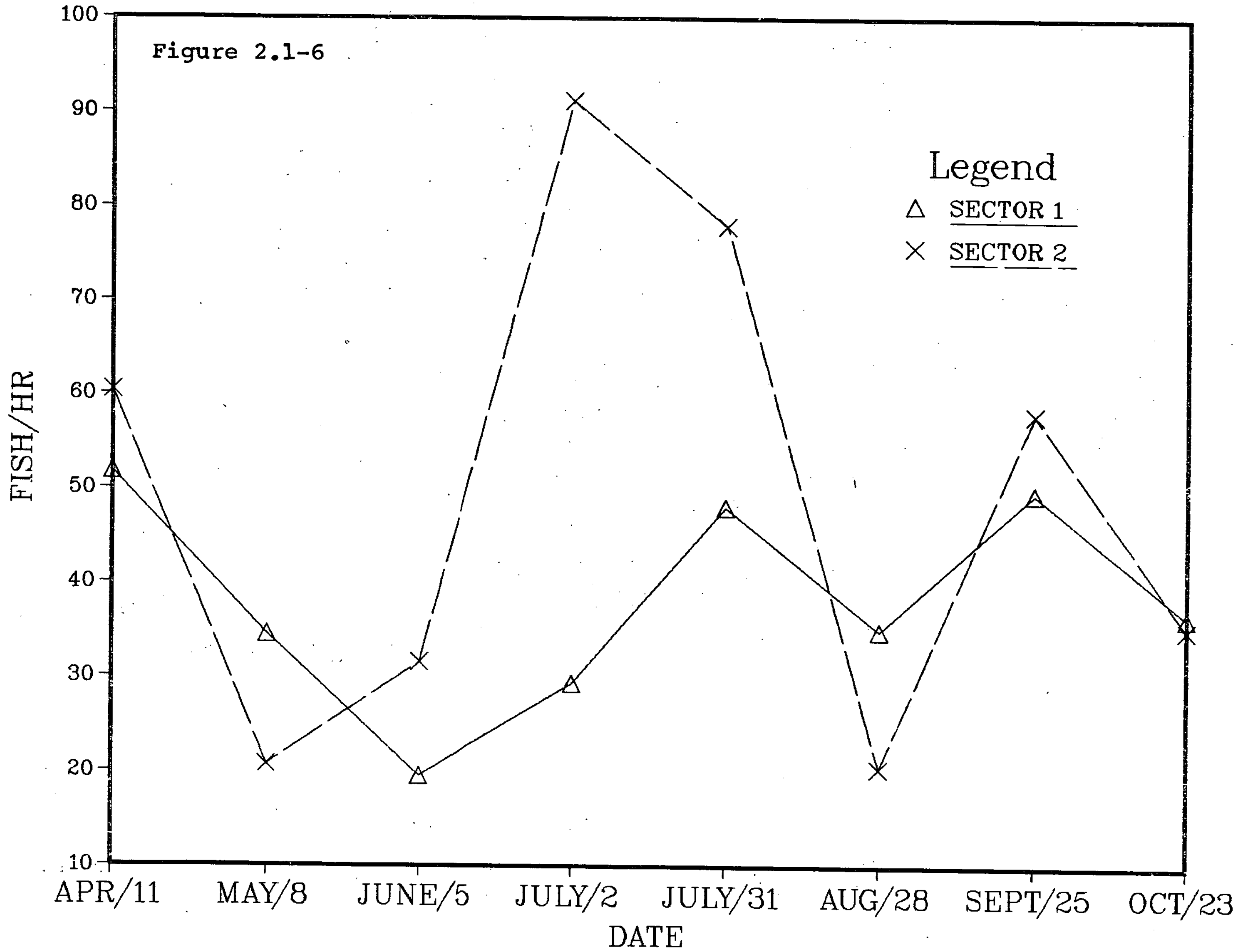


Figure 2.1-5

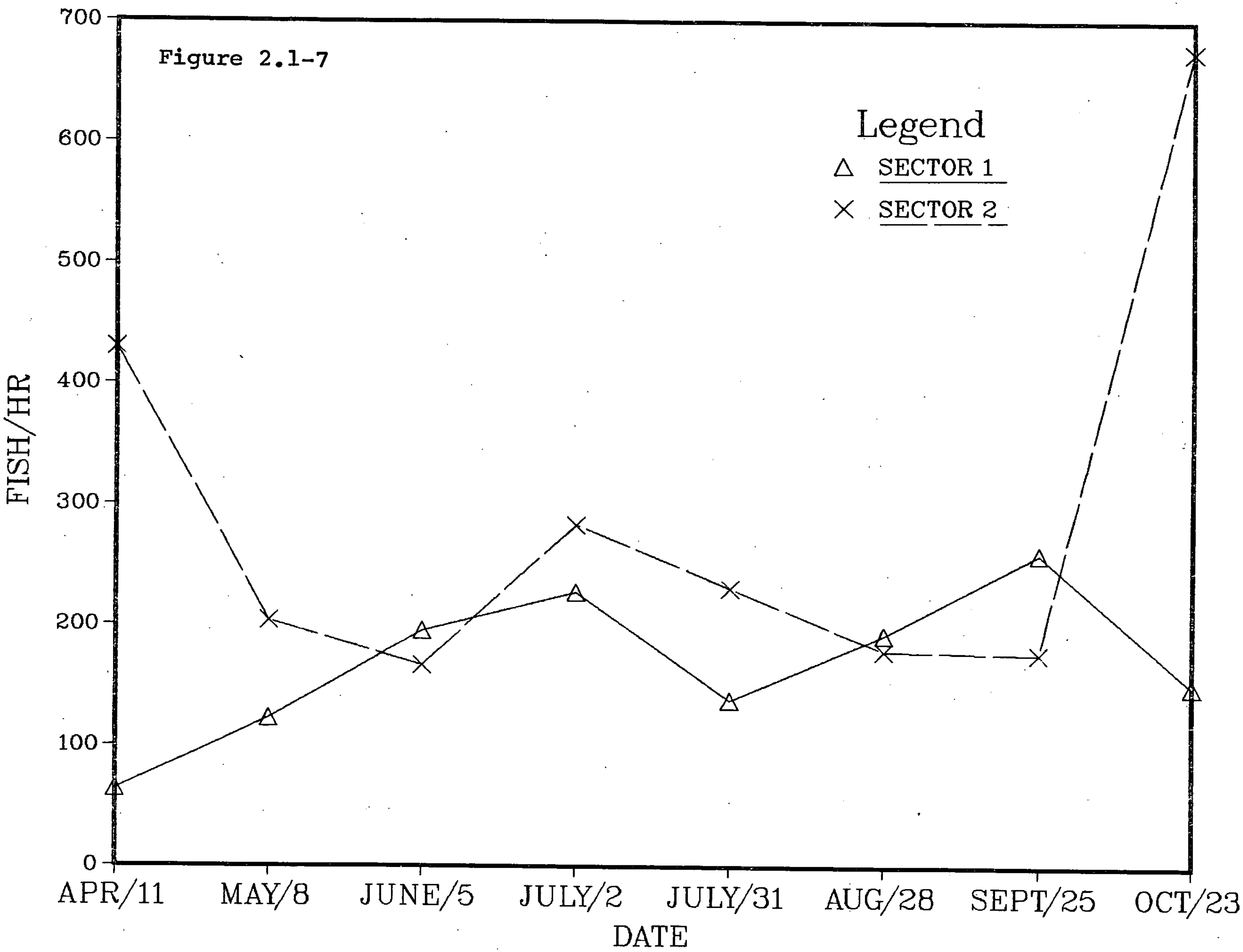
SECTOR 2 FISH CATCH



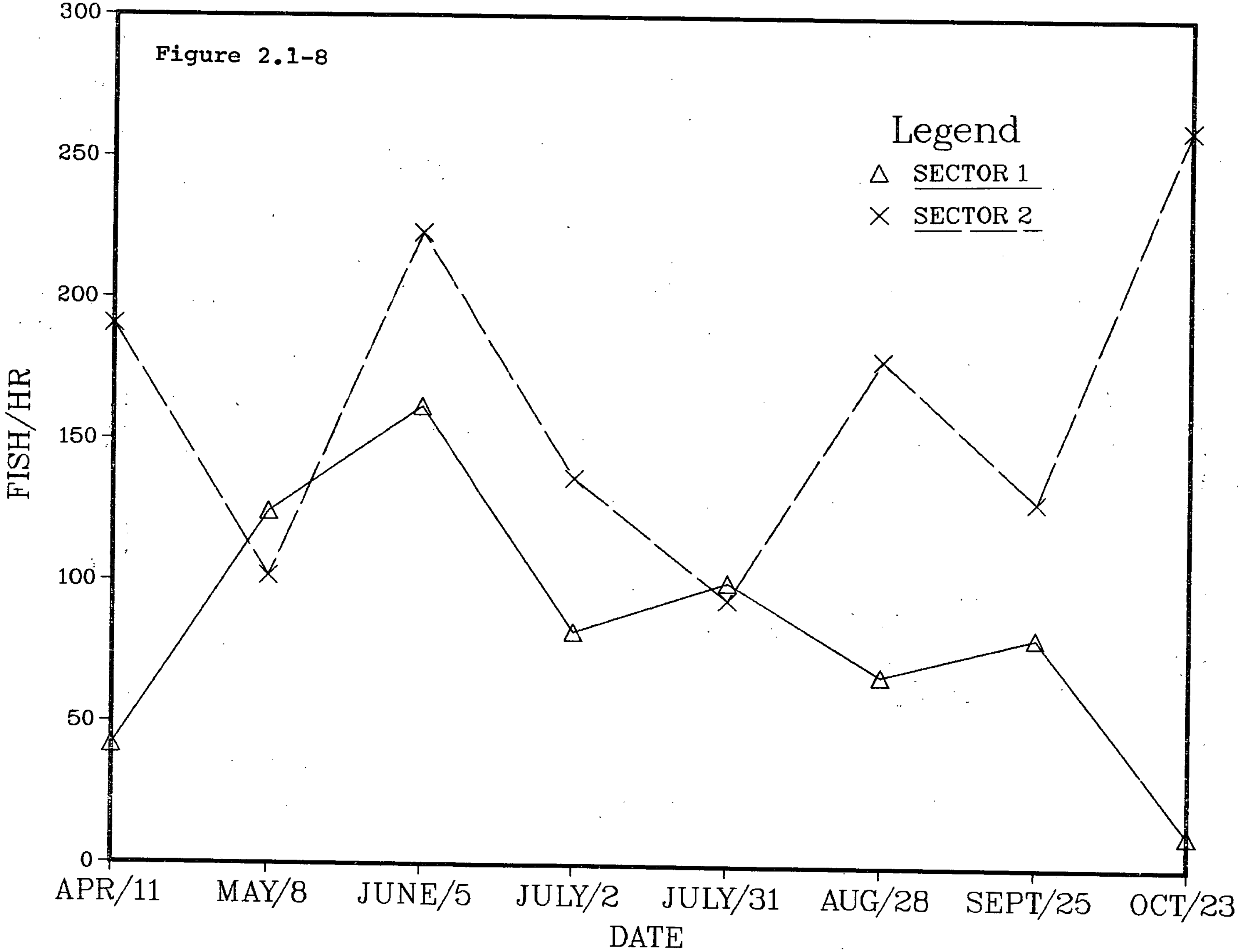
1980 MONTICELLO ELECTROFISHING CPE (fish/hr) CARP



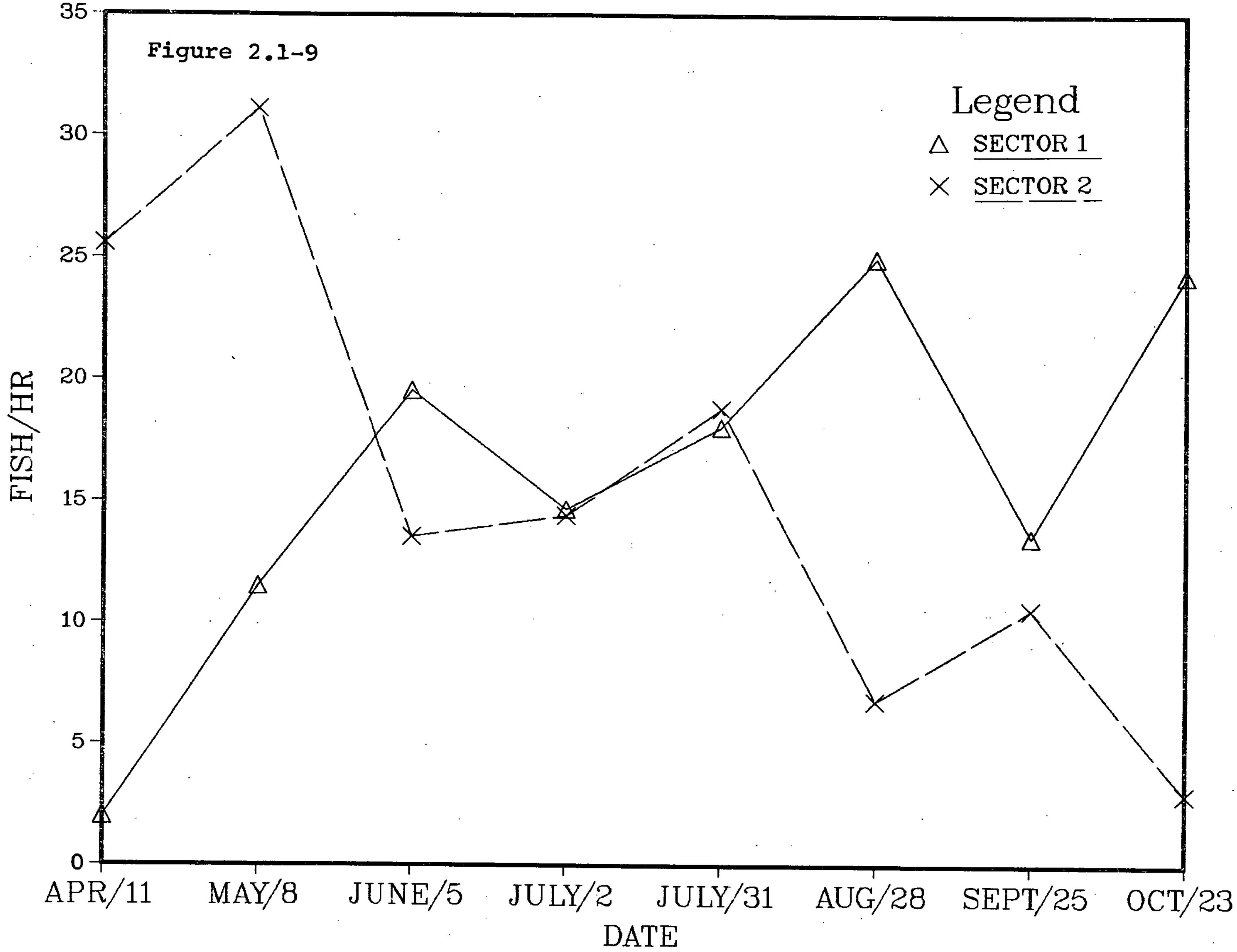
1980 MONTICELLO ELECTROFISHING CPE (fish/hr) SHORTHEAD REDHORSE



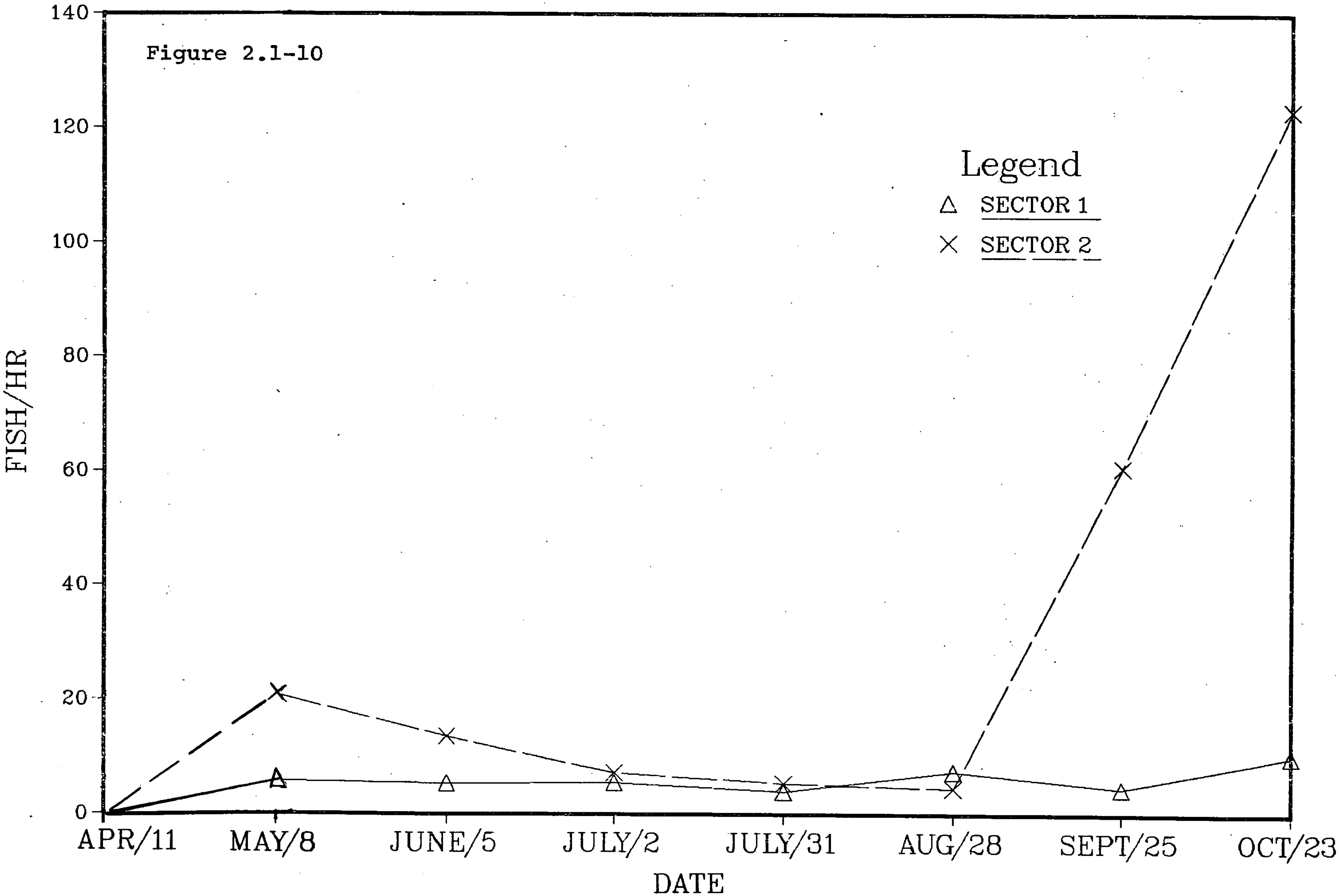
1980 MONTICELLO ELECTROFISHING CPE (fish/hr) SILVER REDHORSE



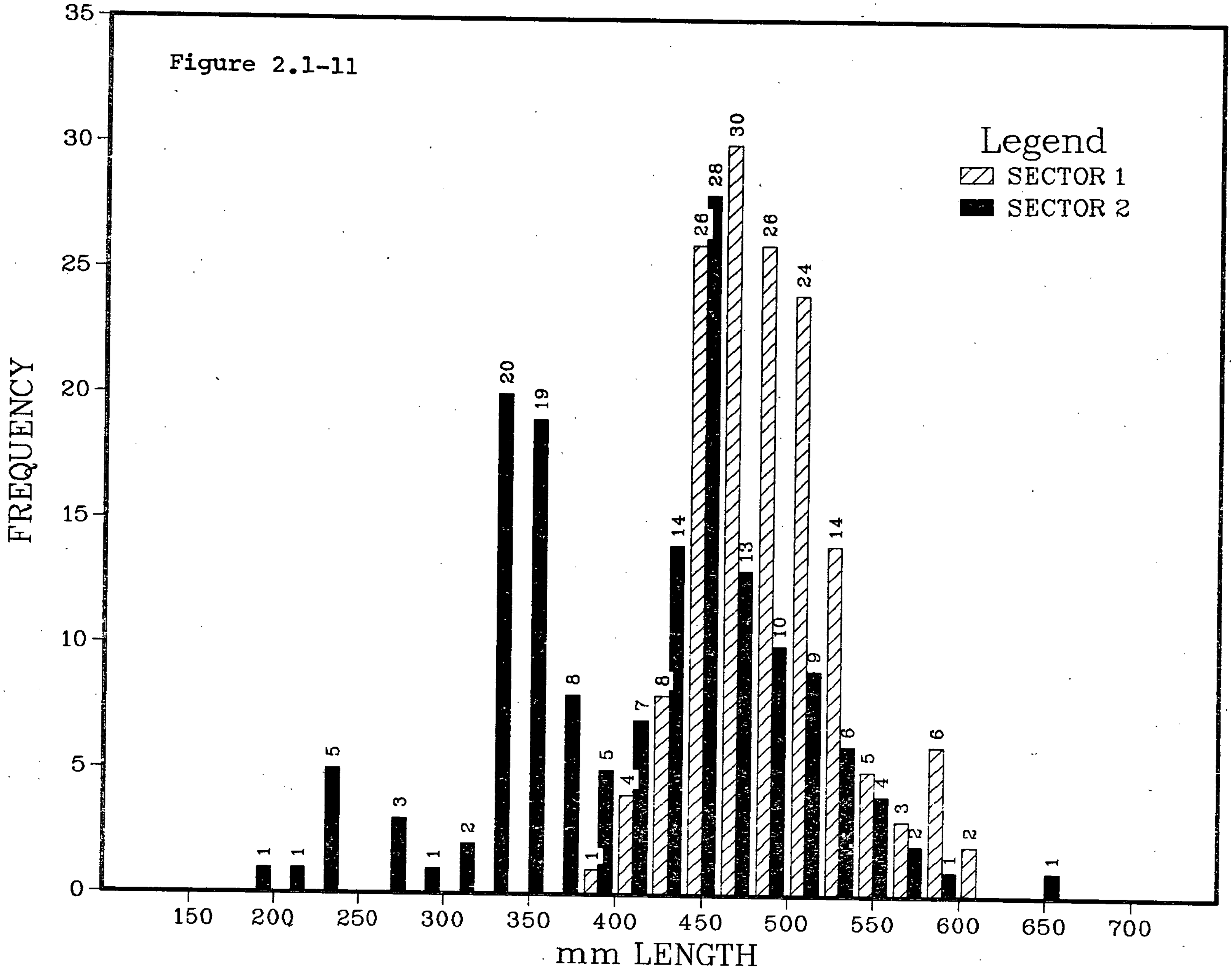
1980 MONTICELLO ELECTROFISHING CPE (fish/hr) WHITE SUCKER



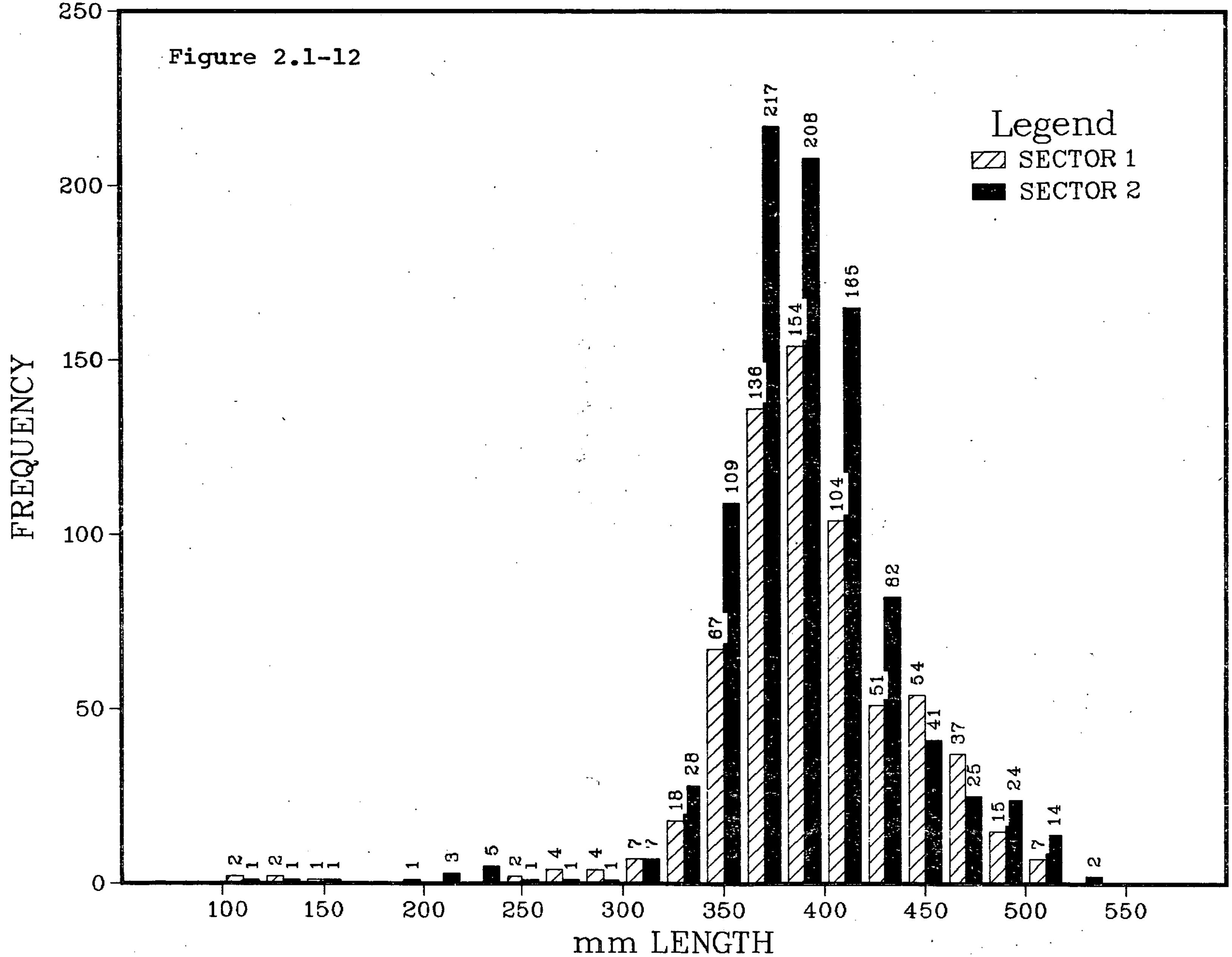
1980 MONTICELLO ELECTROFISHING CPE (fish/hr)
SMALLMOUTH BASS



1980 MONTICELLO ELECTROFISHING LENGTH FREQUENCY CARP



1980 MONTICELLO ELECTROFISHING LENGTH FREQUENCY SHORTHEAD REDHORSE



1980 MONTICELLO ELECTROFISHING LENGTH FREQUENCY SILVER REDHORSE

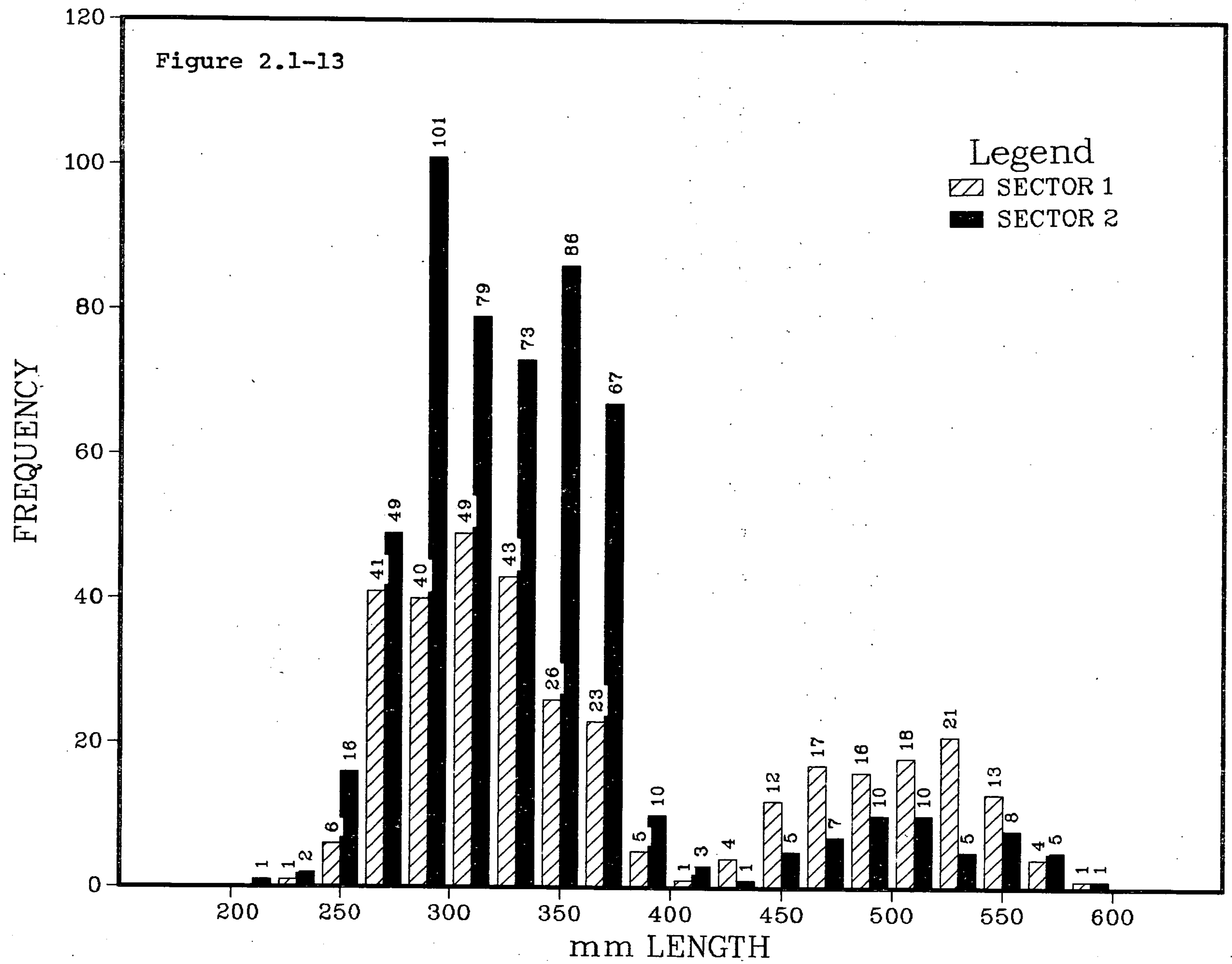
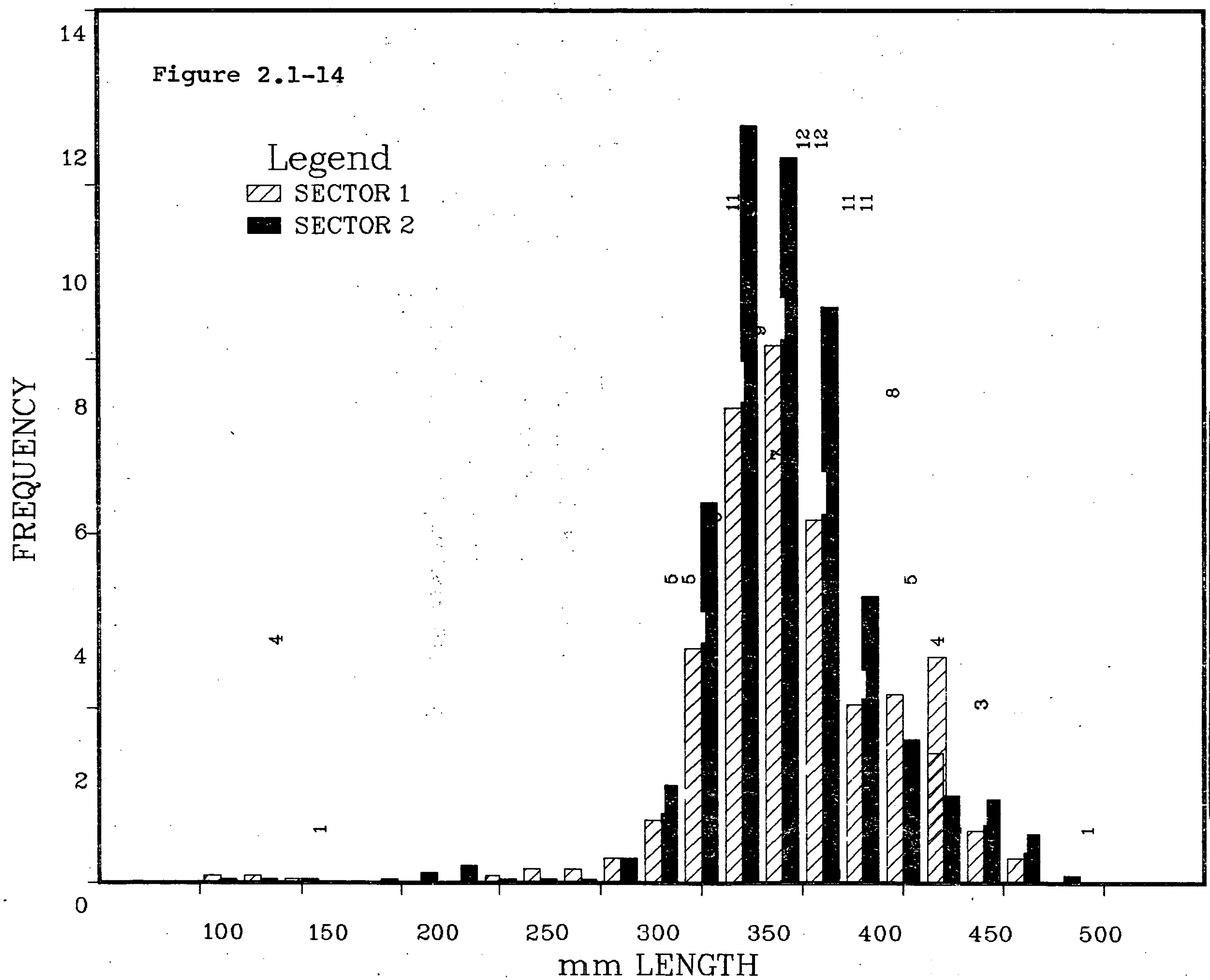


Figure 2.1-13

1980 MONTICELLO ELECTROFISHING LENGTH FREQUENCY WHITE SUCKER



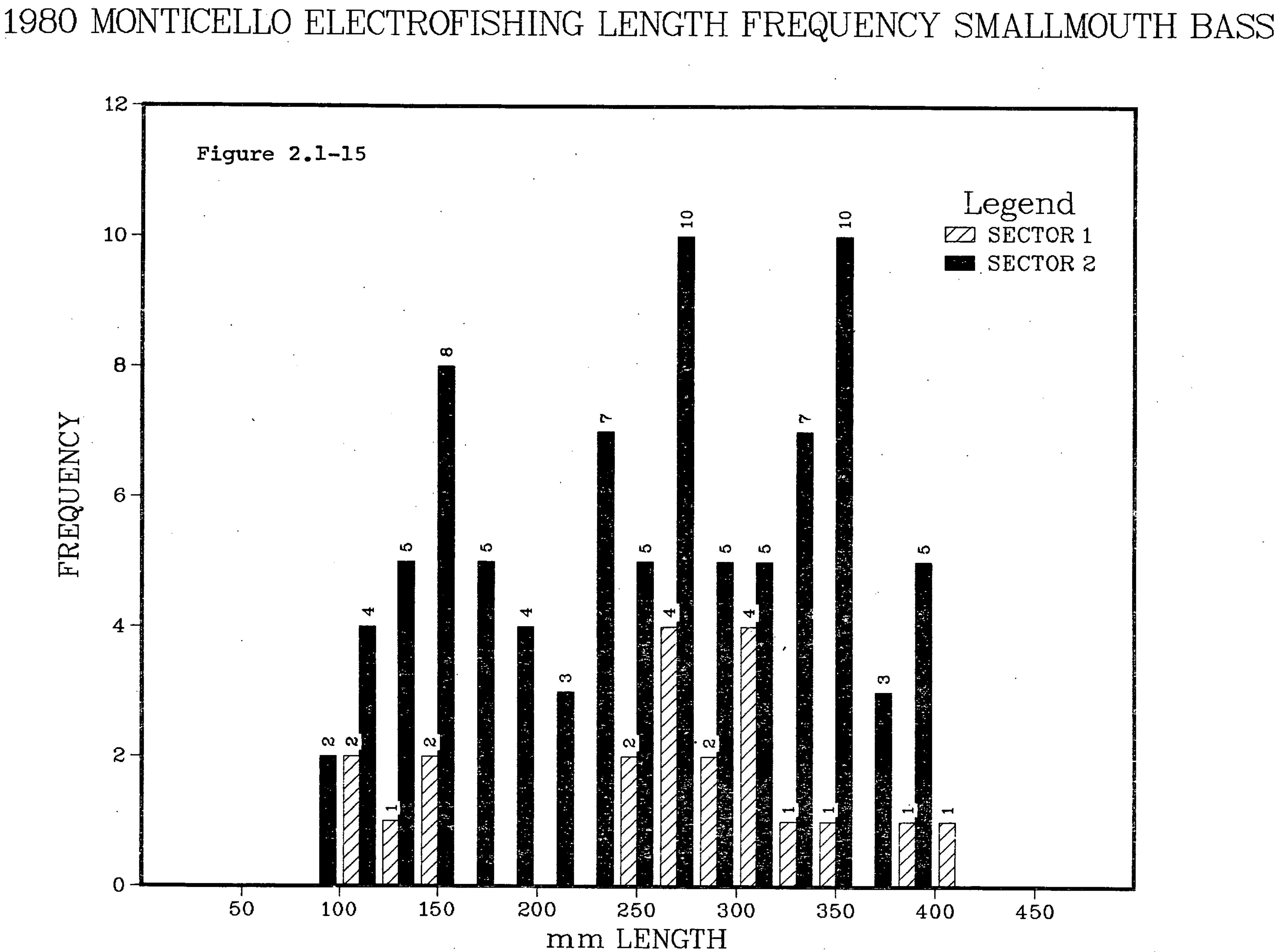

1980 MONTICELLO ELECTROFISHING LENGTH FREQUENCY SMALLMOUTH BASS
Figure 2.1-15
Legend
SECTOR 1
SECTOR 2
FREQUENCY
mm LENGTH

Table 2.1-1. Monticello Electrofishing Species List.

Species	1976	1977	1978	1979	1980
Bowfin *(amia calva)*					x
Cisco *(Coregonus artedi)*				x	
Northern pike *(Esox lucius)*	x	x	x	x	x
Muskellunge *(Esox masquinongy)*	x				
Shorthead redhorse *(Moxostoma macrolepidotum)*	x	x	x	x	x
Silver redhorse *(Moxostoma anisurum)*	x	x	x	x	x
Greater redhorse *(Moxostoma valenciennesi)*			x	x	x
White sucker *(Catostomus commersoni)*	x	x	x	x	x
Bigmouth buffalo *(Ictiobus cyprinellus)*	x			x	
Northern hogsucker *(Hypentelium nigricans)*	x	x	x	x	x
Carp *(Cyprinus carpio)*	x	x	x	x	x
Black bullhead *(Ictalurus melas)*	x	x	x	x	x
Yellow bullhead *(Ictalurus natalis)*	x	x	x	x	
Brown bullhead *(Ictalurus nebulosus)*			x		
Burbot *(Lota lota)*				x	x
Smallmouth bass *(Micropterus dolomieui)*	x	x	x	x	x
Largemouth bass *(Micropterus salmoides)*		x		x	x
Rock bass *(Ambloplites rupestris)*	x	x	x	x	x
Bluegill *(Lepomis macrochirus)*		x	x	x	
Black crappie *(Pomoxis nigromaculatus)*	x	x	x	x	x
White crappie *(Pomoxis annularis)*			x		
Pumpkinseed *(Lepomis gibbosus)*					x
Green sunfish *(Lepomis cyanellus)*					x
Walleye *(Stizostedium vitreum)*	x	x	x	x	x
Yellow perch *(Perca flavescens)*			x		

Table 2.1-2. 1968-1980 Monticello Electrofishing Percent of Total Catch by Number.

	Carp	Shorthead redhorse	Silver redhorse	White sucker	Smallmouth bass	Walleye	Misc
Sector A							
1968	50.7	34.5	4.4	2.7	1.5	4.8	1.4
1969	29.4	48.6	7.4	4.5	1.8	2.0	6.3
1971	25.3	36.9	9.1	13.1	7.6	7.1	0.9
1972	45.1	26.1	9.1	4.1	7.0	1.1	7.5
1973	39.9	34.8	13.0	4.9	2.0	0.7	4.7
1974	44.3	20.3	16.7	9.2	1.5	0.1	7.9
1975	53.5	27.0	9.3	3.7	0.9	0.5	5.1
1976	41.0	36.4	12.3	3.5	3.4	1.4	2.0
1977	19.6	40.3	12.7	3.4	20.4	0.8	2.8
1978	15.4	32.2	26.4	5.0	15.4	0.5	5.1
1979	15.2	43.4	29.5	5.5	4.3	0.2	2.1
1980	11.4	51.0	26.2	4.8	1.6	0.6	4.4
Sector B							
1968	34.3	58.9	2.9	3.0	0.4	0.3	0.3
1969	17.3	65.1	9.6	4.8	2.0	1.2	0.4
1971	27.2	35.9	7.8	6.3	12.6	6.8	3.4
1972	38.4	33.4	8.2	3.3	5.9	2.0	8.8
1973	31.2	41.3	11.5	4.0	2.9	1.2	7.9
1974	47.0	22.6	15.2	6.4	0.9	0.6	6.4
1975	40.8	37.6	10.8	1.9	3.8	1.3	3.8
1976	32.4	40.1	12.6	1.6	9.3	1.5	2.5
1977	21.2	33.1	15.3	2.1	22.8	1.0	4.6
1978	11.3	30.3	31.3	3.8	16.5	0.6	6.2
1979	9.4	49.7	26.9	4.0	5.3	0.3	4.5
1980	8.7	50.8	29.2	2.9	4.8	0.3	3.3

Table 2.1-3 1980 Monticello Electrofishing Catch per Unit Effort by Number (fish/hr).

	Carp	Shorthead redhorse	Silver redhorse	White sucker	Smallmouth bass	Walleye	Black crappie	Misc	Total
Sector A									
4/11	51.7	63.7	41.8	2.0	0	0	8.0	13.9	181.1
5/8	34.5	122.7	124.6	11.5	5.8	0	0	7.6	306.7
6/5	19.5	195.5	161.7	19.5	5.3	0	0	9.0	410.5
7/2	29.3	227.3	82.5	14.7	5.5	1.8	7.3	23.7	392.1
7/31	48.1	138.3	100.2	18.0	4.0	2.0	4.0	8.0	322.6
8/25	35.0	192.4	67.5	25.0	7.5	10.0	5.0	12.5	354.9
9/25	49.6	259.4	81.2	13.5	4.5	4.5	0	15.8	428.5
10/24	36.5	150.1	12.2	24.3	10.1	0	0	4.2	237.4
Mean	38.0	168.7	84.0	16.1	5.3	2.3	3.0	11.8	329.2
Sector B									
4/11	60.4	430.0	190.6	25.6	0	0	0	0	706.6
5/8	20.7	203.3	101.7	31.1	20.8	0	0	6.2	383.8
6/5	31.6	166.9	223.3	13.5	13.5	2.3	9.0	4.5	465.3
7/2	91.2	283.2	136.8	14.4	7.2	0	0	9.6	542.4
7/31	78.0	231.2	94.1	18.8	5.4	0	0	18.8	446.3
8/25	20.4	179.1	179.1	6.8	4.5	0	0	15.9	405.8
9/25	58.0	176.7	129.2	10.5	60.7	0	2.6	55.4	493.1
10/24	35.2	674.8	261.1	2.9	123.2	14.7	0	67.5	1179.4
Mean	49.4	293.2	164.5	15.5	29.4	2.1	1.5	22.2	577.8

Table 2.1-4 1980 Monticello Electrofishing Catch per Unit Effort by Weight (Kg/hr).

	Carp	Shorthead redhorse	Silver redhorse	White sucker	Smallmouth bass	Walleye	Black crappie	Misc	Total
Sector A									
4/11	73.6	43.1	22.2	0.8	0	0	0.7	7.4	147.8
5/8	49.1	76.8	106.2	7.8	1.4	0	0	2.8	244.2
6/5	30.5	115.7	104.8	11.4	0.9	0	0	3.7	267.0
7/2	45.0	139.3	54.5	8.0	1.6	0.5	1.0	6.4	256.3
7/31	66.0	97.3	49.3	11.4	1.4	0.1	1.3	3.8	230.7
8/25	52.8	142.0	50.9	14.9	1.1	2.1	1.0	6.5	271.3
9/25	70.5	194.7	75.5	8.1	1.6	0.4	0	1.6	352.5
10/24	68.7	109.3	6.7	11.6	6.3	0	0	3.3	205.9
Mean	57.0	114.8	58.8	9.3	1.8	0.4	0.5	4.4	247.0
Sector B									
4/11	80.5	252.5	58.3	15.1	0	0	0	0	406.4
5/8	23.9	124.4	53.8	18.2	6.5	0	0	9.1	235.9
6/5	37.8	101.7	101.0	9.2	3.8	0.5	1.7	0	255.7
7/2	66.1	164.2	70.8	8.5	2.4	0	0	0	312.0
7/31	64.7	152.6	41.6	10.9	0.1	0	0	2.6	272.5
8/25	18.6	137.4	96.2	4.1	1.7	0	0	4.6	262.7
9/25	66.8	122.3	83.6	6.2	10.6	0	0.3	12.0	301.8
10/24	34.1	520.3	136.4	1.5	52.0	6.3	0	19.0	769.6
Mean	49.1	196.9	80.2	9.2	9.6	0.9	0.3	5.9	352.1

Table 2.1-5 1976-1980 Monticello Electrofishing Catch per Unit Effort by Number (fish/hr).

	Carp	Shorthead redhorse	Silver redhorse	White sucker	Smallmouth bass	Walleye	Misc	Total
Sector A								
1976	67.4	59.9	20.3	5.8	5.7	2.3	3.2	164.6
1977	61.3	126.1	39.7	10.5	63.7	2.4	8.9	312.6
1978	51.6	108.1	88.5	16.6	51.7	1.7	17.2	335.5
1979	49.3	140.9	95.8	17.9	13.9	0.5	6.7	325.0
1980	38.0	168.7	84.0	16.1	5.3	2.3	14.8	329.2
Sector B								
1976	77.0	95.2	29.9	3.8	22.2	3.5	6.0	231.6
1977	79.3	123.8	57.2	7.8	85.2	3.8	17.3	374.4
1978	67.7	181.7	187.6	23.0	99.0	3.3	37.3	599.7
1979	43.0	226.8	122.6	18.3	24.3	1.3	20.3	456.6
1980	49.4	293.2	164.5	15.5	29.4	2.1	23.7	577.8
*5 yr. $\bar{x}$	58.4	152.4	89.0	13.5	40.0	2.3	15.5	370.7

*For both sectors combined.

Table 2.1-6. 1976-1980 Monticello Electrofishing Catch per Unit Effort by Weight (kg/hr).

	Carp	Shorthead redhorse	Silver redhorse	White sucker	Smallmouth bass	Walleye	Misc	Total
Sector A								
1976	97.5	46.1	23.3	4.2	1.6	0.6	1.7	185.0
1977	103.6	109.4	64.4	5.7	13.0	1.1	4.6	301.8
1978	74.8	70.2	47.2	6.0	9.2	0.3	3.9	211.6
1979	66.3	91.8	57.1	8.1	3.2	0.4	5.6	232.5
1980	57.0	114.8	58.8	9.3	1.8	0.4	4.9	247.0
Sector B								
1976	75.2	89.0	34.4	2.9	4.5	1.4	1.4	209.3
1977	99.7	85.7	61.9	11.7	15.6	2.1	2.5	279.2
1978	86.0	106.2	60.4	7.0	17.4	2.6	6.0	285.5
1979	53.1	145.5	69.8	7.9	6.0	0.6	7.6	290.5
1980	49.1	196.9	80.2	9.2	9.6	0.9	6.2	352.1
*5 yr. $\bar{x}$	76.2	105.6	55.8	7.2	8.2	1.0	4.4	258.4

*For both sectors combined.

Table 2.1-7 1980 Condition Factor for Sector A and B.

Length	Carp A	Carp B	Shorthead redhorse A	Shorthead redhorse B	Silver redhorse A	Silver redhorse B	White sucker A	White sucker B	Smallmouth bass A	Smallmouth bass B
100			1.32	1.19					1.71	1.40
120			1.24	1.28			1.08		1.22	1.39
140			1.16	1.23			1.09		1.41	1.37
160										1.21
180		1.51		1.31						1.23
200		1.91		1.00		1.28				1.25
220		1.71		1.16	1.20	1.29				1.49
240			1.19	1.18	1.18	1.25			1.48	1.33
260		1.46	1.19	1.27	1.16	1.23			1.28	1.48
280		1.45	1.07	1.17	1.17	1.19			1.32	1.57
300		1.40	1.15	1.20	1.16	1.17	1.17	1.21	1.35	1.45
320		1.37	1.09	1.06	1.14	1.12	1.19	1.32	1.79	1.48
340		1.29	1.08	1.07	1.11	1.11	1.21	1.19	1.55	1.60
360		1.27	1.10	1.09	1.11	1.08	1.22	1.24		1.58
380	1.18	1.19	1.08	1.09	1.10	1.07	1.15	1.26	1.53	1.61
400	1.30	1.31	1.07	1.08	1.14	1.08	1.14	1.17	1.66	
420	1.26	1.27	1.05	1.06	1.14	1.20	1.13	0.97		
440	1.29	1.25	1.03	1.02	1.19	1.17	1.13			
460	1.30	1.23	1.02	1.02	1.14	1.15				
480	1.27	1.24	1.00	1.01	1.12	1.14		1.04		
500	1.27	1.25	0.95	1.06	1.14	1.09				
520	1.23	1.22		0.95	1.08	1.05				
540	1.16	1.30			1.11	1.06				
560	1.31	1.36			1.05	1.13				
580	1.23	1.33			1.17	1.06				
600	1.19									
620										
640		1.20								
660										
Mean	1.25	1.36	1.11	1.12	1.14	1.15	1.15	1.18	1.48	1.43

Table 2.1-8 Annual Average Condition Factor for 1976-1980 Monticello Electrofishing.

	Carp		Shorthead redhorse		Silver redhorse		White sucker		Smallmouth bass	
	A	B	A	B	A	B	A	B	A	B
1976	1.31	1.37	1.10	1.04	1.18	1.18	1.30	1.15	1.47	1.59
1977	1.35	1.35	1.14	1.15	1.19	1.20	1.17	1.14	1.55	1.43
1978	1.35	1.33	1.00	0.99	1.10	1.09	1.14	1.08	1.31	1.31
1979	1.27	1.28	0.99	0.97	1.04	1.05	1.12	1.19	1.39	1.29
1980	1.25	1.36	1.11	1.12	1.14	1.15	1.15	1.18	1.48	1.43

Table 2.1-9 1980 Length-Weight Relationships for Fish Collected via Monticello Electrofishing (Length in Millimeters and Weight in Grams).

Species	Log Formula	Arithmetic Formula	Length Range (mm)
Carp	log W = -4.282 + 2.769 log L	$W = (5.22 \times 10^{-5})L^{2.769}$	180 - 660
Shorthead redhorse	log W = -4.545 + 2.836 log L	$W = (2.85 \times 10^{-5})L^{2.836}$	120 - 520
Silver redhorse	log W = -4.634 + 2.878 log L	$W = (2.32 \times 10^{-5})L^{2.878}$	220 - 580
White sucker	log W = -5.012 + 3.034 log L	$W = (9.73 \times 10^{-6})L^{3.034}$	120 - 480
Smallmouth bass	log W = -5.005 + 3.069 log L	$W = (9.88 \times 10^{-6})L^{3.069}$	80 - 420

MONTICELLO NUCLEAR GENERATING PLANT

ENVIRONMENTAL MONITORING PROGRAM

1980 ANNUAL REPORT

SEINING STUDY

(2.2)

Prepared for

Northern States Power Company

Minneapolis, Minnesota

by

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Northern States Power Company

2.2 1980 MONTICELLO SEINING STUDY

2.2.1 INTRODUCTION

During 1980, seining studies were conducted on the Mississippi River near the Monticello Nuclear Generating Plant (MNGP). Locations within a kilometer, upstream and downstream from the MNGP site, were sampled to ascertain small fish populations. The objectives of this study were to determine relative abundance and species composition of the small fish community, with possible observations on the effect of the MNGP's thermal discharge.

Seining was conducted once every two weeks between May 16 and September 22, 1980. The study area included 1.6 km of river extending 0.8 km upstream and 0.8 km downstream from the MNGP discharge structure. Two upstream stations and two downstream stations were utilized (Figure 2.2-1).

Station M-1 was located in a small channel between Beaver and Cedar Island. The bottom structure consisted of a sand-gravel mixture. Current was approximately one meter per second, with an average depth of 0.75 meter. No aquatic vegetation was present at this location.

Station M-2 was located in a small channel between two islands approximately 0.4 km upstream of Station M-1. Current of 0.75 meter per second over a sand-gravel bottom and a depth of one meter depict the characteristics of this seining station.

Station M-3 was located within the plant's thermal plume 0.3 km downstream from the MNGP discharge structure. This site had a current velocity of 0.75 meter per second, a gravel substrate, and an average depth of one meter.

Station M-4, which was also within the thermal plume, was located 0.8 km downstream from the MNGP discharge structure. Gravel bottom, current velocity of 0.4 meter per second, and an average depth of one meter depict the characteristics of this seining station.

2.2.2 MATERIALS AND METHODS

A 15-foot seine with 1/8" mesh was used for sampling. Hauls were directed downstream with the current. The distance of each seining haul was determined and recorded. Captured fish were immediately placed in a water-filled basin, identified, tabulated, and released. Voucher specimens were preserved in a 10 percent formalin solution. Freshwater Fishes of Canada (Scott and Crossman 1973), Northern Fishes (Eddy and Underhill 1976), The Fishes of Missouri (Pflieger 1975), and Illustrated Key to the Minnows of Wisconsin (Becker and Johnson 1970) were used to identify specimens.

Computation of the area sampled was accomplished by multiplying the length of the haul by the width of the seine. Species abundance indices, or catch per effort (cpe), were computed by expanding the number of fish captured per area seined to the number of fish that would have been captured in a hectare. Abundance indices were utilized to calculate percentage composition of each species in the total catch.

2.2.3 RESULTS

A total of 4,246 fish was collected during the 1980 study. Of these, 25 species were identified (Table 2.2-1). Mimic shiner, carp, blacknose dace, rockbass, brook stickleback, and logperch were collected during the 1980 study, but were not found in 1979. Creek chub, river shiner, brassy minnow, golden shiner, northern redbelly dace, black bullhead, brook silverside, white crappie, walleye, and yellow perch were collected in previous years but not in 1980.

Twenty-two species were found in each sector. Mimic shiner, blacknose dace, black bullhead, and trout perch were found exclusively in the upstream area during 1980. Common shiner, bluegill, rock bass, and brook stickleback were found only in the downstream sector.

Species abundance indicies (fish/ha) are presented for both sectors in Table 2.2-2. Species percentage contributions to the total catch for both sectors are presented in Table 2.2-3. Species percentage contributions to total catch since 1970 are listed in Table 2.2-4. Seasonal abundance of individual species, as actual fish captured, for each seining station is presented in Tables 2.2-5 through 2.2-8. Abundance indicies for young-of-the-year of selected species (smallmouth bass, white sucker, and the Moxostoma species) are presented in Table 2.2-9. These indicies are reviewed annually for an indication of reproductive success for these dominant "large fish" species. A species list with both common and Latin names of fish discussed in this text is compiled in Table 2.2-10.

2.2.4 DISCUSSION

A total of 35 species has been identified during the seven years that seining studies were conducted (Table 2.2-4). Brook stickleback was the only new species added to this species list in 1980. The brook stickleback's preferred habitat is small, cool-water streams. Its presence in the effluent section of the study area (Table 2.2-2) is believed to arise from accidental introductions by the Monticello Environmental Protection Agency (EPA) field station. The EPA outfall structure is located approximately 400 meters downstream from the MNGP discharge. Canals used by the EPA for toxicology studies were stocked with fathead minnows. Brook sticklebacks are commonly found in stocks of fathead minnows supplied to the EPA field station by local bait distributors, and it is quite possible that some of these individuals have escaped to the Mississippi River.

Creek chub, brassy minnnow, river shiner, golden shiner, northern redbelly dace, brook silverside, white crappie, yellow perch, and walleye are incidental species found in previous studies and not in 1980.

Mature northern hogsuckers have been observed since 1976 in Monticello electrofishing surveys (see Section 2.1). This species first appeared as young-of-the-year in 1979 seining surveys. Its abundance also increased in 1980 (Table 2.2-4). Seining data and visual observation while electrofishing indicate an excellent 1980 year class of this species. Northern hogsuckers generally prefer clear and productive river systems for their habitats. Its appearance and reproductive success is, therefore, believed to arise from substantial improvement in water clarity and quality, beginning with the 1975 to 1977 drought.

Species which dominated the 1980 upstream sector collections were: white sucker, sand shiner, Johnny darter, spotfin shiner, bigmouth shiner, and Moxostoma spp. (unidentified juvenile silver and shorthead redhorse). Major components in the downstream sector were: white sucker, spotfin shiner, smallmouth bass, spottail shiner, and bluntnose minnow (Table 2.2-3). A preference for warm water was demonstrated by smallmouth bass, spottail shiner, bluntnose minnow, carp, largemouth bass, black crappie, and northern hogsucker, and is reflected by their greater abundance in Sector B (Table 2.2-2).

The species dominance ranking for 1976-1980 studies is as follows:

<u>1976</u>

Bigmouth & sand shiner
Bluntnose minnow
Spotfin shiner
Moxostoma spp.
White sucker

<u>1977</u>

Bigmouth and sand shiner
Bluntnose minnow
Spotfin shiner
White sucker
Johnny darter

<u>1978</u>

Bluntnose minnow
Bigmouth and sand shinner
Spotfin shiner
White sucker
Johnny darter

<u>1979</u>

Bigmouth and sand shiner
Spotfin shiner
Bluntnose minnow
Moxostoma spp.
White sucker

<u>1980</u>

White sucker
Spotfin shiner
Johnny darter
Sand shiner
Moxostoma spp.

The taxon *Moxostoma* spp. was utilized in this text due to the difficulty of field separating early juvenile stages of silver and shorthead redhorse.

Bluntnose minnow, sand shiner, and bigmouth shiner were not as abundant in 1980 as they have been in previous studies. Conversely, white sucker, smallmouth bass, Johnny darter, logperch, and northern hogsucker had increased abundance in 1980 (Table 2.2-4).

Seasonal abundance (Tables 2.2-5 through 2.2-8) of juvenile white sucker and smallmouth bass indicates that spawning occurred in late May through natural attrition, increased sampling gear avoidance, and shifts in preferred habitat; the juvenile abundance of these species decreased after midsummer.

Collections of spotfin shiner, sand shiner, and bluntnose minnow increased after midsummer. The seasonal abundance pulse for these species is attributable to their young-of-the-year attaining a recruitable size for the seining gear.

Table 2.2-9 illustrates the average abundance (fish/ha) of smallmouth bass, white sucker, and Moxostoma spp. (silver and shorthead redhorse) since 1973. This table reveals that young-of-the-year abundance for 1980 year classes of smallmouth bass and white sucker were the highest recorded over the seven-year period. Although Moxostoma spp. did not reach record abundance, it joined smallmouth bass and white sucker by showing tremendous increases over 1978 and 1979 averages.

2.2.5 SUMMARY

1) A total of 4,246 fish was collected by seining in the Mississippi River near MNGP in 1980. Twenty-five species were identified in 1980, 35 species have been identified during the seven years studied. The one new species identified in 1980 was the brook stickleback.

2) Dominant species occurring in 1980 were; white sucker, spotfin shiner, Johnny darter, sand shiner, and Moxostoma spp.

3) Smallmouth bass, spottail shiner, bluntnose minnow, carp, largemouth bass, black crappie, and northern hog-sucker showed a marked preferrence for the MNGP heated effluent.

4) Decreased abundance of bluntnose minnow, bigmouth shiner, sand shiner, and spotfin shiner was observed in 1980.

5) Increased abundance for young-of-the-year smallmouth bass, white sucker, and Moxostoma spp. indicates a strong 1980 year class for these major large fish species.

2.2.6 ACKNOWLEDGEMENTS

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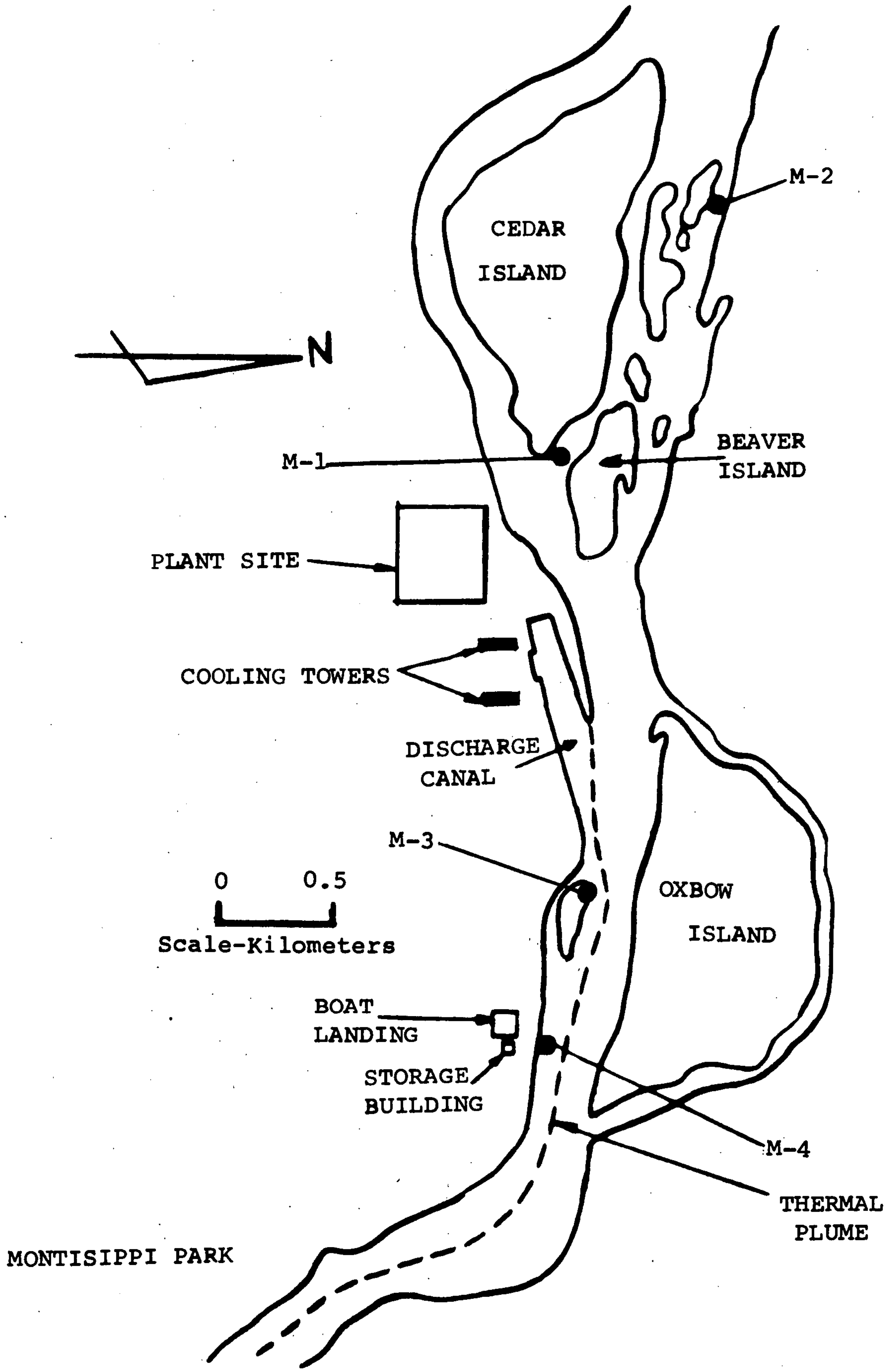

Figure 2.2-1. 1980 Monticello Seining Station Locations.

Table 2.2-1 1980 Monticello Seining Study - Species Lists for 1970, 1973, 1976, 1977, 1978, 1979, and 1980.

Species	1970	1973	1976	1977	1978	1979	1980
Hornyhead chub	X	X	X	X	X	X	X
Creek chub	X	X		X			
Fathead minnow		X	X	X	X	X	X
Bluntnose minnow	X	X	X	X	X	X	X
Brassy minnow		X					
Spotfin shiner	X	X	X	X	X	X	X
Bigmouth shiner	X	X	X	X	X	X	X
Sand shiner	X	X	X	X	X	X	X
River shiner				X		X	
Spottail shiner	X	X		X	X	X	X
Common shiner	X	X	X	X	X	X	X
Golden shiner	X						
Mimic shiner			X				X
Carp			X	X			X
Longnose dace	X	X	X	X		X	X
Blacknose dace	X	X	X	X	X		X
Northern redbelly dace		X					
Silver redhorse	X	X	X	X	X	X	X
Shorthead redhorse	X	X	X	X	X	X	X
White sucker	X	X	X	X	X	X	X
Northern hogsucker						X	X
Black bullhead	X						
Trout perch		X		X	X	X	X
Brook stickleback							X
Brook silverside				X	X		
Smallmouth bass	X	X	X	X	X	X	X
Largemouth bass		X				X	X
Black crappie	X				X	X	X
White crappie					X		
Rock bass	X			X			X
Bluegill			X	X	X	X	X
Logperch		X	X	X	X		X
Johnny darter	X	X	X	X	X	X	X
Walleye						X	
Yellow perch					X	X	

X - Denotes presence

Table 2.2-2 1980 Monticello Seining Study - Fish per Hectare for Sampling Stations Upstream and Downstream of the Monticello Plant Discharge.

	Upstream			Downstream			Overall
	1	2	Ave	3	4	Avg	Avg
Hornyhead chub	82	120	101	146	18	82	92
Fathead minnow	22	94	58	15	9	12	35
Bluntnose minnow	560	436	498	584	145	364	431
Spotfin shiner	1396	769	1082	1693	300	996	1040
Sand shiner	1515	1282	1398	102	64	83	741
Bigmouth shiner	888	1113	1030	73	0	36	523
Spottail shiner	45	0	22	620	155	388	205
Common shiner	0	0	0	22	0	11	6
Mimic shiner	0	26	13	0	0	0	6
Carp	0	9	4	102	9	56	30
Longnose dace	866	214	540	88	36	62	301
Blacknose dace	0	26	13	0	0	0	6
Shorthead redhorse	119	137	128	117	64	90	109
Silver redhorse	157	154	156	36	9	22	89
White sucker	2724	3940	3332	1861	2045	1953	2642
Northern hogsucker	82	60	71	533	73	303	187
Black bullhead	0	9	4	0	0	0	2
Trout perch	7	0	4	0	0	0	2
Smallmouth bass	231	179	205	599	1200	900	552
Largemouth bass	37	0	18	15	100	58	38
Black crappie	0	9	4	7	36	22	13
Bluegill	0	0	0	80	0	40	20
Rock bass	0	0	0	0	9	4	2
Johnny darter	1522	1222	1372	109	282	196	784
Logperch	455	299	377	482	91	286	332
Brook stickleback	0	0	0	0	9	4	2
Shiner spp.	15	103	59	0	0	0	30
Moxostoma spp.	851	829	840	51	509	280	560

Table 2.2-3 1980 Monticello Seining Study - Species Percentage Contribution to Total Catch by Number for Upstream and Downstream Areas.

Upstream		Downstream	
White sucker	29.4%	White sucker	31.3%
Sand shiner	12.3	Spotfin shiner	15.9
Johnny darter	12.1	Smallmouth bass	14.4
Spotfin shiner	9.6	Spottail shiner	6.2
Bigmouth shiner	9.1	Bluntnose minnow	5.8
Moxostoma spp.	7.4	Northern hogsucker	4.9
Longnose dace	4.8	Logperch	4.6
Bluntnose minnow	4.4	*Moxostoma* spp.	4.5
Logperch	3.3	Johnny darter	3.1
Smallmouth bass	1.8	Shorthead redhorse	1.4
Silver redhorse	1.4	Sand shiner	1.3
Shorthead redhorse	1.1	Hornyhead chub	1.3
Hornyhead chub	0.9	Longnose dace	1.0
Northern hogsucker	0.6	Largemouth bass	0.9
Shiner spp.	0.5	Carp	0.9
Fathead minnow	0.5	Bluegill	0.6
Spottail shiner	0.2	Bigmouth shiner	0.6
Largemouth bass	0.2	Silver redhorse	0.4
Mimic shiner	0.1	Black crappie	0.4
Blacknose dace	0.1	Fathead minnow	0.2
Carp	0.1	Common shiner	0.2
Black crappie	0.1	Rock bass	0.1
Black bullhead	0.1	Brook stickleback	0.1
Trout perch	0.1		

Table 2.2-4 1980 Monticello Seining Study - Species Percentage Contribution to the Total Catch 1970 Through 1980.

Species	1970	1973	1976	1977	1978	1979	1980
Hornyhead chub	3.1	1.7	0.1	3.0	0.1	1.0	1.1
Creek chub	0.3	0.1		0.2			
Fathead minnow		0.9	0.6	0.2	0.5	0.1	0.4
Bluntnose minnow	12.7	16.2	23.4	17.3	40.2	6.8	4.9
Brassy minnow		0.3					
Spotfin shiner	21.1	23.5	23.4	16.8	21.9	14.0	11.9
Bigmouth shiner	27.3	21.8	12.4	30.8	29.0	57.6	6.0
Sand shiner	18.4	21.6	15.3				8.4
River shiner				6.2		0.5	
Spottail shiner	1.0	0.8		1.2	0.2	1.0	2.3
Common shiner	2.9	3.4	0.2	1.1	0.8	0.3	0.1
Golden shiner	0.1						
Mimic shiner			0.1				0.1
Carp			0.5	0.1			0.3
Longnose dace	3.1	0.7	2.0	1.1	0.1	2.5	3.4
Blacknose dace	0.4	0.3		0.1			0.1
Northern redbelly dace		0.1					
Silver redhorse				1.2	0.9	0.1	1.0
Shorthead redhorse				0.8	0.1	0.2	1.2
White sucker	2.5	3.9	2.5	7.4	1.4	4.4	30.1
Northern hogsucker						0.3	2.1
Black bullhead	0.1						0.1
Trout perch		0.4		0.1	0.9	0.1	0.1
Brook silverside				0.1	0.1		
Smallmouth bass	1.7	1.0	0.4	0.3	1.2	3.5	6.3
Largemouth bass		0.1				0.1	0.4
Black crappie	0.1				0.6	0.1	0.2
White crappie					0.1		
Rock bass	0.1			0.2			0.1
Bluegill				0.1	0.1	0.3	0.2
Yellow perch				3.8	0.1	0.1	
Logperch		0.2	0.3		0.1		3.8
Johnny darter	5.0	2.6	1.3	6.8	1.3	1.4	8.9
Walleye						0.4	
Brook stickleback							0.1
Shiner spp.			0.3	1.0	0.1	0.6	0.3
Moxostoma spp.	0.3	0.6	16.9	0.6	0.5	5.1	6.4

Table 2.2-5 1980 Monticello Seining Study - Station 1
Actual Number of Specimens Collected

Species	5/16	5/28	6/19	6/23	7/7	7/21	8/6	8/18	9/8	9/22	Total
Hornyhead chub		6	5								11
Fathead minnow		3									3
Bluntnose minnow		20	19	2	13		13	1		7	75
Spotfin shiner		33	47	3	13	61			4	26	187
Sand shiner		32	50		88	21	4			8	203
Bigmouth shiner		4	52		47	16					119
Spottail shiner		6									6
Common shiner											
Mimic shiner											
Carp											
Longnose dace	4	21	11	33	42	5					116
Blacknose dace											
Shorthead redhorse									7	9	16
Silver redhorse									2	19	21
White sucker		127	96	25	20	60		21	5	11	365
Northern hogsucker				1		10					11
Black bullhead											
Trout perch											
Smallmouth bass			5	3		10		9	1	3	31
Largemouth bass								5			5
Black crappie											
Bluegill											
Rock bass											
Johnny darter			5	15	9	70	92	8	3	2	204
Logperch		2	20			35		1	3		61
Brook stickleback											
Shiner spp.											
Moxostoma spp.											
Haul lengths (ft)	80	80	40	50	60	90	60	70	90	100	720

Table 2.2-6 1980 Monticello Seining Study - Station 2
Actual Number of Specimens Collected

Species	5/16	5/18	6/19	6/23	7/7	7/21	8/6	8/18	9/8	9/22	Total
Hornyhead chub	1	1						3	9		14
Fathead minnow	1	5							5		11
Bluntnose minnow		5	2	1		1	1	1	24	16	51
Spotfin shiner		23		12	16		9	15	8	7	90
Sand shiner		18	34	2	21		17	29	12	17	150
Bigmouth shiner			51	7	18		3				79
Spottail shiner											
Common shiner											
Mimic shiner							3				3
Carp					1						1
Longnose dace		5	10	7	1	2					25
Blacknose dace									3		3
Shorthead redhorse									13	3	16
Silver redhorse					8				8	2	18
White sucker		207	131	15	20		23	3	54	8	461
Northern hogsucker			4	1			2				7
Black bullhead								1			1
Trout perch											
Smallmouth bass					2	5	14				21
Largemouth bass											
Black crappie						1					1
Bluegill											
Rock bass											
Johnny darter			19	10	47	28	3	23	13		143
Logperch						7	20	4	4		35
Brook stickleback											
Shiner spp.								12			12
<u>Moxostoma</u> spp.		27		15			12	43			97
Haul Lengths (ft)	100	60	40	50	40	60	50	60	70	100	630

Table 2.2-7 1980 Monticello Seining Study - Station 3
Actual Number of Specimens Collected

Species	5/16	5/28	6/19	6/23	7/7	7/21	8/6	8/18	9/8	9/22	Total
Hornyhead chub				2	3				7	8	20
Fathead minnow	2										2
Bluntnose minnow	5	12	20	1	34				3	5	80
Spotfin shiner	5	11	46	54	57	35			4	20	232
Sand shiner	5		1	2	4						14
Bigmouth shiner		8			2						10
Spottail shiner	1									84	85
Common shiner				2	1						3
Mimic shiner											
Carp				4						10	14
Longnose dace	2	8	1	1							12
Blacknose dace											
Shorthead redhorse									9	7	16
Silver redhorse			2						3		5
White sucker		167	16	59	12					1	255
Northern hogsucker				1	2	7	18	3	20	22	83
Black bullhead											
Trout perch											
Smallmouth bass			2	11	19	13	13	6	3	15	82
Largemouth bass									1	1	2
Black crappie										1	1
Bluegill										11	11
Rock bass											
Johnny darter		5	3	7							15
Logperch					11	48	4		3		66
Brook stickleback											
Shiner spp.											
Moxostoma spp.				7							7
Haul Lengths (ft)	70	70	40	70	60	90	90	70	60	115	735

Table 2.2-8 1980 Monticello Seining Study - Station 4
Actual Number of Specimens Collected

Species	5/16	5/28	6/19	6/23	7/7	7/21	8/6	8/18	9/8	9/22	Total
Hornyhead chub					1					1	2
Fathead minnow	1										1
Bluntnose minnow		2			1	1			2	10	16
Spotfin shiner	6					5			10	12	33
Sand shiner											
Bigmouth shiner										7	7
Spottail shiner					17						27
Common shiner											
Mimic shiner											
Carp				1							1
Longnose dace			3								4
Blacknose dace											
Shorthead redhorse								6	1		7
Silver redhorse									1		1
White sucker		217	3	3			1			1	225
Northern hogsucker							1		4	2	8
Black bullhead											
Trout perch											
Smallmouth bass			9	12	32	38	13	8	14	6	132
Largemouth bass						7		2			11
Black crappie									2	2	4
Bluegill											
Rock bass											
Johnny darter			21	10							31
Logperch				2		7			1		10
Brook stickleback								1			1
Shiner spp.											
Moxostoma spp.			56								56
Haul Length (ft)	50	40	40	40	40	80	60	80	90	70	590

Table 2.2-9 1980 Monticello Seining Study
Average number of smallmouth bass, white sucker, and Moxostoma sp. collected per hectare in upstream and downstream areas in 1973, 1974, 1976*, 1977, 1978, 1979, and 1980.

Smallmouth bass

	Upstream Fish/ha	Downstream Fish/ha	Average
1973	256	92	174
1974	380	152	266
1976			135
1977	101	12	56
1978	101	167	134
1979	9	465	237
1980	205	552	378

White sucker

	Upstream Fish/ha	Downstream Fish/ha	Average
1973	1881	1416	1648
1974	250	78	164
1976			1501
1977	2401	157	1279
1978	240	65	152
1979	364	236	300
1980	3332	2642	2987

Moxostoma species

	Upstream Fish/ha	Downstream Fish/ha	Average
1973	989	1140	1064
1974	841	797	819
1976			9823
1977	405	494	450
1978	201	125	163
1979	103	179	141
1980	1124	758	941

*1976 data from NUS Monticello 316 a & b NPDES demonstration.

Table 2.2-10 1980 Monticello Seining Study
Species List of Fish Discussed in This Text

Common Name	Scientific Name
Hornyhead chub	Nocomis biguttatus
Creek chub	Semotilus atromaculatus
Fathead minnow	Pimephales promelas
Bluntnose minnow	Pimephales notatus
Brassy minnow	Hybognathus hankinsoni
Spotfin shiner	Notropis spilopterus
Bigmouth shiner	Notropis dorsalis
Sand shiner	Notropis stramineus
River shiner	Notropis blennius
Spottail shiner	Notropis hudsonius
Common shiner	Notropis cornutus
Golden shiner	Notemigonus crysoleucas
Mimic shiner	Notropis volucellus
Carp	Cyrpinus carpio
Longnose dace	Rhinichthys cataractae
Blacknose dace	Rhinichthys atratulus
Northern redbelly dace	Chrosomus eos
Silver redhorse	Moxostoma anisurum
Shorthead redhorse	Moxostoma macrolepidotum
White sucker	Catostomus commersoni
Northern hogsucker	Hypentelium nigricans
Black bullhead	Ictalurus melas
Trout perch	Percopsis omiscomaycus
Brook silverside	Labidesthes sicculus
Smallmouth bass	Micropterus dolomieui
Largemouth bass	Micropterus salmoides
Black crappie	Pomoxis nigromaculatus
White crappie	Pomoxis annularis
Rock bass	Ambloplites rupestris
Bluegill	Lepomis macrochirus
Yellow perch	Perca flavescens
Logperch	Percina caprodes
Johnny darter	Etheostoma nigrum
Walleye	Stizostedion vitreum
Brook stickleback	Culaea inconstans

MONTICELLO NUCLEAR GENERATING PLANT
ENVIRONMENTAL MONITORING PROGRAM
1980 ANNUAL REPORT

DEVELOPMENT OF A MODEL FOR PREDICTING YEAR-CLASS STRENGTH OF FISH IN THE UPPER MISSISSIPPI RIVER

(2.3)

Prepared for

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2.3 DEVELOPMENT OF A MODEL FOR PREDICTING YEAR-CLASS STRENGTH OF FISH IN THE UPPER MISSISSIPPI RIVER

2.3.1 INTRODUCTION

Understanding of the relationship between stream stage, other physical conditions, reproductive success (year-class strength), and fish abundance could be useful in managing stream use by the electric power industry in a manner which promotes fish production and efficient power production. As part of monitoring requirements, Northern States Power Company has been collecting information on physical conditions and fish populations in the Mississippi River between their plants at Becker and Monticello, Minnesota since 1973.

During this study, literature review and analysis of physical data were used to develop and test a basic model useful in predicting year-class strength of important Mississippi River fish populations. Literature review was used to identify the mechanisms which influence year-class strength and abundance of fish in streams and formed the basis for development of the model. The model and information on temperature, discharge, and turbidity were used to predict relative strength of 1973-1980 smallmouth bass (*Micropterus dolomieu*) year-classes in the study area. Application of the model in predicting year-class strength was useful in identifying the area where data are needed to improve the predictive capacity of the model. Estimates of year-class strength based on the model will be compared with those based on analysis of age class structure of smallmouth bass populations in the study area to validate the assumptions upon which the model is based.

Fishing pressure is substantial in the stream section between Becker and Monticello and has increased from 2,600 hours in 1973 to 20,000 hours in 1979. During the period, total catch increased from 173 kg to 2,644 kg (Heberling and Weinhold 1979). Most of the pressure is directed at smallmouth bass (Micropterus dolomieu), the dominant game fish in the area. Black crappie (Pomoxis nigromaclatus), walleye (Stizostedion vitreum vitreum), and northern pike (Esox lucius) are important in the catch. Rockbass (Ambloplites rupestris), black bullhead (Ictalurus melas), carp (Cyprinus carpio), shorthead redhorse (Moxostoma macrolepidotum), silver redhorse (M. anisurum), white sucker (Catostomus commersoni), bigmouth buffalo (Ictiobus cyprinellus), and musky (Esox mascuinongy) are taken in limited numbers. Although shorthead and silver redhorse are of limited importance to the fishery, they are the dominant species in the area.

2.3.2 LITERATURE REVIEW

Smallmouth bass

The influence of stage and related habitat conditions on the reproductive success of smallmouth bass has been studied extensively. There appears to be general agreement that catastrophic flow (flood stage) conditions during the reproductive period result in weak year classes and reduced abundance of smallmouth (Brown 1960; Cleary 1956; Funk and Fleener 1974; Reynolds 1965). Timing appears to be critical, however, as Funk and Pflieger (1975) found catastrophic flow prior to spawning may serve to improve spawning areas and subsequent spawning success. They also suggest that the influx of allochthanous material and subsequent increases in invertebrate production may have a positive influence.

Temperature variations which may accompany changes in stage have been associated in several ways to year-class success and smallmouth bass abundance. Delays in nesting behavior (Pflieger 1975; Shuter et al. 1980) and nest abandonment by spawning males (Cleary 1956; Henderson and Foster 1956; Latta 1963; Marz 1964) occur when temperatures during the spawning and nesting period fall below approximately 15 °C. Spawning to hatch time and the period between hatch and the rising of fry in the nest are dependent on temperature (Webster 1948; Kerr 1968; Shuter et al. 1980). Early development time increases from approximately 8 days at 20°C to 14 days at 17°C. Although slower development within the nest does not result in direct mortality, it increases the probability of mortality from predation, siltation, or temperature declines below 15°C. Larimore and Suever (1968) and Coutant (1975) showed swimming of fry was slowed under reduced temperatures, increasing their susceptibility to current and predators. Under optimum feeding conditions, growth of young-of-the-year smallmouth increases from approximately 0.2 mm/day at 16°C to 1 mm/day at 22°C (Rowan 1962; Peak 1965; Shuter et al. 1980).

Oliver et al. (1979) and Shuter et al. (1980) provide evidence that young smallmouth stop feeding when temperatures drop below 7-10°C in the autumn, and that smaller individuals do not possess the essential energy reserves to live through extended winters. Based on the energy reserves and energy requirements of young-of-the-year smallmouth bass, Shuter et al. (1980) accurately predicted changes in size structure of over-wintering young smallmouth for a natural system. They concluded that the controlling influence of temperature on reproductive success and growth are the primary mechanisms controlling survival during the first year of life and subsequent year-class strength in lacustrine systems. The mechanisms through which temperature influences first year survival are identified by a

conceptual model (Figure 2.3-1). Shuter et al. (1980) demonstrated that the geographic range and year-class strength of lacustrine populations of smallmouth bass could be predicted from information on temperature variation during the spawning period and from average July air temperatures.

Although temperature represents the primary controller of smallmouth bass abundance in lacustrine systems, flow appears to be extremely important to survival and abundance of populations in riverine habitats. Smallmouth require quiet waters for nesting behavior to occur, and high flow rates have been found to delay nest construction to restrict the availability of spawning habitat (Pflieger 1975) and to result in nest abandonment by males. While few studies provide information on flow rates critical to nesting, Weinmeller (Personal Communication)[1] observed 100 percent nest abandonment occurred at flows exceeding 55 mm/sec. (near the bottom) in Indian Creek, Ohio. It was not clear whether nest abandonment occurred due to the direct effects of current or as a result of cover loss associated with higher stage and flow conditions. Weinmeller observed that all nesting was associated with cover, and that cover was destroyed under high flow conditions.

Flow has been shown to have direct effects on smallmouth fry survival. Surber (1939) and Webster (1954) found smallmouth fry are extremely sensitive to currents and are displaced from their nests under high stage conditions. In laboratory flumes, Larimore (1975) observed that the capacity of young smallmouth bass (22-25 mm total length) to maintain position was related to visual and tactile orientation, which was

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[1]Kirk Weinmeller, Dept of Zoology, Miami University, Oxford, Ohio.

reduced under darkness, turbidity, or turbulence. Most young smallmouth could maintain position for short periods (15 minutes) under flows of 170 mm/sec. in lighted conditions, but were displaced at flows of 100 mm/sec. under darkness or turbid conditions. Larimore (1975) showed that darkness and turbidity resulted in loss of visual orientation, which promoted displacement, and that rapid changes in flow rates had similar effects due to loss of tactile orientation. He concluded that high flow, turbulence, and turbidity associated with high stage conditions promote year-class failure in smallmouth bass due to loss of orientation and related displacement of young bass. Another form of displacement is suggested by Munther (1970), who observed that smallmouth bass concentrate in the lee of currents or quiet areas. These observations suggest that during high flow periods, young smallmouth bass are displaced or actively seek out quiet water areas of reduced current, reducing the total habitat available to the population. The concentrating effects associated with this response to flow can be expected to promote intraspecific and interspecific predation and competition (Eipper 1975). Although not measured in smallmouth, observations on other species (Symon 1976) suggest that energy directed at coping with flow can be expected to reduce energy available for growth.

Increased turbidity and sedimentation generally occur under high stage conditions in low flow areas of streams where smallmouth nest. High sedimentation rates and turbidity levels have been found to cause spawning failure and slow growth of smallmouth fry in ponds (Swingler 1949; Buck 1956).

Other Species

Information on factors which control abundance of other dominant species in the study area are limited. Larimore et al. (1952) and Funk (1975) found abundance and weight distribution of smallmouth bass to be correlated with those of several catostomid species, suggesting that factors which control year-class success are similar. Large, slow-moving, warm water streams of moderate depth and with a mixed substrate are identified as optimum walleye habitat by Ketchill et al. (1977). Substrate requirements and spawning behavior of walleye and the redhorse sucker group are well adapted to riverine conditions. Walleye and the suckers spawn in riffle areas. Walleye spawning generally occurs between temperatures of 6-10°C (Smith and Koenst 1975). Shorthead redhorse spawn earlier and at lower temperature (12°C) than silver redhorse (16°C) (Meyer 1962).

After hatching and early development in the spawning areas, walleye and sucker fry drift passively downstream in near surface waters. Drifting occurs primarily at night (Gale and Mohr 1978). Priegel (1970) found walleye fry are unable to feed during the drifting period, even under moderate current conditions, and must reach quiet waters where feeding can take place within 3-5 days to avoid starvation. He also found that highly turbulent water results in significant walleye fry mortality. Houde (1969) showed walleye fry less than 9.3 mm could not maintain their positions in current velocities of 30 mm/sec., and only 50 percent of fry 10-16 mm could maintain position at flows from 30-50 mm/sec.

Although information on the biology of redhorse suckers is limited, Gale and Mohr (1978) found larger fry occur in shallow, quiet water near the stream margin, suggesting a

preference for low-current velocities exists and low velocities are critical to survival and growth. Meyer (1962) found that although adult redhorse may enter areas of high current velocities, the young inhabit slow water over muck bottoms, often under banks.

Susceptibility to current is increased at reduced temperatures, which slow growth. Walburg (1972) found much of the variation in sauger (Stizostedion canadense) year-class strength is associated with early summer temperatures and flow in Lewis and Clark Lake, and impoundment of the Missouri River. Slow growth and greater displacement of young saugers occurred during summers, where temperatures fell below 21°C and water retention in the reservoir dropped below five days. Smith and Koenst (1975) showed fast growth and high survival of walleye after yolk sac absorption requires temperatures of 21-22°C.

2.3.3 A CONCEPTUAL MODEL OF YEAR-CLASS FORMATION

Information on the factors which control year-class strength in smallmouth bass indicates that reproductive behavior and development are controlled through several mechanisms, acting on different phases of the reproductive and developmental processes. The available data suggest that year-class success and fish abundance are the products of the combined success of all phases of the reproductive and early development processes. Measurement of year-class success and the factors which control it may, therefore, best be approached through a model which considers the success of each phase of the reproductive and early development processes.

In smallmouth bass, nest construction, spawning, nest guarding, embryo development, fry development, growth of young, and overwinter survival represent phases in the

reproductive and development processes which control strength of year-classes and abundance. These phases may be viewed as a series of compartments through which percentages of the adult population (reproductive compartments) or young (development compartments) pass (Figure 2.3-2). Year-class strength may be viewed as the outcome of the number of young created within the reproductive compartments and their survival through the developmental compartments.

Under conditions where early summer temperatures are not favorable to spawning or current, turbidity, sedimentation, and cover conditions prohibit nest building, spawning, or nest guarding, reproduction does not occur and the species is absent from the system. Where temperature, current, and related conditions retard spawning, large numbers of young may be produced, but the probability of survival through the developmental compartments is generally low because of the demonstrated influence of small size on the capacity of young to cope with current, predation, and winter energy demands. Therefore, in situations where spawning is delayed, year-class strength can be expected to be comparitively low. Early spawning may also lead to year-class failure, because temperature instability early in the year promotes high embryo and fry mortality (Shuter et al. 1980).

By considering the temperature critical to embryo survival and time required to accumulate the energy required to overwinter, Shuter et al. (1980) predicted that the largest year-classes of smallmouth bass occurred in the Baie du Dove', Lake Huron, population when spawning occurred between June 10-20. In stream populations, several studies have shown that flow, turbidity, and sedimentation can have similar effects on spawning and embryo survival. Generally, strong year-classes should be promoted in stream habitats when temperatures are maintained above 15°C by mid-June and flow, turbidity, and sedimentation remain low. If tempera-

tures remain below 15°C after mid-June and flow, turbidity, and sedimentation are high, or if temperatures and other conditions are appropriate for reproduction prior to mid-June but subsequently are altered in a manner which reduces fry survival (low temperature; high flow, turbidity, and sedimentation), poor year-classes should result. Among the variables important to year-class strength in stream habitats, flow during the fry development stage appears to be most critical.

Beyond the fry stage, temperature and flow appear to be primary controllers of the amounts of energy accumulated in the young through the growth process. Because size attained through growth is important in coping with current and predators, survival during summer should be promoted by higher temperatures and reduced current conditions. Years of low summer temperatures and increased flow should result in reduced summer and overwinter survival, resulting in weaker year-classes. Overwinter survival is also influenced by winter severity, which determines the energy expenditure required to survive.

If temperature, current, turbidity, and sedimentation are determined to a large degree by stage, the existing data suggest that stage is the ultimate determiner of year-class strength and abundance of fish in riverine habitats. The existing data also make it clear that defining the influence of stage on year-class strength will require identifying the relationships between stage temperature, current, turbidity, and sedimentation levels. Data collected by NSP were analyzed to define relationships between stage and the other important physical stream parameters.

2.3.4 PHYSICAL CONDITIONS IN THE MISSISSIPPI

Discharge, Temperature, and Turbidity Relationships

Stage, discharge, temperature, and turbidity measurements taken at the NSP Monticello facility from 1973 to present were analyzed to determine their relationships and potential influence on fish abundance. Discharge was estimated from stage and represent a good indicator of stage and current conditions.

Daily discharge and temperature observations were averaged for 15-day periods, starting January 1, for all years of record. The 15-day averages were plotted to define normal trends for the eight-year period (Figure 2.3-3). The records show that discharge starts to increase from a winter average of approximately 4,000 CFS during March and reaches a peak of 14,000 CFS in late April. Discharge declines from early May through July. An average discharge of 3,700 CFS occurred during August and September. Temperatures increased with discharge in early March and continued to rise until late July. Temperature declines slowly from July through early December.

Temperatures appeared to vary independent of discharge except during the May-early June period. During May and early June it was apparent from the records that short term increases in flow resulted in lower temperatures. Regression analysis was used to define the relationship between 15-day average temperatures and discharge for the years 1973-1980. The analysis showed that temperature decreased at a rate of 0.4°C per 1,000 CFS increase in discharge, within a range of 1,000-16,500 CFS, during May and the first 14 days of June (Figure 2.3-4). Late June temperatures did not appear to be influenced significantly by variations in discharge.

Turbidity (NTU) and total suspended solids (mg/l) were measured on a weekly basis. General analysis indicated turbidity and suspended solids increased considerably during periods of high discharge and remained high during periods of reduced discharge which followed. Turbidity and suspended solid measurements were higher during spring and summer months than during winter (Table 2.3-1). The difference appeared related to the fact that both measurements are influenced by plankton abundance as well as sediment load. Suspended solid values averaged four and one half times the winter NTU values and six times the summer NTU values, indicating they were most responsive to changes in plankton abundance. The limited number of measurements, delayed response of turbidity and suspended solid measurements to changes in discharge, and the influences of plankton abundance on these measurements made it impractical to precisely define the influence of discharge on turbidity or sedimentation. However, mean NTU and suspended solid measurements during the reproductive-early development and growth periods of smallmouth bass were useful indicators of relative sedimentation rates and food availability.

2.3.5 PREDICTING YEAR-CLASS STRENGTH

Approach

The conceptual model (Figure 2.3-2) is based on the assumption that flow and temperature are primary controllers of smallmouth bass year-class strength in the study area. The model, information from the literature, and information on physical conditions in the study area were applied in estimating relative strength of smallmouth bass year-classes during the period 1973-1980. This application of available information was used to test the validity of the assumptions upon which the model is based, and to identify areas where additional quantitive information is needed to convert the

conceptual model into a more useful predictive tool. Predictions based on the model will be tested against estimates based on population age structure. The relative probability of successful completion of nesting, spawning, nest guarding, embryo, and fry development phases was estimated on the basis of physical conditions during May and June. The relative probability of overwinter survival was based primarily on summer temperatures and length of the growing season.

Two-day average temperature and discharge during May and June of each year were plotted against the eight-year averages to determine if conditions were above or below average. Time of major nest construction was predicted to occur when two-day average temperatures reached 15°C and discharge was not high enough to cause turbulence in protected areas. Because field data are lacking, 12,000 CFS was selected somewhat arbitrarily as the level of discharge above which all spawning would be inhibited. This discharge represents three times the normal summer, autumn, and winter average. During periods when discharge fell below 12,000 CFS, peak spawning was predicted to occur using the formula of Shuter et al. (1980).

$$D = 8.0 - 0.55d$$

Where:

D = days after nest construction

d = number of degree days above 10°C accumulated prior to the date nest construction began

Time from spawning to hatch and hatch to rise were predicted from regression relationships between temperature and time (days) developed by Webster (1948) and Kerr (1968) and presented graphically by Shuter et al. (1980).

Relative survival during the time from spawning to hatch, hatch to rise, and the first five days after larvae rise in the nest was ranked as either excellent, good, average, below average, or poor on the basis of temperature, discharge, or turbidity observations. Although quantitive observations are needed, for the purposes of this test of the model, survival during the critical early development period was generally classified as follows:

1) Excellent - Temperature remains above 16°C and increasing; discharge less than 4,000 CFS; turbidity, below average.

2) Good - Temperature above 15°C remains stable or increases; discharge less than 6,000 CFS and declining; turbidity average or below.

3) Average - Temperature above 15°C and remains stable; discharge above 8,000 CFS and fluctuating; turbidity average or below.

4) Below Average - Temperature remains at about 15°C; discharge between 6-12,000 CFS; turbidity above average.

5) Poor - Discharge above 12,000 CFS; turbidity above average.

Initiation of active summer growth was considered to occur five days after larvae were predicted to rise in the nest. Active growth was considered to end when temperatures dropped below 10°C in the autumn.

Applying data summarized by Shuter et al. (1980), growth was estimated to occur at the following rates:

0.14 cm/day	at temperatures between	25-36°C
0.10 cm/day	at temperatures between	20-24°C
0.06 cm/day	at temperatures between	18-19°C
0.02 cm/day	at temperatures between	15-17°C
0.01 cm/day	at temperatures between	10-14°C

Quantitative information relating discharge and turbidity to growth is lacking. However, evidence is available that turbulence and reduced visibility have a negative influence on growth. Therefore, discharges above 12,000 CFS were considered to have a negative influence on growth. For the purpose of this analysis, growth was estimated to be reduced by 50 percent during periods when discharge approached or exceeded 12,000 CFS. Survival during summer and over winter was considered to be positively correlated with size at the end of the growing season. Size at the end of the growing season was estimated as length accrued during the period of active growth and length before growth started (15 mm).

Estimated Spawning and Early Development Success

During 1973 temperatures, discharge, and turbidity were generally below average during May and June (Figure 2.3-5). Temperatures promoting nest construction were reached on May 19. Peak spawning was estimated to occur on May 25, when discharge had declined to a low for the period of 5,600 CFS (Figure 2.3-5; Table 2.3-2). Discharge, however, started to increase on May 27 and reached a peak of 8,008 CFS about May 30. During this period turbidity reached 17 NTU and temperatures remained at approximately 14.8°C. The reduced temperature, increased current, and high turbidity probably promoted nest abandonment and poor embryo survival. Discharge and turbidity declined after May 28, and temperatures rose to 20°C by June 8, which probably stimulated a second nesting and good survival of any fry that survived the incubation period from the first spawning. Conditions

remained good after June 8 for survival of embryo and fry phases. Temperatures during the summer of 1973 were about normal during June-September, but never reached into the optimum growth range. Discharge exceeded 12,000 CFS after October 12, when temperatures reached 13°C and growth was considered to have ceased. The period of growth was estimated at 133 days (June 10-October 12) for the first spawning and 121 days (June 22-October 12) for fish from the second spawning.

During 1974 discharge remained above 12,000 CFS until June 1, when it dipped to an average of 11,700 CFS for 6-7 days. Nest construction in protected areas was estimated to occur at this time, with a spawning peak occurring approximately June 5. Discharge began to rise on June 7 and reached 16,221 CFS by June 12. Discharge declined slowly from that date and fell below 12,000 CFS by June 22. The high discharges are predicted to have resulted in below average survival of embryo and fry in the nest and poor survival of the black fry stage. A second nesting period is predicted to have begun on June 22. Although discharge was high at this time, it declined and subsequent temperatures were in the range which promoted rapid incubation and fry development. The delay spawning and low October temperatures (10°C on October 1) would have resulted in a short growing season and poor survival during later development stages, even though July temperatures fell in the optimum growth range.

Discharge on May 1, 1975 was 40,668 CFS and did not drop below 12,000 CFS until June 1 when nest construction was considered to have begun in protected areas. Temperatures were above 20°C at this time, and peak spawning is expected to have occurred around June 3. Discharge continued to decline from June 3 through June 11 when it reached 6,094 CFS. However, temperatures declined below average to 17°C prolonging the incubation and nest fry stages. The black

fry stage is predicted to begin around June 14, when discharge began to rise to a peak of 11,405 CFS which occurred June 24. Turbidity was above average (10-12 NTU) during the predicted black fry stage. The high discharge and turbidity is predicted to have promoted displacement and below average survival during the black fry stage. Discharge remained above 12,000 CFS through July 16, and is predicted to have slowed growth during the period by 50 percent. Temperatures were above average and within the optimum growth range through early August and remained above average during early September. Temperatures fell below 10°C on October 16.

Conditions were optimum for reproduction and early development during 1976 (Figure 2.3-6). Temperatures reached 15°C by May 9 when discharge was 2,500 CFS and falling. Based on the thermal conditions prior to that date, the spawning peak is predicted to have occurred on May 14. Temperatures during and following spawning were above normal and averaged 18.5°C. This would have resulted in a four-day incubation period and a seven-day early fry development stage. Throughout the incubation and early fry development period, temperatures continued to rise, discharge declined to an average of 1,700 CFS, and turbidity remained below normal (3.8 NTU), indicating survival was excellent. Temperatures were above average or average through late September and remained above 10°C until October 10.

Conditions at the beginning of May, 1977 were very similar to 1976, with discharge below 4,000 CFS and temperatures above average. Based on thermal history, spawning can be predicted to have occurred May 5. Average discharge remained low through the early development stages, however, starting on about May 17 and continuing through June, discharge and temperature began to fluctuate in response to rain events. Although discharge never exceeded 4,000 CFS

and temperatures did not drop below average, turbidity was abnormally high and reached 25 NTU. This turbidity may have resulted in considerable fry displacement. Temperature and discharge remained in the optimum range for growth through most of July, but temperatures were below normal during August and September. Temperatures dropped below 10°C after October 10.

Temperatures reached 15°C on May 14, 1978 when discharge was 6,366 and dropping. Peak spawning was predicted to occur May 19. Conditions continued to be excellent into the black fry stage, when discharge increased rapidly to 9,670 CFS during the period May 29-June 4. Turbidity increased (7.4 NTU) and temperatures fell below average during the period suggesting considerable fry displacement occurred. Discharge fluctuated and declined toward the average in late June, but climbed above 12,000 CFS in early July when temperatures were well below normal. Temperatures were also below normal during August and discharge remained above normal (6,000-9,000 CFS).

During 1979 discharge did not drop below 12,000 CFS until May 27, which was also the approximate date that temperatures surpassed 15°C. Based on the thermal history, spawning was estimated to occur 6 days later. Temperatures ranged between 17-19°C during the period following spawning, and incubation and early fry development were estimated to require 5 and 7 days, respectively (Table 2.3-2). Temperatures fluctuated but remained below normal while discharge declined toward the normal level during the early development period. However, on June 17, discharge began a steady increase and reached 12,117 CFS by June 25. Turbidity was measured at 23 NTU on June 29, and the combined effects of turbidity and discharge are predicted to have induced considerable fry displacement. Temperatures were below normal during July and August and dropped below 10°C October 8.

Temperatures reached the lower end of the preferred spawning range by April 28, 1980 when discharge was 5,993 CFS and declining. Based on thermal history, spawning was predicted to peak seven days later. However, temperatures dropped below 15°C May 4 and did not exceed that temperature again until May 15. The reduced temperatures expanded the period of development, and were predicted to cause nest abandonment and poor survival. Based on temperature, a second spawning could be expected to have occurred May 22. Discharge during the period was below 3,000 CFS, and temperatures were above normal promoting rapid incubation and early fry development. Discharge began to increase May 28 and reached 4,730 CFS by June 8. This rise resulted in a temperature decline to the eight years norm but turbidity remained below normal. The rise in discharge is expected to have caused some displacement of fry. Discharge remained low throughout the major growth period, and temperatures were average or above through early September when discharge rose above 7,000 CFS. Temperatures remained below 10°C after October 10.

Estimated Overwinter Survival and Year-Class Strengths

Estimates of total length and the end of the growing season were based on laboratory data developed under conditions of a continuous food supply. It is probable, however, that the small size of young spawned at later dates limited the range of forage sizes available to them restricting their food consumption and growth. If food availability was lower for smaller fish it is likely that real size differences would be greater than indicated by the estimates given in Table 2.3-2. Because both spawnings in 1973 occurred fairly early, growth was good and winter (period below 10°C) was not extended (189 days); survival was expected to be average or above and year-class strength was ranked as good. Winter length was extended (200 days) in 1974, and survival and

growth during the summer was not good; therefore, year-class strength was ranked as weak. The year-class produced during 1975 was also ranked weak due to poor survival during early development and poor growth during the summer, although winter length was short (178 days). The combination of successful spawning, early development, rapid summer growth, and a short winter (176 days) during 1976 should have promoted development of a dominant year-class. A good year-class should have developed during 1977 as a result of the early spawning, although summer temperatures were not excellent for growth and the winter period was long (197 days). High water, poor growth, and extended winters during 1978 (213 days) and 1979 (191 days) were predicted to result in weak year classes. The 1980 year-class was ranked as strong as a result of the expected excellent survival and good growth, although winter length is yet to be determined.

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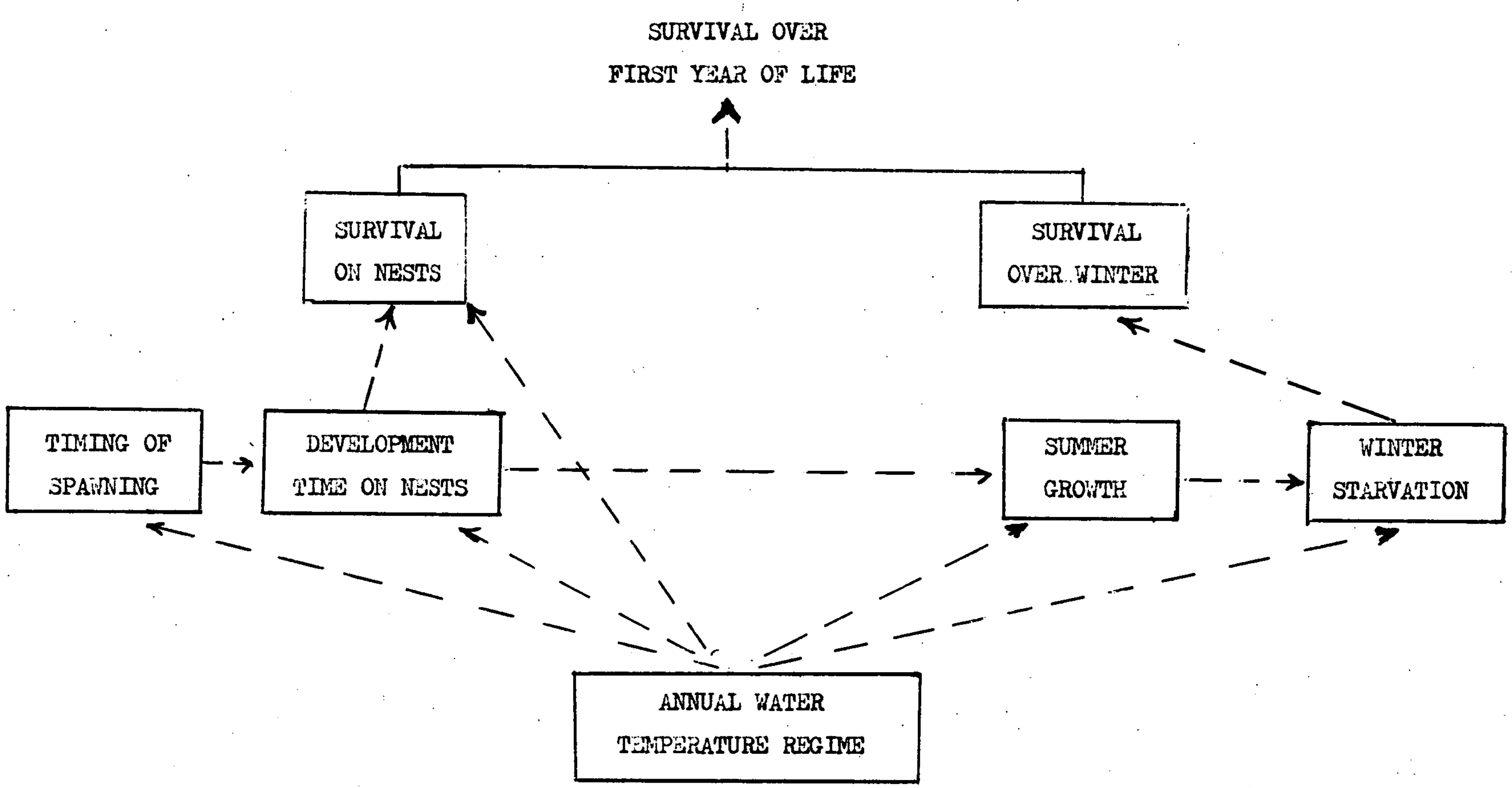


Figure 2.3-1. Schematic outline of the model of the influence of the annual water temperature regime on first-year survival of smallmouth bass (Shuter et al. 1980).

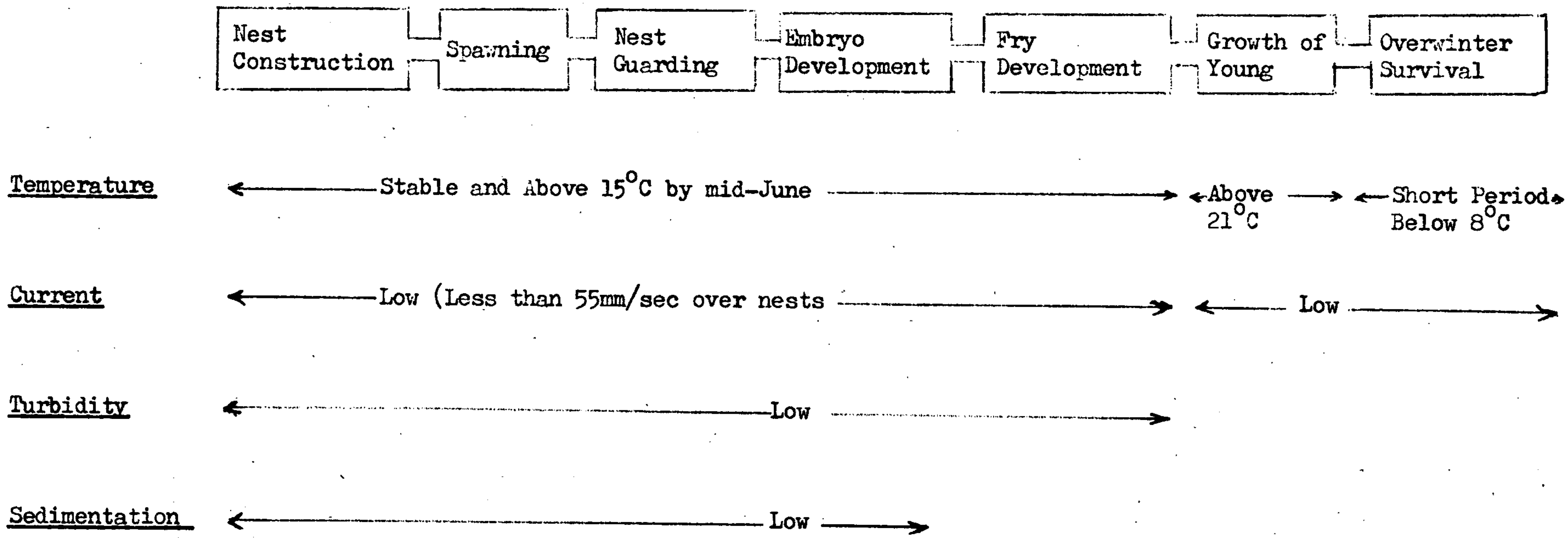


Figure 2.3-2. Schematic diagram of the reproductive and developmental phases (compartments) important to year-class survival in smallmouth bass with habitat conditions suggested by the literature to promote strong year-classes.

Figure 2.3-3. Average discharge (CFS) and temperature (°C) in the Mississippi River near Monticello, Minnesota for the period 1973-1980.

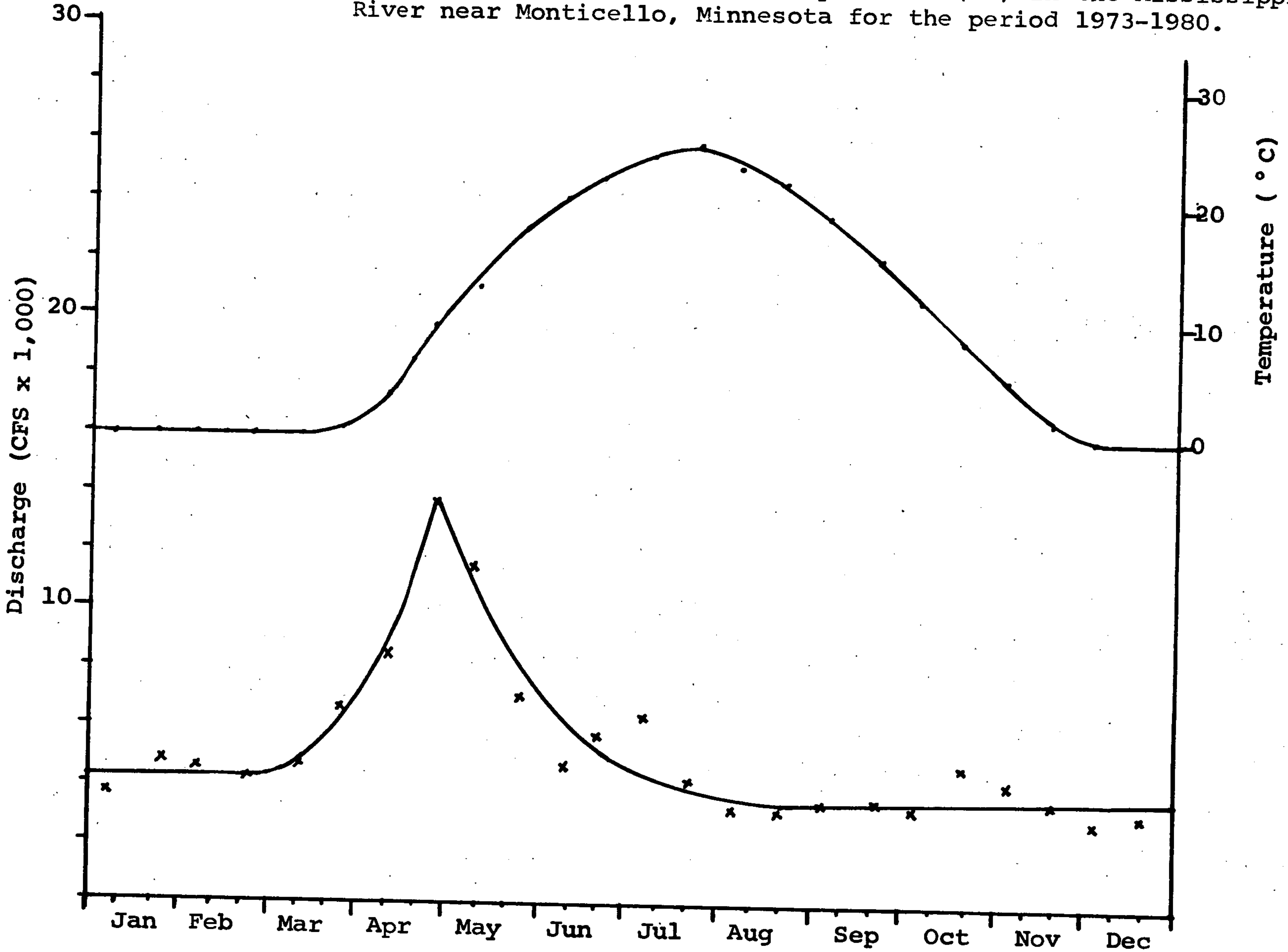
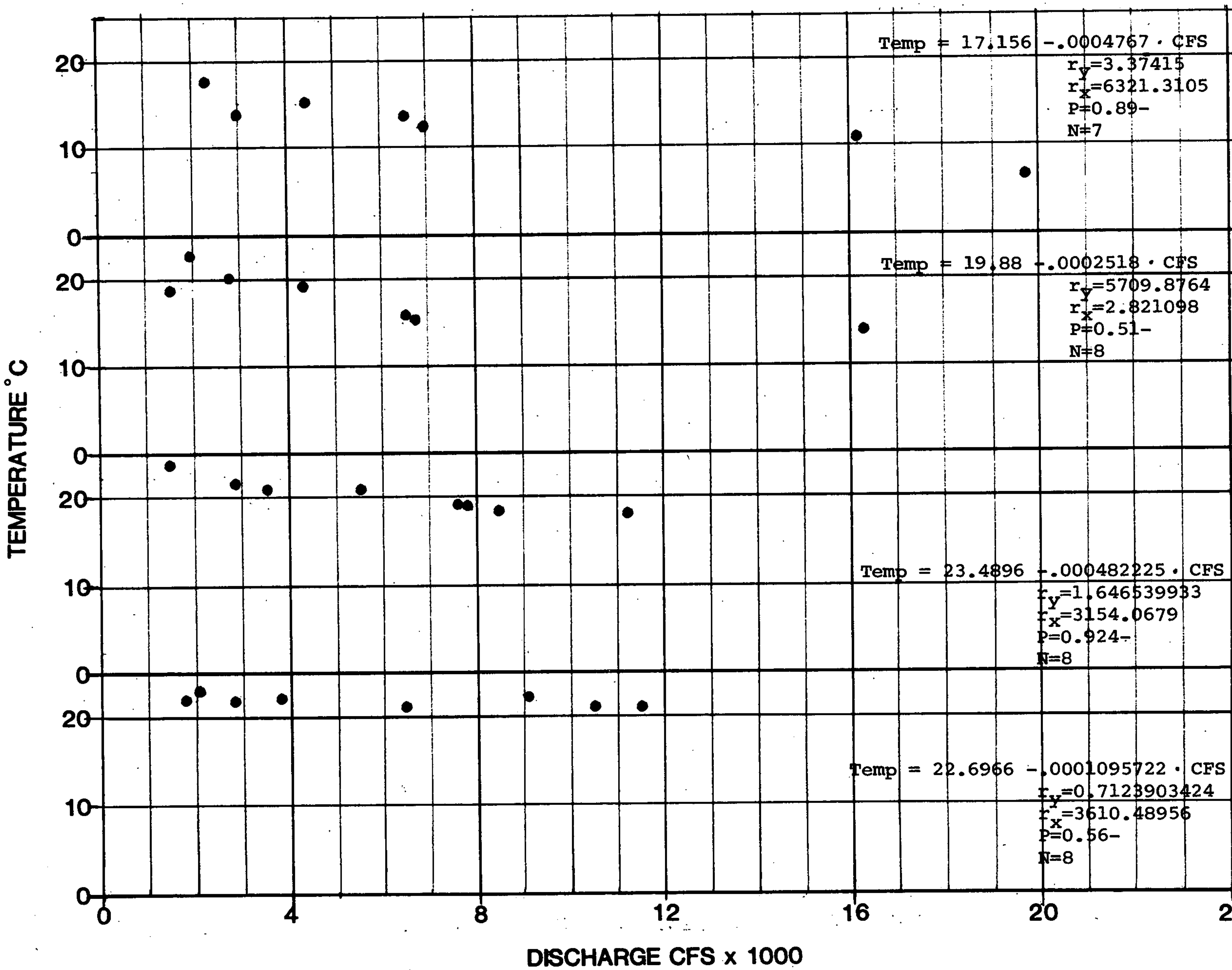


Figure 2.3-4. Relationship between average discharge and temperature during May and June.



May 1-15		
1973	6929	12.2
1974	16425	11.1
1975	32579	11.1
1976	3067	13.8
1977	2512	18.3
1978	6712	13.9
1979	19849	6.7
1980	4448	15.5

May 16-30		
1973	6515	15.6
1974	16334	13.9
1975	16592	18.9
1976	1482	18.3
1977	1868	23.3
1978	4865	19.4
1979	5706	15.5
1980	2706	20.0

May 31-June 14		
1973	5586	21.1
1974	11361	18.8
1975	8624	18.8
1976	1478	23.9
1977	2750	21.6
1978	7974	19.4
1979	7886	19.4
1980	3647	21.1

June 15-29		
1973	2821	22.2
1974	11627	21.1
1975	9500	21.6
1976	1625	22.2
1977	2157	23.3
1978	6416	21.1
1979	9333	22.7
1980	3730	22.2

Figure 2.3-5. Relationship between normal and 1973 temperature and discharge.

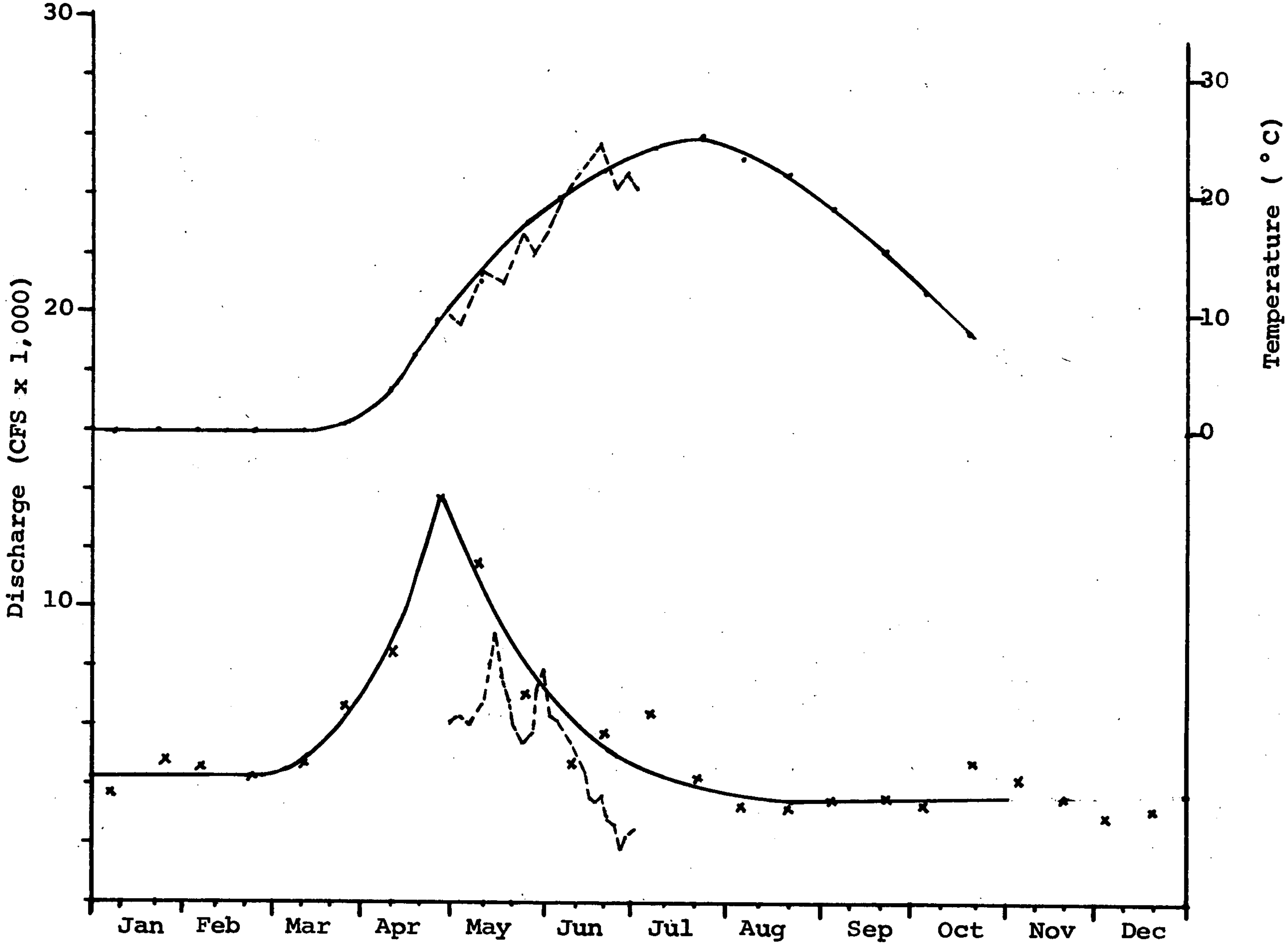


Figure 2.3-6. Relationship between normal and 1976 temperature and discharge.

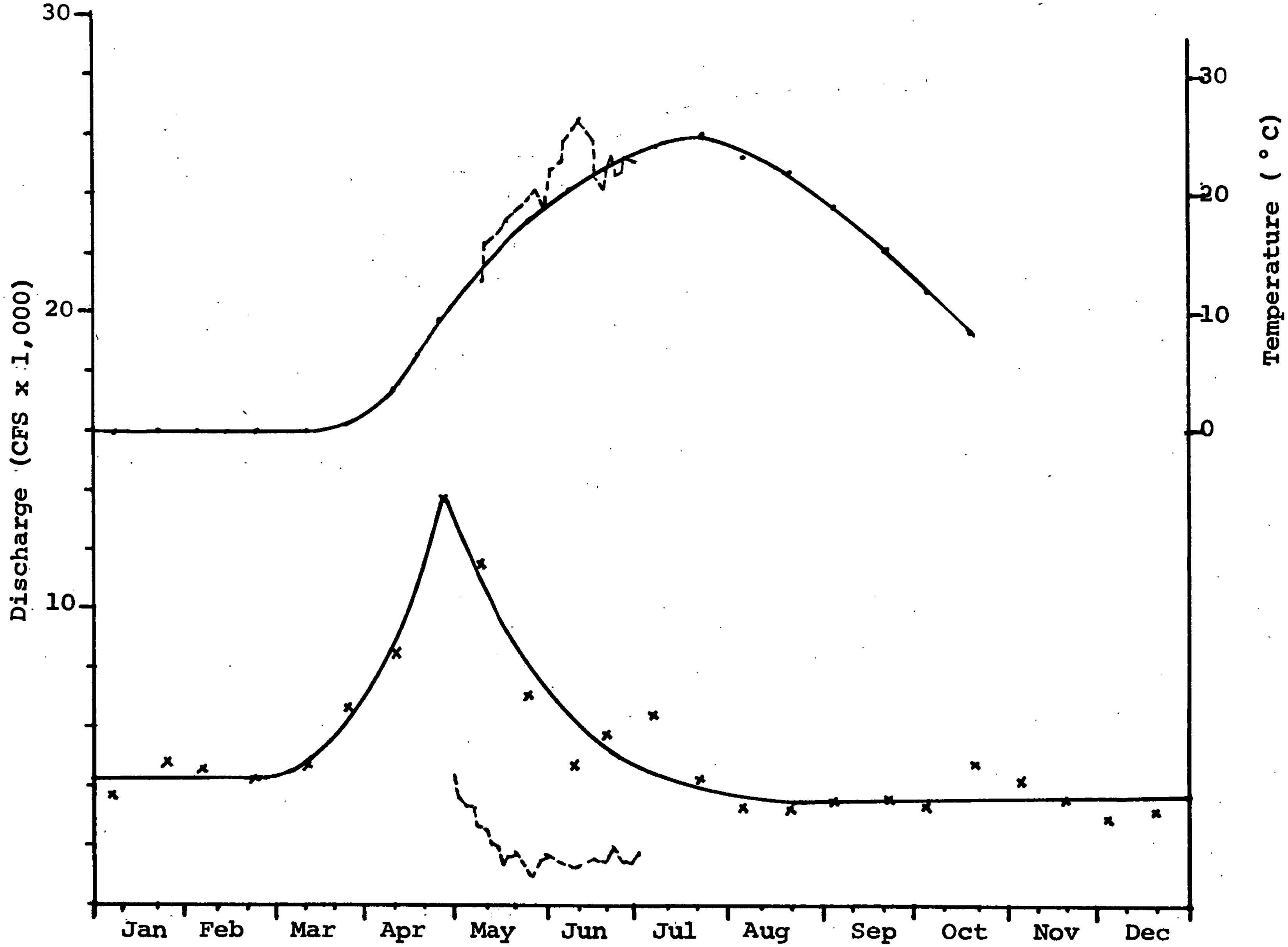


Table 2.3-1.

Mean Turbidity (NTU) and suspended solids (mg/l) in the Mississippi during winter (December-February) and during the reproductive (May-June) and growth periods (July- September) of smallmouth bass.

Year	Period					
	Winter		Reproduction		Growth	
	NTU	mg/l	NTU	mg/l	NTU	mg/l
1973	2.5	9.5	8.9	47	4.2	29
1974	1.6	18.0	13.3	41	not available	
1975	1.6	9.9	5.5	26	7.0	69
1976	3.8	8.7	3.6	71	6.0	39
1977	2.1	5.5	13.5	45	7.4	39
1978	3.3	16.5	8.4	46	11.1	37
1979	2.1	11.1	14.8	99	9.6	54
1980	3.4	12.5	5.2	21	not available	
Mean	2.6	11.5	9.2	50	7.6	45

Table 2.3-2.

Predicted reproductive development and survival success of smallmouth bass in the Mississippi based on the stage effects.

	Nesting Peak (date)	Spawning (date)	Incubation Period (days)	Incubation Success (rank)	Fry in Nest Period (days)	Fry in Nest Survival (rank)	Black Fry Survival rank	Growth Period (days)	Growth Size (mm)	Summer-Winter Survival rank	Year-Class Rank
1973 First	5/19	5/24	6	Below Average	6	Good	Good	133	112	Good	Good
Second	6/08	6/10	3	Good	4	Good	Good	112	100	Average	
1974 First	6/01	6/05	3	Below Average	5	Below Average	Poor	103	107	Average	Weak
Second	6/21	6/25	3	Average	4	Average	Average	79	83	Poor	
1975 First	6/01	6/04	4	Average	7	Average	Below Average	118	97	Below Average	Weak
1976 First	5/09	5/14	4	Excellent	7	Excellent	Excellent	130	135	Excellent	Dominant
1977 First	5/06	5/11	3	Excellent	6	Excellent	Average	138	113	Good	Good
1978 First	5/14	5/19	4	Excellent	6	Excellent	Below Average	133	96	Below Average	Weak
1979 First	5/27	6/2	5	Average	7	Good	Below Average	141	92	Below Average	Weak
1980 First	4/28	5/05	7	Poor	10	Poor	Excellent	143	138	Excellent	Strong
Second	5/15	5/22	3	Excellent	5	Excellent	Average	126	121	Good	