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SECTION 316(b) DEMONSTRATION FOR THE MONTICELLO NUCLEAR GENERATING PLANT ON THE MISSISSIPPI RIVER AT MONTICELLO, MINNESOTA (NPDES PERMIT NO. MN 0000868)

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1. STATEMENT OF THE PROBLEM

The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), Section 316(b), require that cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. Adverse impact can result from entrainment and impingement of aquatic organisms at water intakes. Entrainment is the withdrawal of organisms into the cooling water system. It involves organisms which are small enough to pass through the intake screen mesh, primarily planktonic forms such as phytoplankton, zooplankton, ichthyoplankton and benthic drift organisms. Mortality of entrained organisms can vary, depending on the organisms and the characteristics of the system, from considerably less than 100% in most open systems to nearly 100% in closed systems.

Impingement occurs when organisms too large to pass through the mesh of the intake screens become trapped against them by the force of the intake current. These larger organisms are predominantly fish which may tire or become injured, or are unable to escape. High impingement mortality often results from natural die-offs or weakening of fish prior to impingement (Edsall and Yocum 1972; Quirk, Lawler and Matusky 1974) or from cold-induced lethargy (EPA 1976a, USAEC 1972).

According to EPA (1976b) "Regulatory agencies should clearly recognize that some level of intake damage can be acceptable and thus represents a minimization of environmental impact." This demonstration provides a "best possible estimate of what damage is or may be occurring" and relates this to population levels and natural variability of the indigenous Mississippi River populations near the Monticello Nuclear Generating Plant (MNGP).

2. SUMMARY

Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 requires cooling water users to determine biological effects of their intake systems and to demonstrate that the design, construction, location and operation of the intake systems reflect the best technology available. Under the National Pollutant Discharge Elimination System (NPDES), Section 402 of P.L. 92-500, Minnesota has been given the authority to administer the law using the 316(b) amendments and Minnesota Regulation WPC(u)(3).

The Minnesota guide for the administration of Section 316(b) requires the demonstrator to show the environmental effects of cooling water intakes through documentation of the magnitude of impingement and entrainment impacts (MPCA 1975). Supplemental information on the aquatic ecosystem in the region of the intake is also requested. In this Section 316(b) Demonstration, Federal and State requirements have been addressed by providing the analysis of entrainment and impingement at the Monticello Nuclear Generating Plant (MNGP) and by providing extensive baseline data for the area.

Northern States Power (NSP) has conducted ten years of studies of the Mississippi River ecosystem near MNGP, including three years of preoperational studies. The waters of the Mississippi River are generally considered to be of good quality and to support a healthy and abundant flora and fauna.

This Demonstration is primarily based upon the study of entrainment, impingement and waterbody populations of young fish at MNGP during April 1976-April 1977. This period encompassed some of the lowest flows in the Mississippi River in decades. Consequently, during the study year the plant withdrew relatively high percentages of river water and, along with the cooling water, entrainable organisms.

Phytoplankton is the only community of primary producers that could be significantly impacted by MNGP intake operation. However, phytoplankton is less important to the trophics of the Mississippi River in the MNGP area than periphyton. Periphyton, which has been estimated to contribute from 60 to 82% of the primary production in the aquatic environment near MNGP, is not subject to significant entrainment because it is usually attached to the river substrates.

In the April 1976-April 1977 study year, 19% of the phyto-plankton passing MNGP may have been entrained. Considerably less than 19% would have been impacted since, especially during open cycle operation, survival of entrained algae would be high. Considering the low level of impact, the secondary importance of phytoplankton to the trophic structure of the river and the rapid regeneration times of algae, operation of the MNGP intake does not represent a threat to primary production in the Mississippi River near MNGP.

Approximately 19% of the zooplankton flowing past MNGP may have been entrained during the study year. A considerably smaller percentage of the river zooplankton was impacted since, especially during open cycle operation, a high survival of entrained zooplankters is expected. The trophic importance of zooplankton in the Mississippi River near MNGP is limited due to the low numbers of crustaceans in the community and the limited number of organisms that feed on zooplankton. Considering the predicted rapid downstream recruitment of zooplankton from benthic habitats and protected shoreline areas, the rapid reproductive rates of the protozoans and rotifers that likely dominate the community and the limited trophic significance of zooplankton in the river, operation of the MNGP intake is not considered to have a serious impact on this portion of the aquatic ecosystem.

Benthic macroinvertebrates may be entrained when they drift or are dislodged by high flows. Drift studies near MNGP indicate that numerically the entrainable fauna is composed of 37% mayflies, 28% stoneflies, 30% true flies and 5% other groups. Based on drift densities in 1973-1974 and the flows during the study year, over one billion organisms could have been entrained at MNGP from April 1976-April 1977. Considering that drift constitutes a small proportion of the benthic community and that only 19% of the drift in the area may have been entrained (assuming random distribution of drift in the water), MNGP intake operation is not considered a serious impact to the benthic communities of the MNGP area.

The effects of entrainment and impingement on fish communities are a major consideration in assessing the impact of plant operation. The loss of adult fish due to entrainment of eggs and young at MNGP was estimated by using a simple population model described. Losses from impingement were estimated by using a similar model, since most of the fish impinged were young. The total impact was evaluated by considering the combined effects of impingement and entrainment. Total calculated adult losses were compared with sport fishery statistics and population estimates, when available.

Sport fish (northern pike, rock bass, smallmouth bass, black crappie and walleye) represented less than 0.1% of the total estimated loss of adult fish (256,003-261,462 fish). Between 36 and 60 smallmouth bass, or about 21% of the annual sport harvest for the area near MNGP, were estimated to have been lost due to entrainment and impingement. Estimated losses of 18 to 230 adult black crappie represented about 50% of the sport harvest. These losses are not considered significant because of the very light fishing pressure and resulting low harvests for the stretch of the Mississippi River near MNGP. Losses of northern pike and walleye were less than 5% of the average annual harvest.

Forage fish, mainly logperch, accounted for nearly 94% of the estimated loss of all adult fishes. The estimated loss of 218,000 adult logperch represented about 45% of the estimated spawning population in a 1.8 ha (4.4 ac) area upstream of the MNGP intake. Losses of this magnitude are considered insignificant, based on the minimal impact that comparable percent removal of forage species (mainly minnows) have had in other rivers.

Rough fish, primarily silver and shorthead redhorse, composed about 6% of the estimated adult loss. Losses of shorthead redhorse were estimated at 35 to 40% of the 1968 and 1969 adult population and 19 to 25% of the estimated 1976 adult population. Entrainment and impingement of redhorse in the 1976-1977 study period were considered extremely high when compared to previous operational years. The high redhorse losses in 1976-1977 were attributed to a very successful 1976 year class. MNGP had not had a serious effect on redhorse populations in previous years and it is postulated that the effect of 1976-1977 losses would not be detectable for several years, if at all.

The operation of the MNGP intake does not appear to have damaged the fish community of the Mississippi River near MNGP since it began operation in 1971. With the possible exception of the redhorses (see above), losses during the 1976-1977 study are not expected to have a measurable impact on the fish populations in the vicinity of MNGP. Continued operation of the MNGP intake should not affect the propagation of the balanced indigenous aquatic communities of the Mississippi River.

3. DESCRIPTION OF THE PLANT

The Monticello Nuclear Generating Plant (MNGP), a single unit, boiling water reactor plant, is a baseload facility that contributes a net electrical generating capacity of 545 megawatts to the Northern States Power Company's (NSP) network. Condenser cooling water is obtained from the Mississippi River. Commercial operation began in July 1971.

3.1 LOCATION OF PLANT

MNGP is located on the Mississippi River in Wright County about 5 km (3 mi) northwest of the town of Monticello (Figure 3.1-1). The plant is situated on about 536 ha (1,325 ac), most of which has been leased by NSP to farmers.

3.2 INTAKE DESIGN

Water withdrawn from the Mississippi River passes under a floating catwalk/log boom into the intake approach. The log boom prevents floating debris from entering the approach (Figure 3.2-1). Intake water passes through an approach approximately 30 m wide and 18 m long (98 x 59 ft) that is oriented at a 9° angle in an upstream direction from the bar racks. The water passes through a concrete channel (approximately 19 m or 62 ft wide and 5 m or 16 ft long before

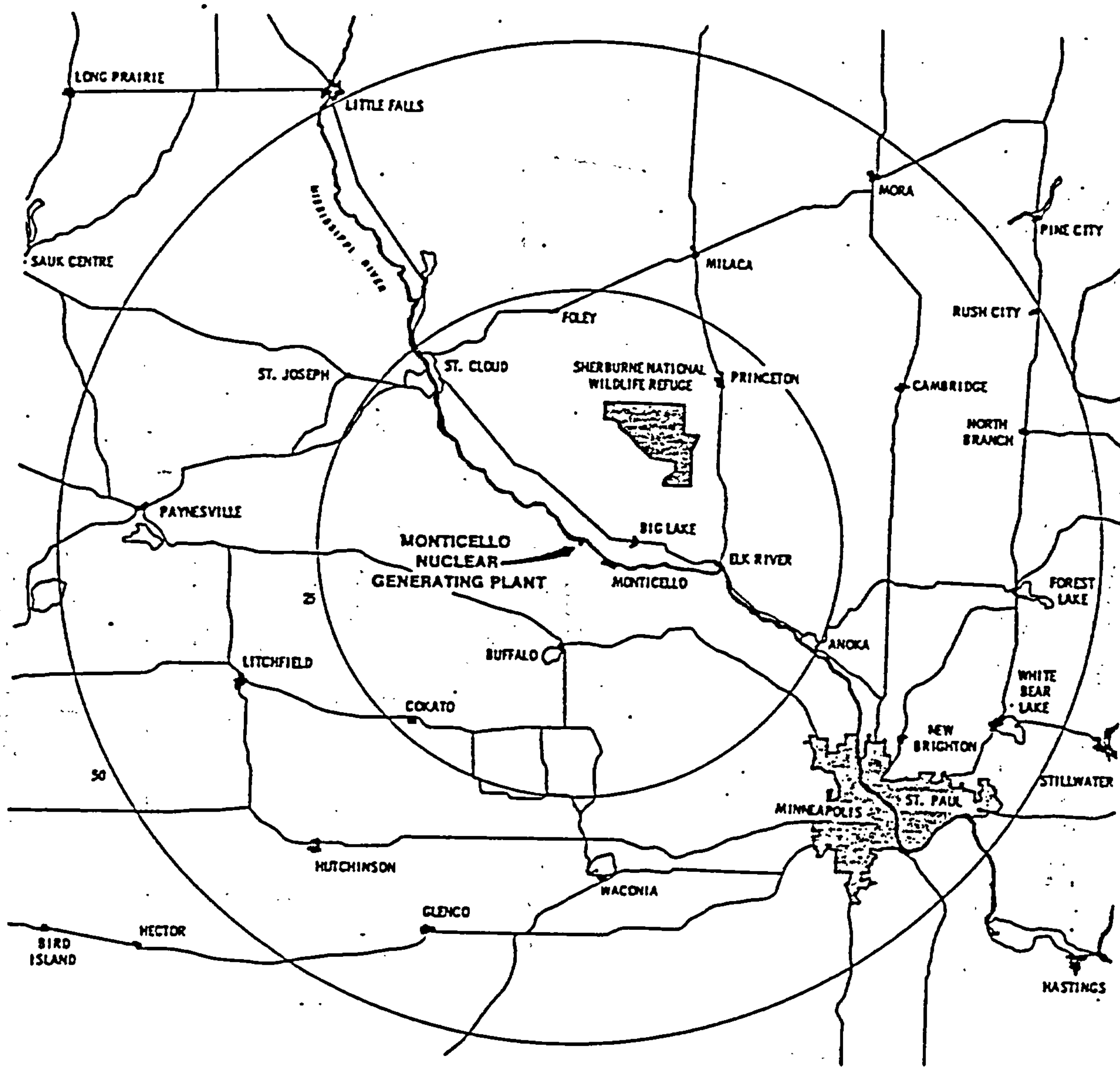


FIGURE 3.1-1

LOCATION OF MNGP

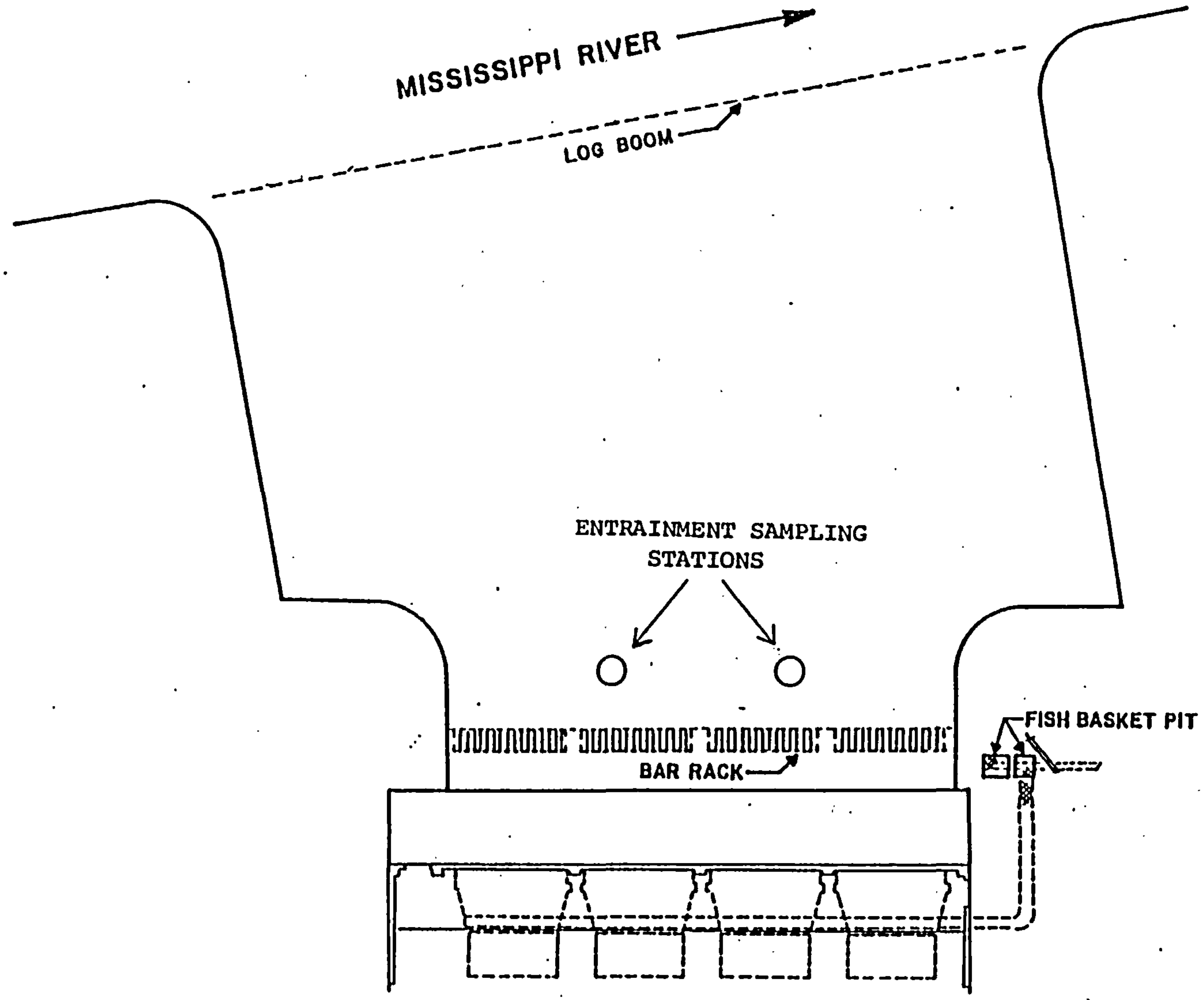


FIGURE 3.2-1

PLAN VIEW OF MNGP INTAKE

reaching the bar racks. The approach is dredged to maintain a bottom elevation of 273 m (896 ft) MSL. River elevation varied between 277 m (910 ft) and 275 m (903 ft) during the April 1976-April 1977 study year; calculated depth in the intake approach varied from 4.4 to 2.3 m (14 to 7.4 ft). Actual depths were somewhat less due to sedimentation of sand and silt washed in from the river.

A concrete sill (elevation 274 m or 899 ft) extends across the intake approach in front of the bar racks. A removable stop-log in the sill allows intake flows when the river is low. A surface to bottom bar rack with 7.6 cm openings prevents the entrance of large debris. Four vertical traveling screens (0.95 cm or 0.375 inch mesh; 64% open area) are positioned 3 m (10 ft) behind the bar rack to remove fine debris. The traveling screens are normally rotated and rinsed each 8-hour shift and run continuously when debris loading is high. Automatic rotation and rinsing can be triggered automatically by heavy debris loads. The debris is rinsed into a common sluiceway which extends to the river downstream of the intake and returns impinged organisms to the river. The flow in the sluiceway can be diverted into either of two collecting baskets (0.95 cm or 0.375 inch mesh) located next to the intake channel.

Cooling water for the condensers at MNGP is moved by two circulating water pumps housed in the intake structure. These pumps produce a flow of 17.7 m^3/sec (624 cfs or 280,000 gpm) during combined (two pump) operation and 11.0 m^3/sec (388 cfs or 174,000 gpm) during individual (one pump) operation.

Additional water is taken from the service pump bay (located in the intake structure) by the screen wash, make-up, residual heat removal, station cooling and fire protection pumps.

Make-up water is supplied by two 0.9 m^3/sec (31 cfs or 14,000 gpm) pumps only during closed cycle operation. These pumps replace water lost to the circulating water system by cooling tower evaporation, drift and blowdown.

The station cooling and fire protection systems together move a maximum of about 0.5 m^3/sec (19.1 cfs) of water. A 36-inch de-icing line runs from the condenser discharge line to the intake structure. When water temperatures approach freezing, the warm effluent can be delivered to the intake structure to keep the area ice-free. Steam can also be delivered to the intake structure for this purpose. The de-icing water is introduced at a point approximately 3.4 m (11 ft) ahead of the bar rack.

3.3 OPERATING MODES

The circulating water system of MNGP has been designed to allow operation in any one or a combination of four modes:

- o once-through (water circulated from and discharged directly to the Mississippi River),

- o helper cycle (cooling towers operating and cooled water discharged from the towers to the river),

- o partial recirculation (cooling towers operating; a portion of the cooled water recirculated back to the intake and a portion discharged to the river), and

- o closed cycle (cooling towers operating; all cooled water recirculated back to the intake).

During open cycle operation, cooling water is circulated from the river intake structure through the condenser to the discharge structure. The water then enters a discharge canal 305 m (1,000 ft) long and returns to the river about 457 m (1,500 ft) downstream from the intake (Figure 3.3-1).

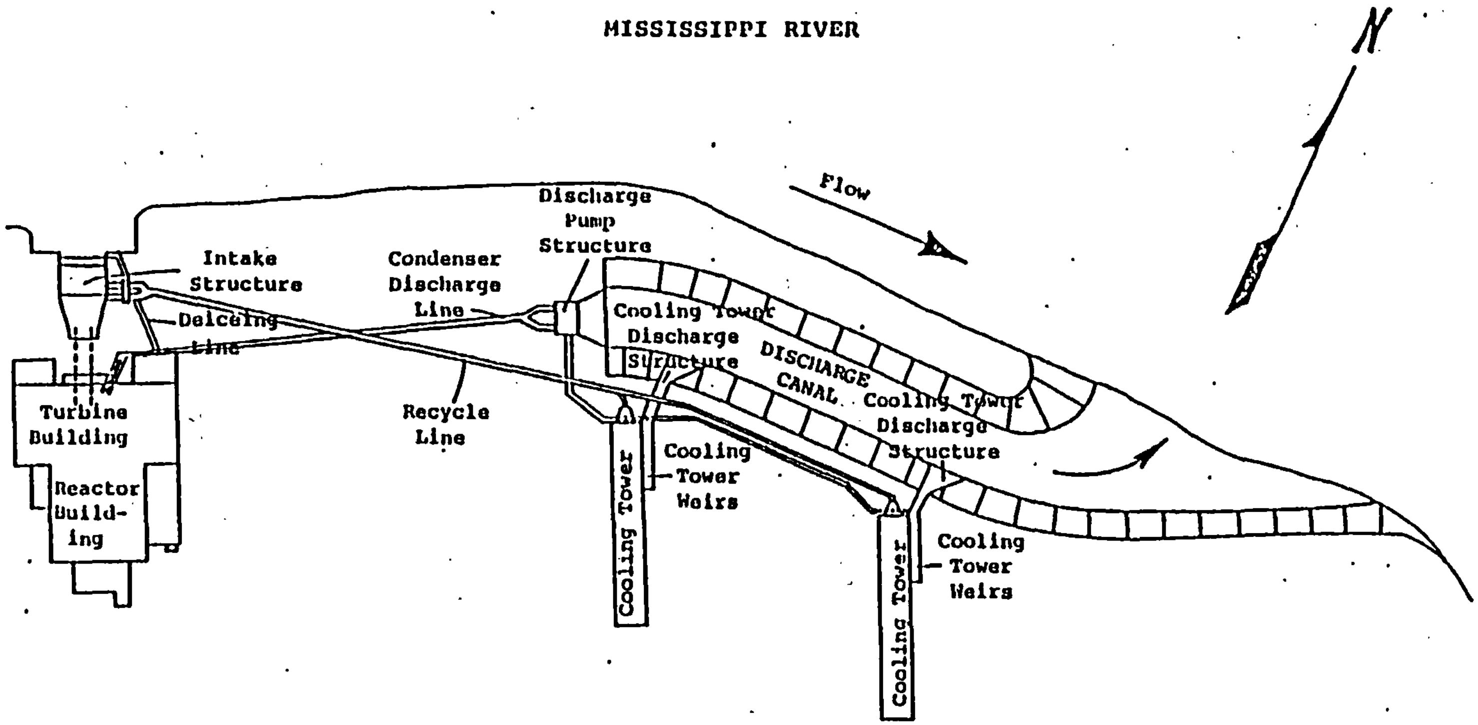


FIGURE 3.3-1

MNGP CIRCULATING WATER SYSTEM

For the three remaining modes of operation, MNGP is equipped with two induced-draft cooling towers which are designed to remove heat rejected to the circulating water system over the range of expected operating loads. The system provides sufficient operational flexibility to return either all, part, or none of the cooled water to the circulating water pump intake (representing closed cycle, partial recycle and helper cycle, respectively). Conversely, none, part, or all of the cooled water may be returned directly to the river via the discharge canal.

During closed cycle operation with full cooling tower capacity, the circulating water flow is isolated from the river by closing the control gates at the inlet and discharge structures. During such operations the control gates in the recirculation lines in the cooling tower basins are open. Recirculating water is introduced to the cooling system inside the traveling screens, except for a small flow diverted to the de-icing line in winter. Operation in the closed cycle and partial recycle modes is intended for periods of low river flow when plant appropriation of water is limited by the terms of the Minnesota Department of Natural Resources (MDNR) permit. This permit dictates that when river flow at the plant is less than 24 m^3/sec (860 cfs) but greater than 7 m^3/sec (240 cfs), the maximum allowable appropriation from the river shall not exceed 75% of the river flow at the intake. During river flows above 24 m^3/sec, the plant may withdraw no more than 18 m^3/sec (645 cfs).

The recirculation gates may be partially opened to allow variable recirculation. Therefore, with the cooling towers operating, the operating mode may vary from helper cycle to full closed cycle, depending upon the amount of flow being recirculated to the intake. For example, when the river flow at the intake is very near but less than 24 m^3/sec, the amount of flow recirculated is minimal since nearly all of the 18 m^3/sec flow (the plant's average water requirement) is available from the river. As the allowable appropriation decreases, the amount of flow recirculated must increase. Therefore, at extremely low river flows the operating mode approaches a fully closed cycle operation.

The recirculating water system is operated on helper cycle by closing the recirculation gates and returning water from the cooling tower basins directly to the river via the basin overflow weirs and the cooling tower discharge structure.

Open cycle operation (cooling towers not in service) is used during all cold weather months, except as required to comply with the MDNR permit relative to maximum water appropriation. When appropriation must be restricted, the plant will recycle some water which, in turn, requires cooling tower operation.

Helper cycle operation is used during the warm months of the year, consistent with NSP agreement with The Minnesota Pollution Control Agency (MPCA) of May 8, 1972. According to this agreement, cooling towers are operated in the helper cycle mode whenever river temperatures consistently exceed 20°C (68°F). This period is generally from late May through early September.

3.4 INTAKE VELOCITIES

The abilities of fish to avoid impingement are related in part to the intake velocities. Velocity profiles were measured in 1972 (Grotbeck and Bechthold 1975) and on July 31 and September 10, 1976 in the present study. Current velocity was measured at the locations shown in Figure 3.4-1. Velocity isopleths are displayed in Figures 3.4-2 and 3.4-3.

Velocities vary with pumping rate and river level. Surface currents in the intake canal appear to move in a clockwise direction, originating at the downstream end of the log boom. Velocities are highest on the downstream side of the

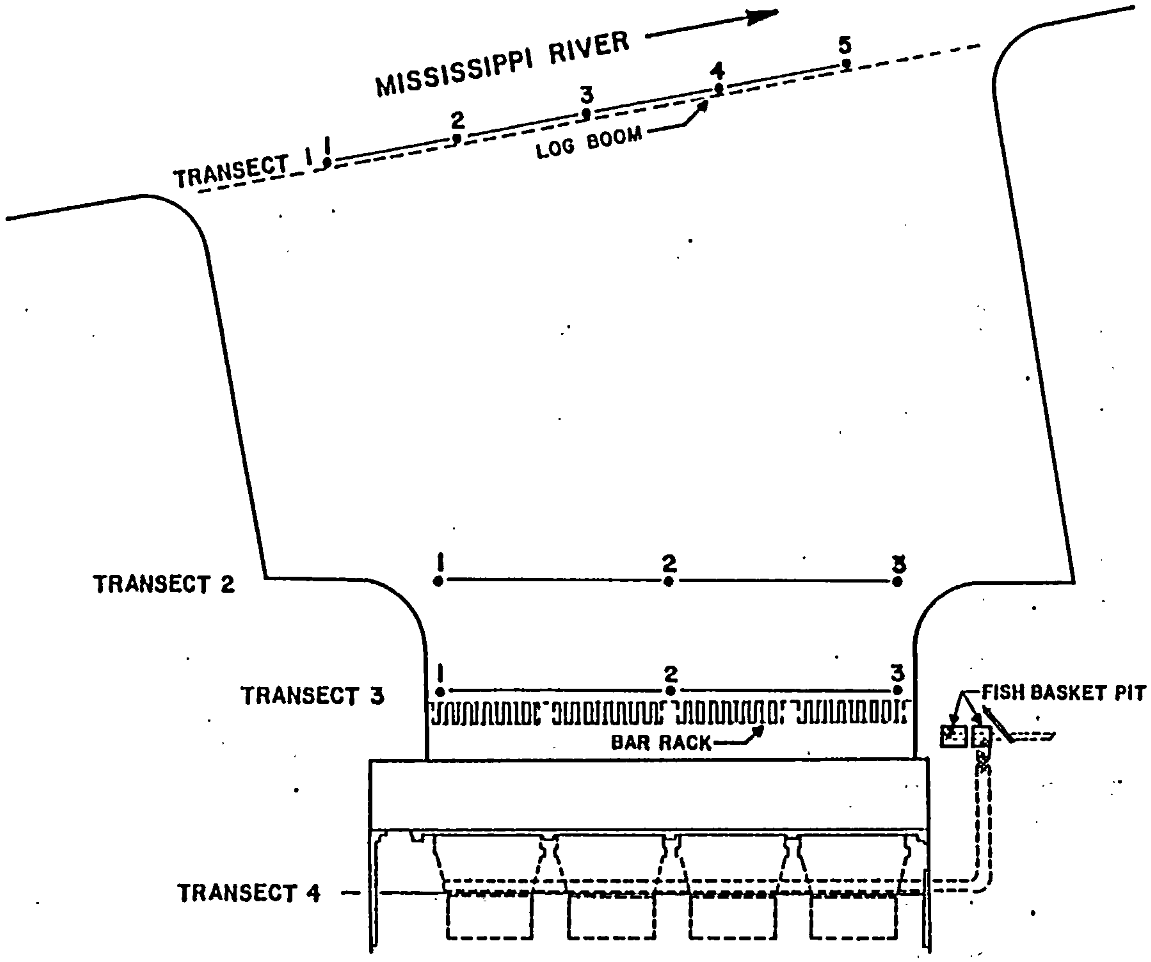


FIGURE 3.4-1

VELOCITY PROFILE TRANSECTS IN MNGP INTAKE

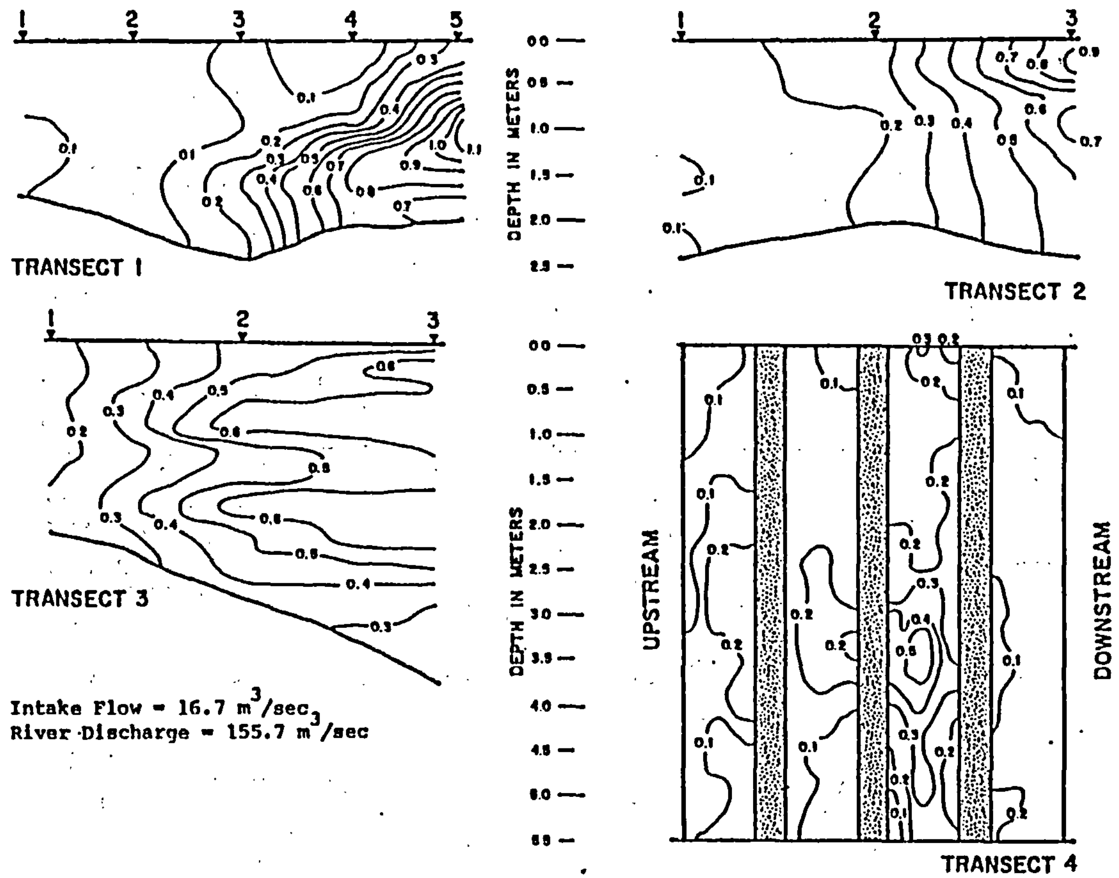


FIGURE 3.4-2

VELOCITY PROFILES (m/sec) IN MNGP INTAKE CANAL, 1972
(From Grotbeck and Bechthold 1975)
(See Figure 3.4-1 for location of transects)

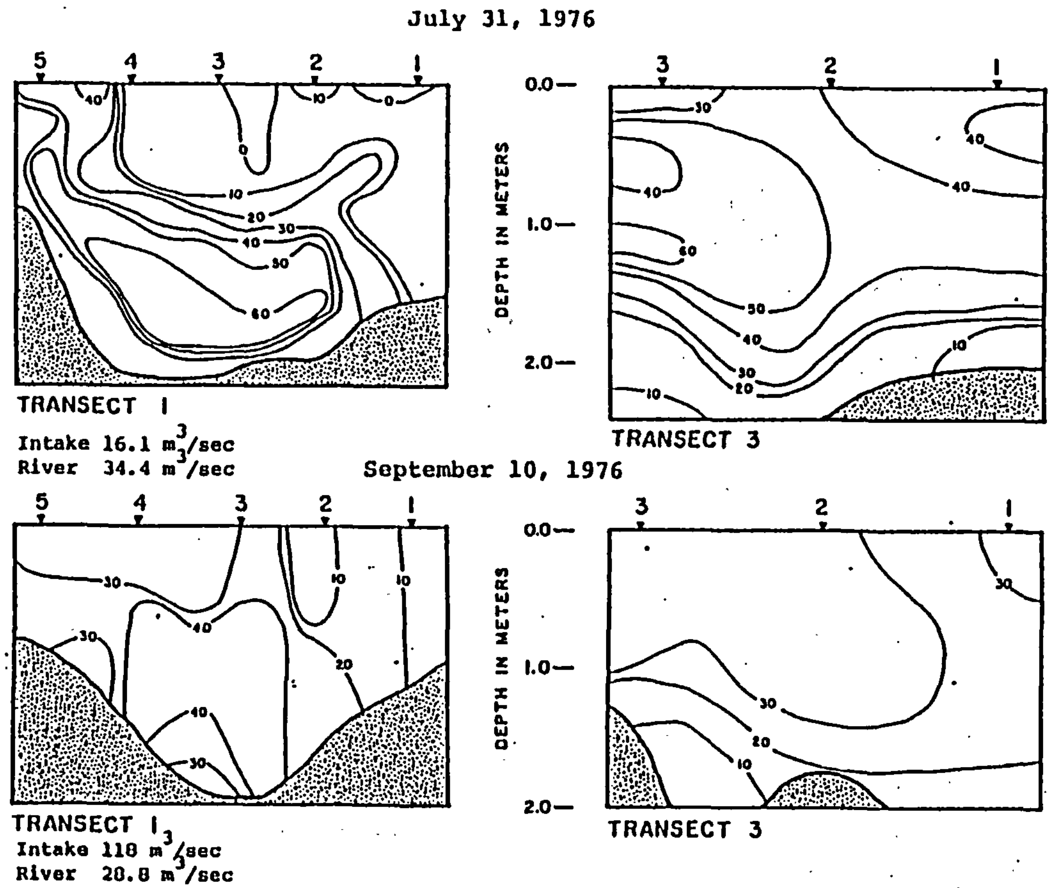


FIGURE 3.4-3

VELOCITY PROFILES (cm/sec) IN MNGP INTAKE CANAL, JULY 31 AND SEPTEMBER 10, 1976
(See Figure 3.4-1 for transect locations)

intake canal, and mostly at depths of 1.2 to 1.5 m (4 to 5 ft). A low velocity eddy occurs on the upstream side of the canal, near the log boom. Approach velocities in front of the bar racks range from less than 10 cm/sec (0.3 fps) to approximately 60 cm/sec (2 fps). Velocities in front of the screens are in the same approximate range. As can be seen in the velocity profiles, velocity varies across the intake canal and with depth.

3.5 INTAKE VOLUMES

Entrainment is directly related to the volumes of water taken into the plant. Impingement has also been correlated to intake volume (EPA 1976b). The maximum daily average pumping rate during the April 1976 - April 1977 study year was 17.7 m^3/sec (626 cfs) (Table 3.5-1). Minimum flow was approximately 0.2 m^3/sec (6 cfs), when only service water was being withdrawn.

During the study year, 3.46 x 10^8 m^3 (122 x 10^{10} ft^3) of water passed through the plant. This volume constitutes an average appropriation of 19.3% of the Mississippi river flow during the period (Table 3.5-2). The monthly maximum, 36% of the river flow, was withdrawn during August 1976 and the minimum, 7%, was withdrawn during April 1976 (Figure 3.5-1).

TABLE 3.5-1

RIVER AND INTAKE FLOWS (m^3/sec) AT MNGP, APRIL 1976-APRIL 1977

	Intake Flow			River Flow		
	Daily Minimum	Daily Maximum	Mean	Daily Minimum	Daily Maximum	Mean
April[a]	16.0	16.4	16.3	159.0	290.8	225.9
May	5.5	17.7	15.6	51.0	159.0	90.5
June	9.6	17.0	15.1	47.8	65.2	54.1
July	15.7	16.5	16.1	30.7	72.9	51.5
August	0.5	16.1	11.9	23.7	38.7	33.1
September	4.1	11.8	7.8	23.7	33.3	30.5
October	0.3	11.0	4.8	28.3	41.6	32.9
November	0.3	7.1	4.6	28.3	54.4	37.7
December	1.9	13.3	7.4	17.7	51.0	31.3
January	11.5	13.7	12.5	21.6	47.8	36.0
February	8.9	12.9	11.7	33.3	65.2	48.0
March	0.2	14.6	11.9	25.9	141.2	82.1
April[b]	12.2	12.8	12.4	77.0	99.2	90.7

[a]Last 17 days only

[b]First 9 days only

TABLE 3.5-2

PERCENT OF RIVER VOLUME WITHDRAWN BY MNGP, APRIL 1976-APRIL 1977

	River Volume (m^3) x 10^7	Intake Volume (m^3) x 10^7	Percent Withdrawn
April[a]	33.17	2.39	7
May	24.24	4.18	17
June	14.03	3.91	28
July	13.80	4.30	31
August	8.87	3.19	36
September	7.90	2.03	25
October	8.82	1.29	15
November	9.76	1.15	12
December	8.39	1.85	22
January	9.63	3.34	35
February	11.62	2.84	24
March	21.98	3.18	14
April[b]	7.05	9.65	14
Total	179.27	34.62	19.3

[a]Last 17 days only

[b]First 9 days only

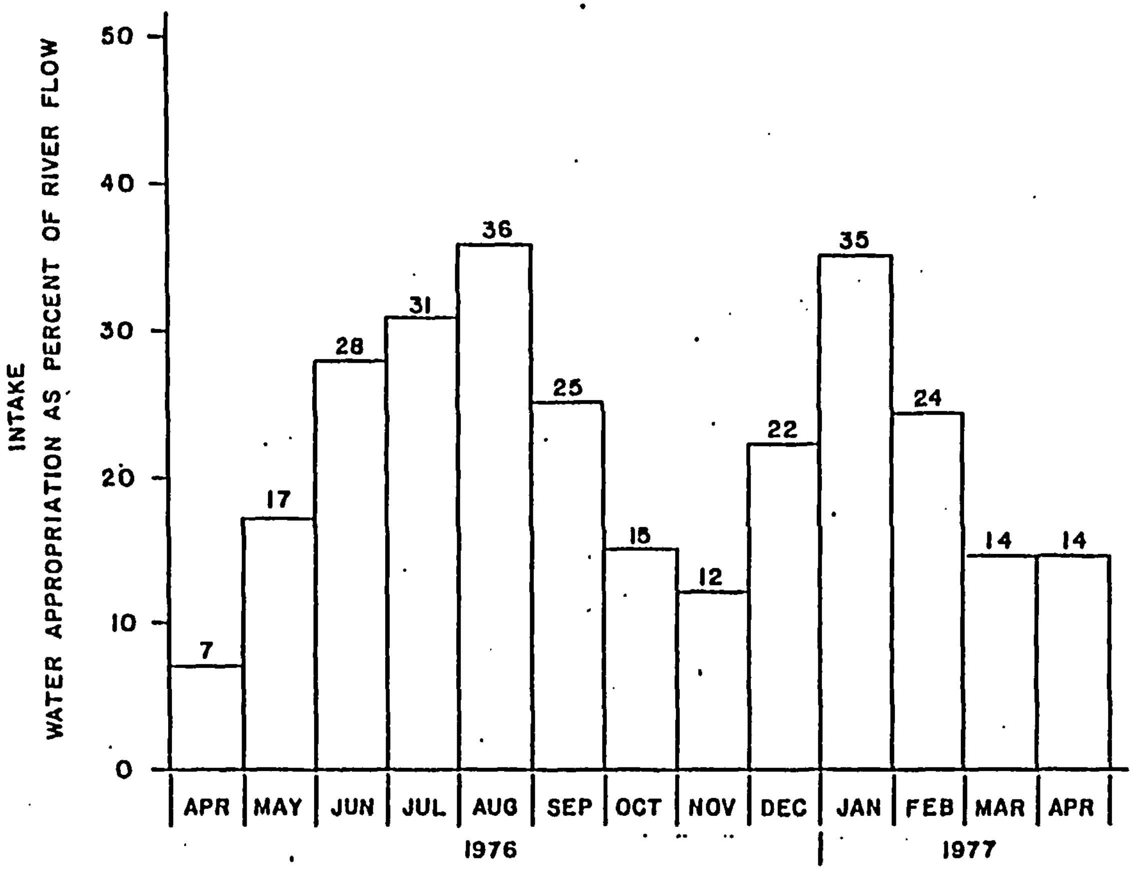


FIGURE 3.5-1

MONTHLY MEAN INTAKE WATER APPROPRIATION OF MNGP AS PERCENT OF MONTHLY MEAN MISSISSIPPI RIVER FLOW

It should be noted that 1976 was a drought year and Mississippi River flows were considerably below normal (Section 4.1).

3.6 COOLING WATER TEMPERATURES

Thermal data collected from 1971 through 1973 indicate that water temperatures in the Mississippi River near the MNGP intake are relatively homothermal throughout the water column (NUS 1976). This is a result of the relatively shallow (<3 m or 10 ft) depth of the river in the reach just upstream of the plant. Because of the shallowness of the river and the rate of river discharge (Section 4.1), thermal stratification of the river in this area is not expected.

Water temperatures during the study period are discussed in Section 4.2.2. In addition, warm recirculating water was used during de-icing. Water temperature ahead of the bar rack was increased less than 4°C (7°F) above ambient. The potential significance of this variance with river ambient temperatures is discussed in Section 5.2.2.

3.7 BIOCIDES

Biofouling in the circulating water system of MNGP is controlled by chlorination. The chlorination procedure and other related factors are outlined below:

(1) Chlorine is injected automatically every 6 hours (four times per day) for 0.5 hour except during shutdowns or outages.

(2) Chlorine demand of intake water is determined about every three months; an injection level resulting in a 0.5 mg/l of free-available chlorine is estimated.

(3) The discharge canal is sampled weekly for free available chlorine.

(4) Chlorine is measured weekly at the discharge of circulating water pumps to ensure a concentration of 0.5 to 0.6 mg/l at this point.

A continuing chlorination study is being conducted at MNGP in accordance with regulatory agency guidelines.

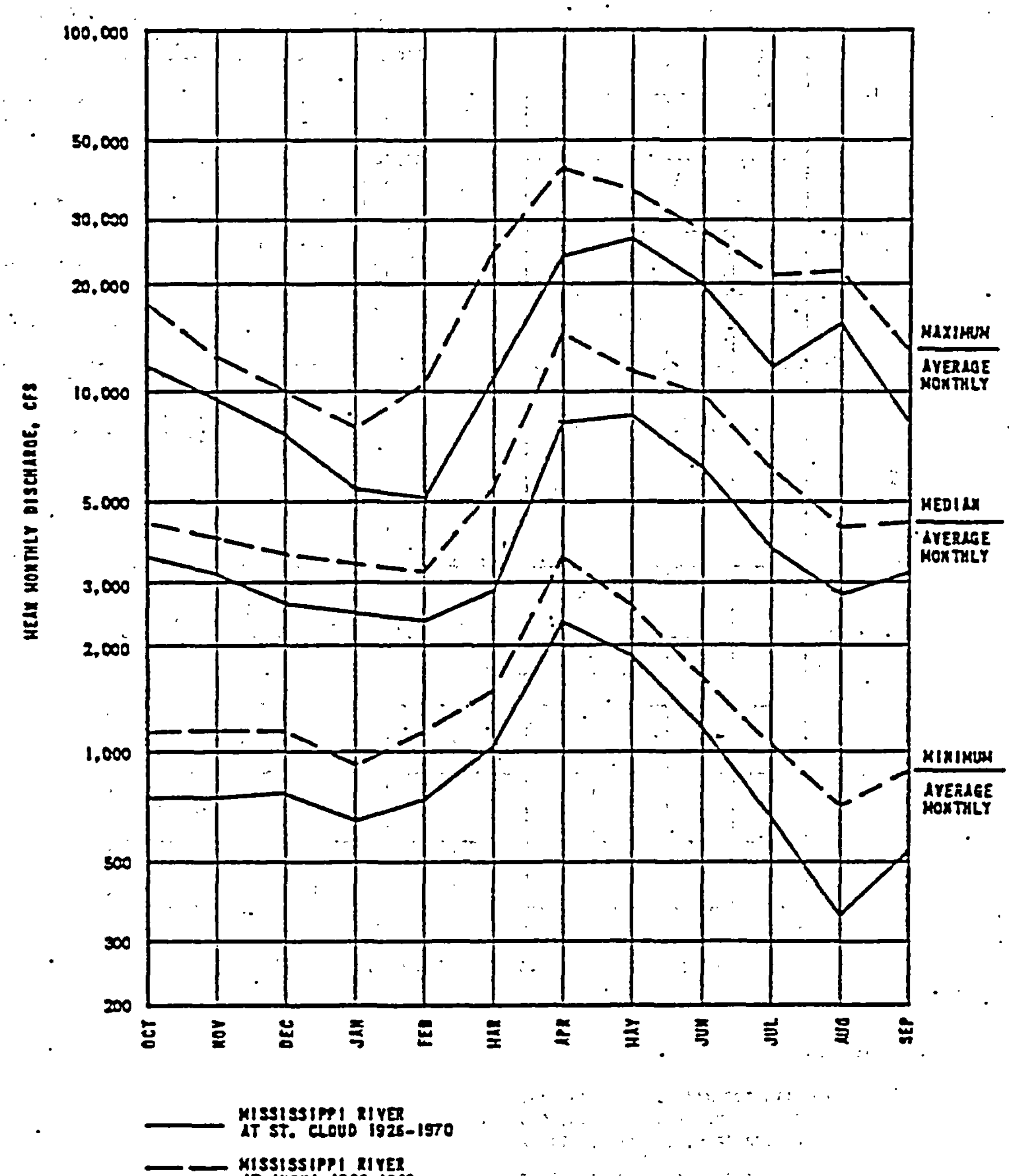
4. DESCRIPTION OF THE AQUATIC ENVIRONMENTS NEAR MNGP

4.1 HYDROLOGY

Mississippi River flow data from gauging stations located above and below the MNGP at St. Cloud and Anoka, respectively, indicate that low flow events are most likely to occur in late summer (August and September) and in winter (December through February) (NUS 1975). Annual and monthly flow duration curves for St. Cloud and Anoka are presented in Appendices 1 and 2. Operation of the St. Cloud gauging station ceased in 1970.

Comparison of average monthly discharge for St. Cloud and Anoka (Figure 4.1-1) and operating river flow at MNGP for the April 1976 through April 1977 period indicates that the Mississippi River flow for the study period averaged well below the median monthly average. Flows would be expected to exceed 1,500 cfs (42.5 m^3/sec) at least 85% of the time (Figure 4.1-2). Flows below 1,500 cfs occurred from August 1976 through January 1977 (Table 4.1-1).

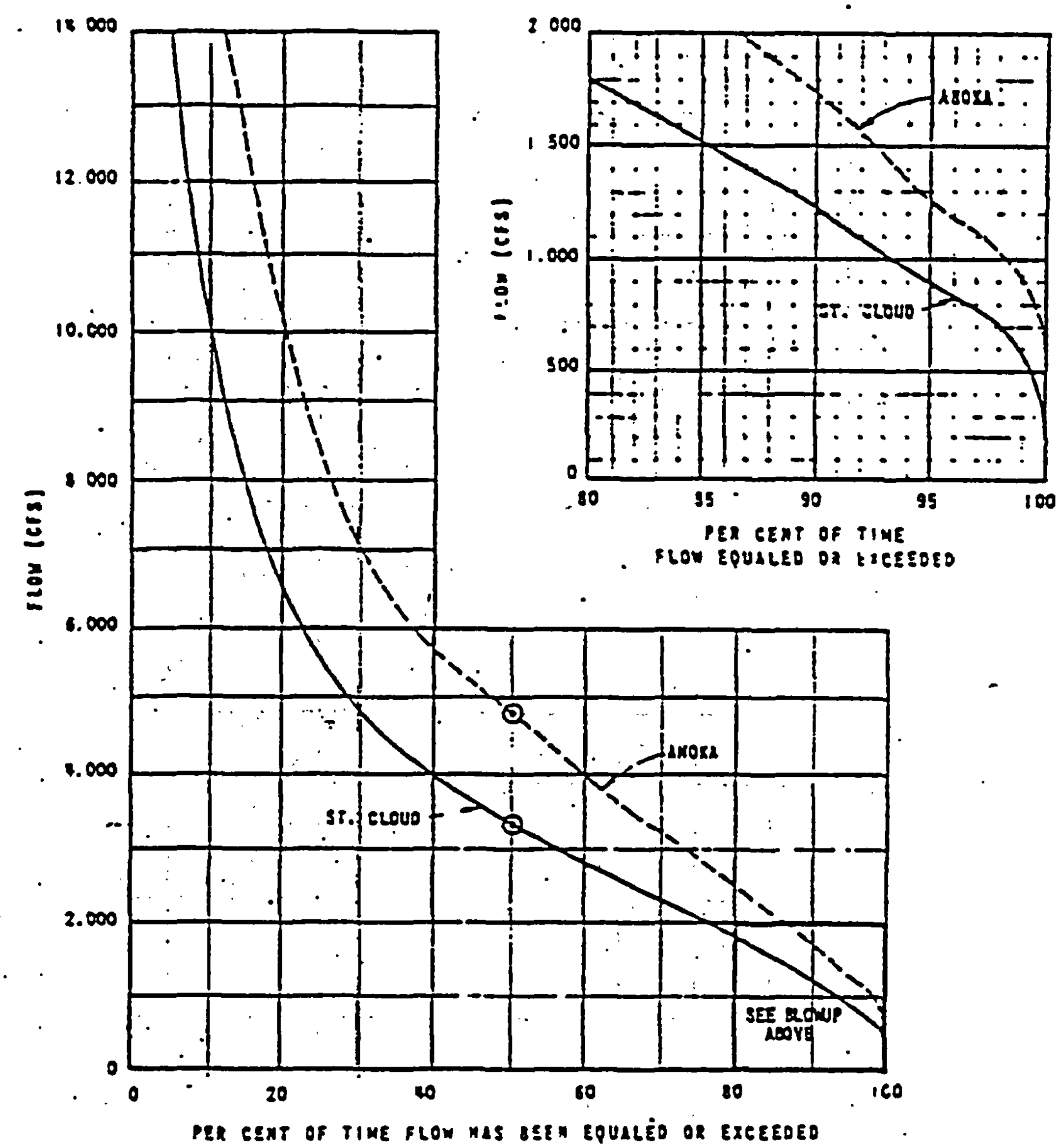
Low river flow recurrence intervals at St. Cloud are presented in Figure 4.1-3. The mean annual flow for the study period ($\sim$2,300 cfs or 65 m^3/sec) would have an annual



SOURCE:
ST. CLOUD - NSP ENGINEERING, USGS RECORDS
ANOKA - WATER RESOURCES OUTLOOK, 1973

FIGURE 4.1-1

AVERAGE MONTHLY DISCHARGE OF THE MISSISSIPPI RIVER AT ST. CLOUD AND ANOKA



LEGEND:

—— DATA FOR MISSISSIPPI RIVER AT ST. CLOUD, MINN. (NSP CO. RECORDS) PERIOD OF RECORD 1-1-26 TO 12-31-70.

- - - DATA FOR MISSISSIPPI RIVER NEAR ANOKA, MINN. (U.S.G.S. RECORDS) PERIOD OF RECORD 1-1-32 TO 12-31-67.

SOURCE:
SHERCO 1 AND 2 ER AND USGS FLOW RECORDS

FIGURE 4.1-2

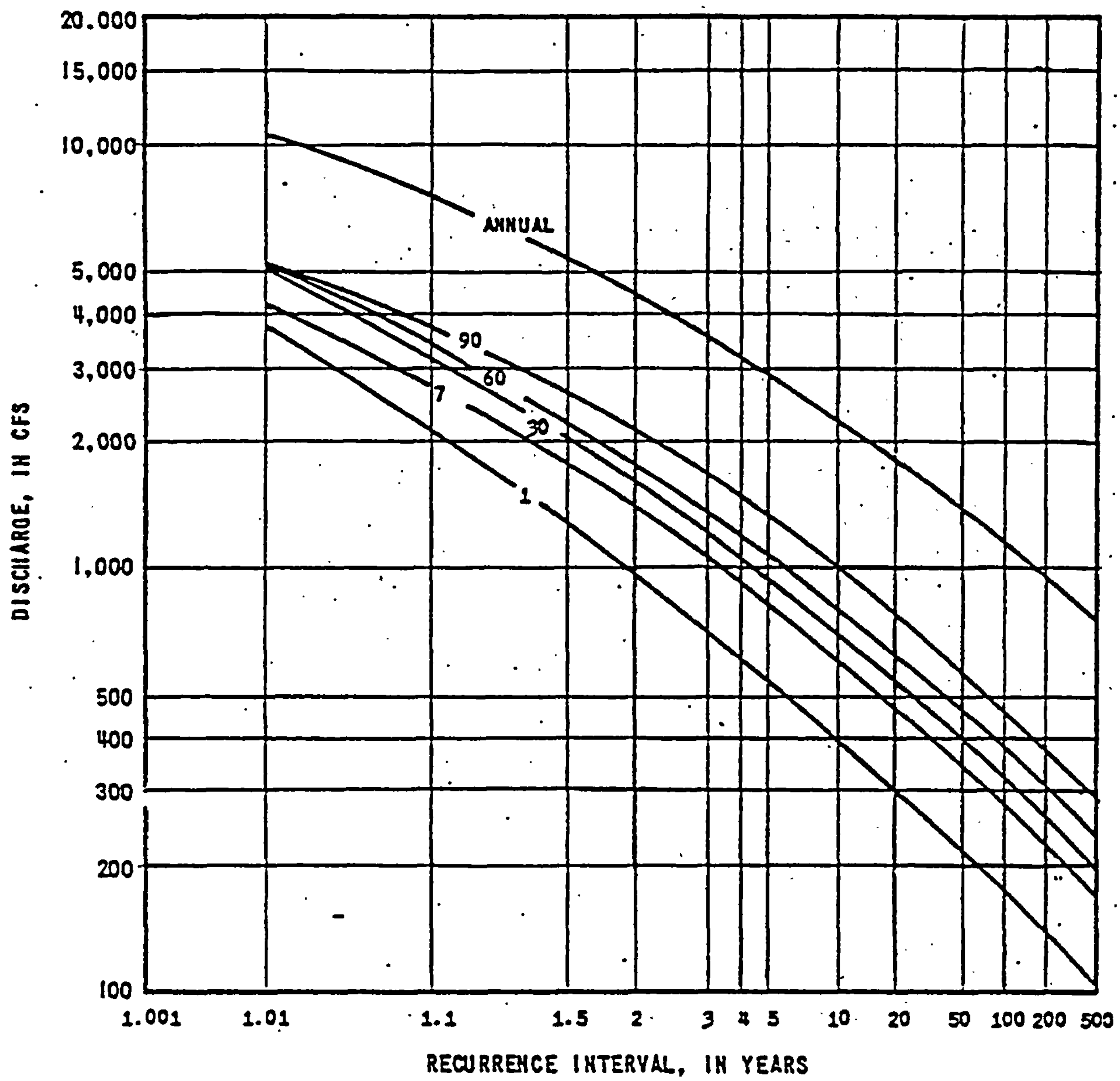
DURATION OF DAILY MEAN DISCHARGE FOR THE MISSISSIPPI RIVER AT ST. CLOUD AND ANOKA

TABLE 4.1-1

MONTHLY LOW FLOWS IN THE MISSISSIPPI RIVER AT ST. CLOUD (1926-1970) AND ANOKA (1931-1970) AND FLOWS AT MNGP (APRIL 1976-APRIL 1977)
(From NSP unpublished data)

	Median Low Flow				Flows at MNGP					
	St. Cloud		Anoka		Daily Minimum		Daily Maximum		Monthly Average	
Month	cfs	m^3/sec	cfs	m^3/sec	cfs	m^3/sec	cfs	m^3/sec	cfs	m^3/sec
April	7,400	209.6	13,700	388.0	5,614[a]	159.0[a]	10,268[a]	290.8[a]	7,976[a]	225.9[a]
May	7,600	215.2	11,600	328.5	1,801	51.0	5,614	159.0	3,197	90.5
June	5,700	161.4	8,400	237.9	1,687	47.8	2,301	65.2	1,912	54.1
July	3,600	102.0	5,700	161.4	1,085	30.7	2,576	72.9	1,820	51.5
August	2,900	82.1	4,250	120.4	837	23.7	1,368	38.7	1,170	33.1
September	3,000	85.0	4,300	121.8	837	23.7	1,175	33.3	1,076	30.5
October	3,200	90.6	4,400	124.6	998	28.3	1,470	41.6	1,162	32.9
November	3,000	85.0	4,400	124.6	998	28.3	1,920	54.4	1,330	37.7
December	2,570	72.8	3,700	104.8	624	17.7	1,801	51.0	1,106	31.3
January	2,360	66.8	3,600	102.0	762	21.6	1,687	47.8	1,270	36.0
February	2,150	60.9	3,400	96.3	1,175	33.3	2,301	65.2	1,696	48.0
March	2,710	76.7	4,400	124.6	916	25.9	4,985	141.2	2,898	82.1
April	7,400	209.6	13,700	388.0	2,719[b]	77.0[b]	3,503[b]	99.2[b]	3,202[b]	90.7[b]

[a] Last 17 days only
[b] First 9 days only



SOURCE:
BLACK & VEATCH ENGINEERING AND
ST. CLOUD FLOW RECORDS, 1926 - 1970

FIGURE 4.1-3

LOW RIVER FLOW RECURRENCE INTERVALS AT ST. CLOUD recurrence interval of about 15 years. Seven consecutive day average low flow-ten year returns near St. Cloud from 1926 to 1970 are presented in Figure 4.1-4. Data from St. Cloud best typify a seasonal discharge cycle similar to that at MNGP because of the drainage from tributary basins between MNGP and Anoka. Discharge at Anoka is greater and low flows are less severe (Table 4.1-1).

The average discharge for the 45-year period (1931 through 1976) from the Mississippi River main stem at Anoka is 7,537 cfs (213 m^3/sec) (USGS 1977). The extreme minimum discharge reported for the entire period at Anoka is 529 cfs (15.0 m^3/sec) which occurred during the study year on August 29, 1976. The seven consecutive day low flow minimum (976 cfs or 27.6 m^3/sec) occurred from September 1 through September 7, 1976 (USGS 1977), also during the study year.

Actual plant operating data on river flow for the study period of April 1976 through April 1977 indicate that the extreme daily minimum flow of 624 cfs (17.7 m^3/sec) occurred in December 1976 (Table 4.1-1). Monthly average flows ranged from 7,976 cfs (225 m^3/sec) in April 1976 to 1,076 cfs (30.5 m^3/sec) in September 1976.

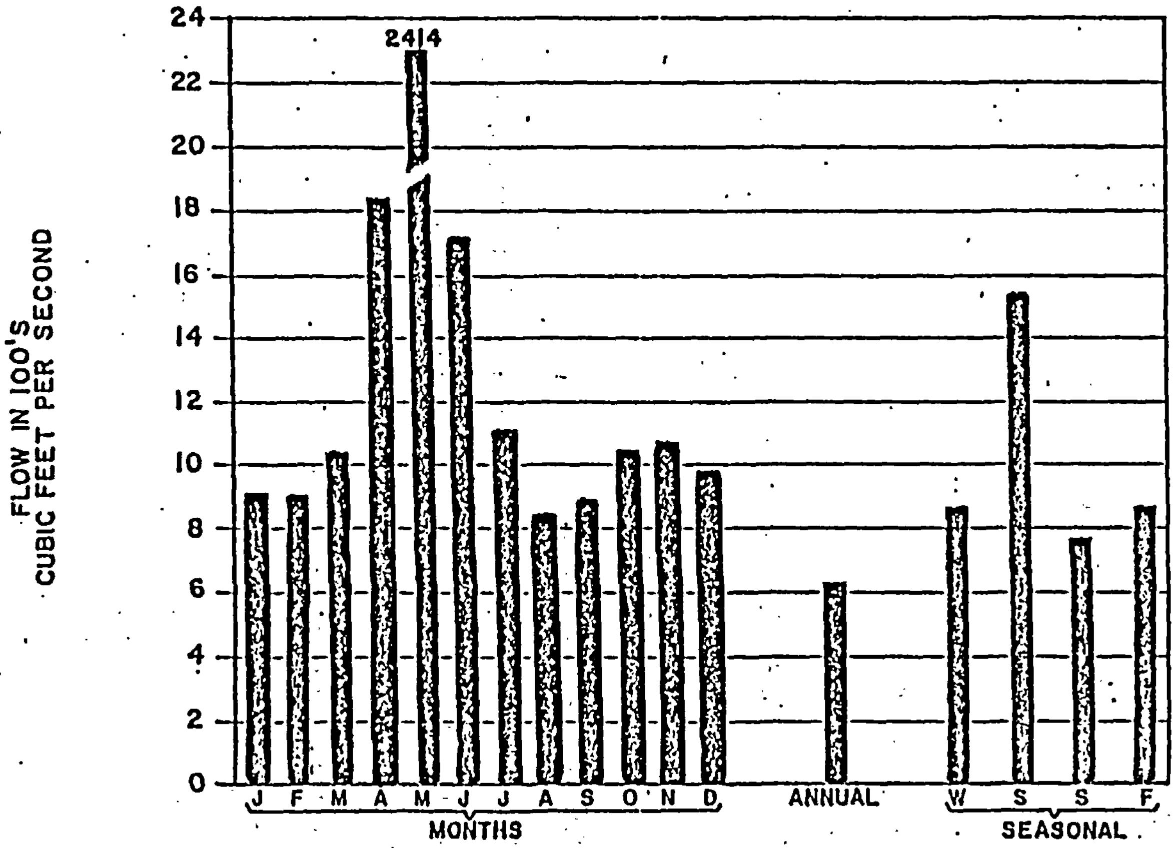


FIGURE 4.1-4

7 CONSECUTIVE DAY AVERAGE LOW FLOW-10 YEAR RETURN, MISSISSIPPI RIVER NEAR ST. CLOUD, MINNESOTA (1926-1970)

Flows in the Mississippi River were unusually low during the study period. The extreme minimum discharge for the period of record (1931-1970) at Anoka and the seven consecutive day low flow both occurred during the April 1976-April 1977 study year. River flows measured at MNGP during the study year are shown in Figure 4.1-5.

4.2 WATER QUALITY

4.2.1 General Characteristics

Chemical characteristics of the Mississippi River near MNGP are typical of temperate climate, unimpounded rivers. The water is moderately hard to hard (138-216 mg/l $CaCO_3$) and, in general, water quality is good. Variations in concentrations of chemical constituents are affected primarily by changes in river flow.

The water quality of the Mississippi River near MNGP has been monitored from 1969 through 1976. Water quality data collected upstream from MNGP in 1976 (Heberling 1977) are summarized in Table 4.2-1. The 1976 data compare favorably with data collected during previous years (NUS 1976, Heberling 1977); only slight differences in chemical parameters are evident among the years.

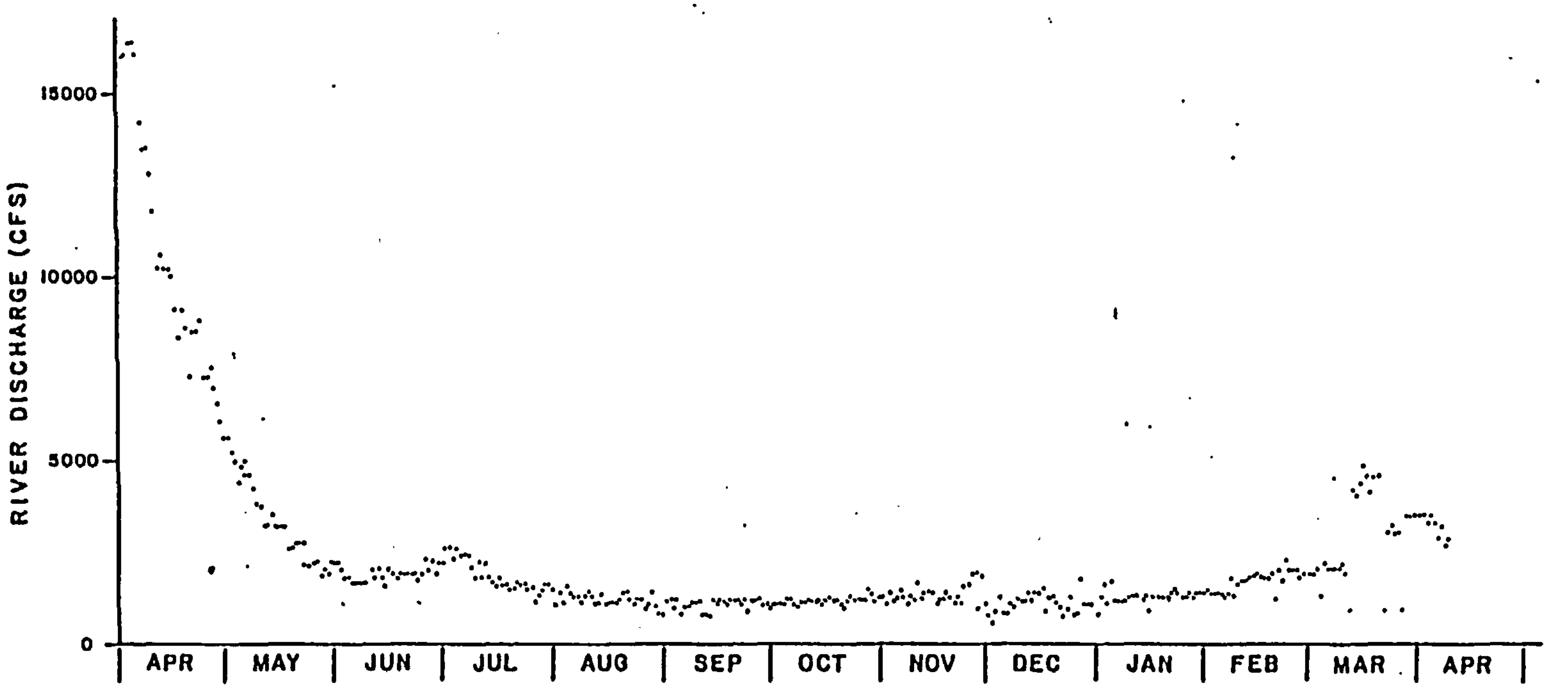


FIGURE 4.1-5

MISSISSIPPI RIVER DISCHARGE AT MNGP,
APRIL 1976-APRIL 1977
(From NSP plant data)

TABLE 4.2-1

WATER QUALITY OF MISSISSIPPI RIVER UPSTREAM FROM MNGP, 1976
(From Heberling 1977)

		MINIMUM	MAXIMUM	AVERAGE	STD.DEV.	NO.
Solids-mg/l	Total	171	258	209.5	22.68	12
	Dissolved	161	257	199.6	26.52	12
	Suspended	0.8	19.2	9.87	6.001	12
Hardness-mg/l (as $CaCO_3$)	Total	138	216	168.5	23.00	12
	Calcium	94	140	108.7	13.73	12
	Magnesium	44	76	59.8	10.03	12
Alkalinity-mg/l (as $CaCO_3$)	Total	130	207	160.4	21.54	12
	Phenolphthalein	0	10	4.3	4.25	12
Gases-mg/l	Dissolved Oxygen	4.0	13.0	9.46	2.521	12
	Ammonia-Nitrogen (N)	0.0	0.38	0.068	0.1140	11
Anions-mg/l	Carbonate (CO_3)	0.0	11.4	5.05	5.023	12
	Bicarbonate (HCO_3)	158	252	185.1	29.86	12
	Hydroxide (OH)	--	--	--	--	--
	Chloride (Cl)	0.70	9.00	4.533	3.2258	12
	Nitrate-Nitrogen (N)	0.05	0.58	0.225	0.1761	12
	Sulfate (SO_4)	7.8	24.0	15.17	5.988	12
	Phosphorus-Soluble (P)	0.017	0.100	0.0430	0.02491	12
	Silica (SiO_2)	0.1	10.9	6.13	3.711	12
Cations-mg/l	Calcium (Ca)	37.6	56.1	43.55	5.512	12
	Magnesium (Mg)	10.7	18.5	14.56	2.451	12
	Sodium (Na)	4.5	11.0	7.58	2.194	12
	Total Iron (Fe)	0.04	0.57	0.244	0.1914	12
	Total Manganese (Mn)	--	--	--	--	--
	Potassium (K)	--	--	--	--	--
Miscellaneous	Color (APHA Units)	15	70	29.6	18.64	12
	BOD (mg/l)	0.7	3.1	2.04	0.941	10
	Temp (Deg C)	0.0	28.0	10.75	10.223	12
	Turbidity (JTU)	1.30	10.00	4.058	2.6211	12
	Ryznar Index (at 77F)	6.33	7.55	6.742	0.3738	12
	Conductivity (umhos/cm)	270	440	340.4	47.74	12
	pH	7.85	8.85	8.417	0.3570	12

4.2.2 Water Temperature

Daily mean intake water temperatures for MNGP from April 16, 1976 through April 9, 1977 are presented in Figure 4.2-1. Water temperatures ranged from 27.8°C (82°F) in July to 0°C (32°F) in November, December, January, February and March. Water temperatures normally remained between 0 to 1.6°C (32.0 and 35°F) from November through March and then increased rapidly until the maximum temperature of 27.8°C (82°F) was reached in July. This pattern corresponds to temporal variations previously noted from 1966 through 1973 (NUS 1976).

The temperature regimes in the MNGP area are typical of large, temperate river systems and are not likely to produce any stress that could contribute to the susceptibility of organisms to entrainment or impingement (other than normal lethargy associated with winter temperatures).

4.2.3 Dissolved Oxygen

Throughout five years of study at MNGP between 1968 and 1972, dissolved oxygen (DO) concentrations fluctuated monthly but always remained above 7 mg/l; yearly average concentrations for 1969 through 1972 were always above 9 mg/l (Table 4.2-2).

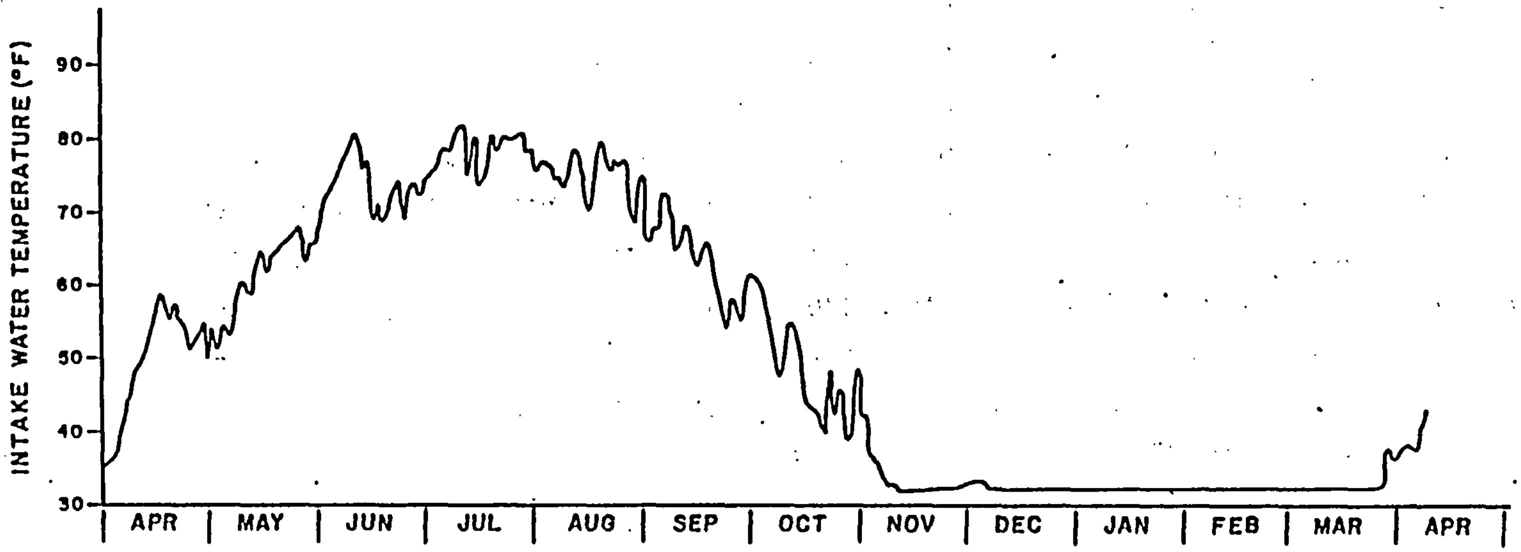


FIGURE 4.2-1

WATER TEMPERATURE IN THE MISSISSIPPI RIVER AT MNGP,
APRIL 1976-APRIL 1977
(From NSP plant operating data)

TABLE 4.2-2

DISSOLVED OXYGEN (mg/l) IN MISSISSIPPI RIVER WATER AT
ONE STATION ABOVE (1) AND TWO BELOW (2 AND 3) MNGP, 1968-1972

Years	1968			1969			1970			1971			1972		
Stations	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
January	-	-	-	10.5	11.0	11.0	10.7	10.9	11.4	10.5	9.8	9.6	11.0	10.4	10.6
February	-	-	-	10.5	10.25	10.5	11.4	11.2	11.8	8.8	9.3	9.5	9.8	9.9	-
March	-	-	-	12.0	12.0	12.0	11.9	11.7	13.3	9.1	8.8	9.5	9.5	9.8	10.5
April	-	-	-	11.0	11.0	10.5	12.5	13.5	13.0	11.9	11.6	9.8	10.2	10.0	10.5
May	-	-	-	9.0	9.3	9.0	10.1	9.9	9.8	10.5	10.5	10.0	8.0	7.0	7.6
June	7.5	7.75	-	9.0	8.5	9.0	7.6	7.5	7.8	8.0	7.6	7.7	8.9	8.6	8.7
July	7.3	7.3	7.3	8.4	8.4	8.5	9.0	11.7	9.7	7.7	7.6	7.6	9.3	7.9	9.1
August	8.3	8.5	8.5	9.0	9.0	9.1	8.0	9.6	8.8	7.1	8.7	8.0	7.7	7.4	7.2
September	8.8	-	9.0	8.5	8.3	8.3	8.6	8.7	9.7	10.3	7.6	7.7	8.3	7.8	8.0
October	10.0	-	9.5	12.5	13.3	12.5	9.4	9.0	9.0	11.1	11.0	10.2	9.1	10.1	10.4
November	12.8	-	12.5	14.5	14.0	13.0	12.4	11.9	12.0	10.6	11.0	11.3	13.6	10.4	12.9
December	12.5	-	14.0	15.5	14.0	15.0	12.1	11.5	11.7	12.7	12.6	12.6	14.1	10.1	12.7
Annual Average	9.6	7.9	10.1	10.9	10.8	10.7	10.3	10.6	10.7	9.9	9.7	9.4	10.0	9.1	9.8

Although 1976 was an exceptionally dry year and river discharge levels were greatly reduced, DO concentrations for samples collected upstream from MNGP averaged above 9 mg/l for the year (Table 4.2-1). DO concentrations remained well in the range required for the maintenance of a diverse biota.

4.2.4 <u>Other Existing or Planned Stresses in the Area</u>

The only other potential or existing stresses in the area are the NSP Sherburne County Generating Plant (SHERCO), approximately 6.5 km (4 river mi) upstream of MNGP, and the municipal waste treatment plant at St. Cloud, approximately 30.5 km (19 mi) upstream of MNGP. The predicted effect of SHERCO on the river is discussed in the Environmental Report and the Section 316(b) Demonstration for SHERCO (NSP 1976, NUS 1976).

The waste treatment plant discharges approximately 25,359 m^3/day (6.7 mgd) of secondary treated effluent. An expanded wastewater treatment facility was completed in the spring of 1976. No noticeable degradation of water quality near MNGP has been noted that can be attributed to the wastewater treatment facility.

One source of temporary stress to the aquatic biota near MNGP results from the periodic (every six to eight years) dredging of the MNGP intake canal to prevent excess sand and silt deposits from being drawn into the plant circulating water system. Pursuant to the amendment in the form of Special Provision VIII, dated December 20, 1972, to the Department of Natural Resource Permit No. PA 67-743, dated July 28, 1967, NSP notified all required agencies of proposed maintenance dredging in the MNGP intake canal in September 1977. Approximately 283 m^3 (370 yd^3) of silt and sand had been deposited in front of the intake by river currents. The material was removed with a clam shell dredge operated by a crane located on the river near the intake structure.

A water monitoring study conducted by NSP in conjunction with the dredging activity analyzed composite water samples collected on September 13, 14 and 15 from surface, mid-depth and bottom levels at 28 stations. Samples were analyzed for total suspended solids, turbidity, sulfate and total mercury (Appendix 3).

Concentrations of total suspended solids, sulfate and turbidity during dredging differed little from mean annual concentrations measured before dredging. Concentrations may have been somewhat higher than during non-dredging years but, since the increases were temporary and relatively small, neither the water quality nor the aquatic biota near MNGP were strongly affected. No comparisons of total mercury concentrations could be made, since no pre-dredging data were available, but all concentrations determined during dredging were less than 1 µg/l, or below the limit of detection for most analytic methods.

4.3 AQUATIC ECOLOGY

Ecological studies of the Mississippi River near MNGP have been conducted since 1968, three years before commercial operation of MNGP. Dr. Alfred J. Hopwood and Dr. Keith M. Knutson of the Biology Department of St. Cloud State College have been closely associated with the monitoring programs, including those dealing with water quality, primary producers, macroinvertebrates and fish. Several graduate students and numerous NSP personnel have also participated in the ecological studies at MNGP. Details concerning the monitoring programs are available in the MNGP annual reports from 1969 to 1976.

4.3.1 Trophic Structure

The trophic structure of the Mississippi River near MNGP has been described by Hopwood (1974a). Detritus and primary producers are the base of the food chain. Detrital material, such as tree leaves, provides nutrients for primary producers and is also consumed by benthic invertebrates. The most important primary producers are the attached algae (periphyton). Planktonic invertebrates (zooplankton) may be important as food for larval fish. Most adult fish feed on benthic macroinvertebrates and, in some cases, on other fish. Fish are the dominant carnivores in this aquatic ecosystem. Some energy is channeled to the terrestrial ecosystem through angling and predation on fish and invertebrates.

4.3.2 Primary Producers

There are three sources of primary production in the Mississippi River: macrophytes, phytoplankton and periphyton. According to Moyle's (1940) studies, macrophytes are important in the upper Mississippi River system. However, there are very few macrophytes in the stretch of the river near MNGP.

Although phytoplankton may be important in some large rivers, the studies conducted at MNGP from 1968 to 1973 indicate that there is little or no true plankton in this section of the Mississippi River, probably because of the high current velocity which carries phytoplankton downstream very quickly. Periphyton is considered to be the major source of primary production at MNGP (Colingsworth 1969).

4.3.2.1 Phytoplankton

Phytoplankton in fast-flowing rivers largely has its origins in backwaters and from the periphyton community (Hynes 1970). The density of phytoplankton in rivers is largely a function of the amount of dilution and scouring resulting from changes in flow. Thus, the ephemeral nature of phytoplankton of rivers often makes the study of this community inconclusive as far as evaluating the ecological status of the river.

The early studies conducted by Wiebe (1928) and Reinhard (1931) on the upper Mississippi River describe a phytoplankton community dominated by diatoms, the most abundant of which were *Cyclotella meneghiniana*, *Melosira granulata*, *Asterionella formosa*, *Fragilaria capucina*, *Diatoma vulgare*, *Synedra ulna* and *Stephanodiscus* spp. Reinhard's (1931) studies indicate that there was a vernal pulse in late May. Diatoms made up the major portion of the summer flora reported by both investigators. Although a number of green and blue-green algae were observed, none were extremely abundant. The common species of green algae, in order of abundance, were *Scenedesmus quadricauda*, *Actinastrum hantzschii*, *Pediastrum duplex* and certain desmids. Common blue-green algae included species of *Anabaena*, *Aphanizomenon*, *Merismopedia*, *Coelosphaerium* and *Microcystis*.

Moyle (1940) described three types of plankton communities in the summer flora of the upper Mississippi River system. In two of those, the community structure was dominated by blue-green algae such as *Anabaena*, *Coelosphaerium*, *Microcystis*, *Aphanocapsa* and *Aphanizomenon*. The common green algae were *Pediastrum*, *Closterium* and *Scenedesmus*. Diatoms, represented by *Navicula*, *Stephanodiscus*, *Fragilaria* and *Melosira*, were relatively less important. The third type of community was characterized by a diatom group; the most common genera encountered were *Navicula* and *Surirella*. The important green algae were the same as reported for the other two types of plankton communities.

Mischuk (1976) investigated primary productivity in the Mississippi River near MNGP and noted that the phytoplankton assemblage was dominated by diatoms throughout most of the study year (September 1973 - September 1974). Diatoms constituted 92% of the algal species found. Diatoms decreased to 50% of the total composition by cell count in mid-summer and were replaced by green algae, predominantly of the genera *Ankistrodesmus* and *Cosmarium*. From data on community respiration and chlorophyll concentrations, Mischuk calculated that phytoplankton could contribute as much as 18 to 40% of the primary productivity of the community.

4.3.2.2 Periphyton

Periphyton may be defined as the community of attached plants, excluding macrophytes, that develop on underwater substrates. The periphyton of the Mississippi River near MNGP has been studied from 1968 through 1976. Studies were based on algae that had colonized artificial substrates.

A total of 149 algal taxa, mostly diatoms, were collected from the periphyton near MNGP from 1968 through 1976 (Weber and Knutson 1977, NSP unpublished data).

Total periphyton cell densities from 1969 through 1976 varied both from year to year and among seasons of the year, but there was a general trend of large populations from June to mid-September. Periphyton species composition was similar in preoperational and operational years. Production was low in the winter because of low water temperatures and ice cover. The winter community structure was dominated by diatoms, the most abundant of which was Gomphonema olivaceum. There was an early maximum in spring; diatoms were still the dominant group. The most common species were Gomphonema olivaceum, Diatoma vulgare, Synedra ulna and Navicula gracilis. Peak production occurred during the summer. The summer flora was dominated by blue-greens and diatoms. Diatoms dominated in fall with Cocconeis placentula and Cocconeis pediculus the most abundant species.

4.3.2.3 Macrophyton

The majority of aquatic vascular plants are higher plants which respond to seasonal changes in much the same manner as do terrestrial plants. Aquatic vascular plants are seldom consumed alive by aquatic fauna; however they enter the aquatic food web as detritus and thereby contribute significantly to the energy flow with these systems. They also may play an important role in stabilizing substrates and in providing habitat for algae and invertebrates and protective cover for fish. In some rivers, vascular plants may contribute significantly to maintaining high dissolved oxygen concentrations.

There have been no recent detailed studies of aquatic vascular plants of the upper Mississippi River. Moyle (1940) surveyed this area and reported 81 species, of which 15 were common. Vallisneria americana, Potamogeton americanus and Potamogeton pectinatus were the most common submerged species.

Studies conducted near MNGP in 1968, 1969 and 1970 indicate that only three species of macrophytes are found in this stretch of the river. The high current velocity results in shifting sand and gravel which are unsuitable substrates for colonization by vascular plants. The three species reported were water moss, *Fontinalis antipyretica*, which was quite common in the river, and *Potomogeton americanus* and *Potamogeton pectinatus*, which were restricted to pools. *Cladophora glomerata*, a macroscopic green alga, is also an important primary producer in this area of the Mississippi River (Hopwood 1975).

4.3.3 Zooplankton

Zooplankton is the animal component of the community of organisms suspended in the water column. In rivers, zooplankton is constantly carried downstream by the current. Consequently, the zooplankton community at any point in a river is more representative of upstream conditions than those in the immediate vicinity of the collection point. The communities of large rivers, such as the Mississippi, are usually composed of large numbers of protozoans and rotifers and limited numbers of crustaceans. Wiebe (1928) noted that the most abundant taxon in the upper Mississippi was an unidentified rotifer and that *Cyclops* and nauplii were the most abundant crustaceans, although they were usually present in lower numbers than rotifers. Reinhard's (1931) study confirmed the predominance of rotifers in this river system. *Keratella cochlearis* was the most abundant rotifer and was present at all stations throughout the year. Studies of the upper Mississippi by Galtsoff (1924b) and Moyle (1940) are in general agreement with those of Reinhard (1931).

The major components of river zooplankton tend to be temporary or tychoplanktonic. Consequently, zooplankton lacks great stability, as it depends heavily on scouring and backwater recruitment. Due to the lack of stability, few consumers have evolved that depend exclusively on zooplankton for food. There are a small number of filter-feeding benthic organisms that consume zooplankton as well as phytoplankton and detritus. Many fish larvae are also reported to feed on zooplankton, but most adult fish do not actively consume zooplankton.

4.3.4 Benthic Macroinvertebrates

Benthic macroinvertebrates are an important link in the food web of the Mississippi River near MNGP. Although benthic organisms are normally sessile, many species characteristically drift with the river flow during part of their life cycles. Although the drift period of an organism is ephemeral, drift makes several important contributions to the aquatic system. In summer, drift may play an important role in recolonization of denuded areas. Drifting organisms are highly susceptible to entrainment and to predation by secondary consumers, such as fish.

Moyle (1940) published the first comprehensive species list of benthic macroinvertebrates from the upper Mississippi drainage system between Minneapolis and Crosby. He estimated that the bottom of the upper Mississippi was 66.9% gravel, 28.5% sand, and 4.6% cobble and boulders. He found the most dense bottom faunal populations in shallow weed beds, the most sparse populations on the bare gravel bottom of the channel and an intermediate number in shallow water lacking weedbeds. The most abundant nonpredaceous macroinvertebrates were aquatic oligochaetes, mayflies, midges, black flies, caddisflies, snails and clams. Moyle recorded nine species of clams above Minneapolis; five species were collected from the Mississippi River proper: Actinonaias carinata, Anodonta grandis plana, Ligumia recta, Lampsilis siliquoidea and Lampsilis ventricosa.

Intensive benthos studies were conducted near the MNGP Site by staff and students from St. Cloud State University, starting in the summer of 1968. McConville (1972) showed that benthic populations near MNGP do not significantly change with depth in the main channel. In backwater pools and inshore areas where vegetation is able to establish itself, the benthic fauna is more diverse. Sixty-six genera were collected in these backwaters while 24 genera were collected in the main channel from four artificial substrate samplers (McConville 1969). Dipterans, isopods and a few coleopterans were common in backwaters whereas trichopterans and ephemeropterans were common in the main river.

Hopwood and his students collected 11 orders of macroinvertebrates, of which seven belonged to the class Insecta (Department of the Army 1974). Caddisflies (Trichoptera), true flies (Diptera) and mayflies (Ephemeroptera) were the most common orders.

In Nemanick's (1973) study on recolonization, the overall estimated number of organisms was composed of Trichoptera (47%), Ephemeroptera (14%), Diptera (33%) and miscellaneous groups (6%). The estimated distribution of total weight of insects was Trichoptera (83%), Ephemeroptera (7%), Diptera (8%), and "others" (2%). *Hydropsyche* and *Cheumatopsyche* represented 93% of the Trichoptera. Hydropsychidae have dominated the fauna throughout the years of study. *Hydropsyche*, *Cheumatopsyche* and *Macronemum* were the most common genera of this family near MNGP and most probably in the upper Mississippi River. The mayflies _Pseudocloeon_ and _Stenonema_ were present during all sampling times and composed 48% and 21% of the Ephemeroptera, respectively. _Ephemerella_ dominated in fall and spring sample periods. Larvae of the black fly _Simulium_ composed 81% of the dipterans and midges (Chironomidae) composed 19%.

Composition of the drift differs somewhat from that of the benthic community. Beetle larvae, oligochaete worms, certain heavy snails and stony-cased caddisfly larvae generally do not drift, whereas the larvae of mayflies, true flies, stoneflies and some caddisflies may be relatively abundant in the water column. During high river flows, many organisms are carried downstream, but this catastrophic drift differs from drift which occurs during normal flows. Diel variations in drift are common. Many studies have shown drift to increase at night, with a peak shortly after dark (Elliott 1965; Waters 1962, 1965; Andersen 1966).

Very few studies on large river invertebrate drift are available because of difficulties in sampling. Matter (1975) investigated invertebrate drift near MNGP from July 1973 through July 1974. Nine orders of macroinvertebrates were collected. Approximately 90% of the organisms collected belonged to the mayfly, caddisfly and true fly orders. The drift was composed of 37% mayflies, 28% stoneflies, 30% true flies and 5% "miscellaneous".

Almost 90% of the caddisflies were Hydropsyche and Cheumatopsyche. Of the mayflies, 50% belonged to the genus Pseudocloeon and 13% to Rhithrogena. Dipteran drift was primarily Simulium and Chironomidae. At a station above the MNGP discharge, it was estimated that from 7.15×10^6 to 74.35×10^6 organisms passed the sampling points in 24 hours in the entire river cross-section for the 1973-1974 study year.

Seasonally, two slight peaks in drift were observed, one from late May through early June and one in mid-August. Both peaks were apparently due to high river discharge. The minor spring peak of drift densities included black fly larvae and riffle-beetle larvae. In the August peak, the mayfly Pseudocloeon and midges of the tribe Chironomini were the most numerous organisms, whereas the greatest contributors to biomass were hydropsychid larvae and Pseudocloeon. In the June 21-22 samples, stoneflies represented more than 20% of the total number of organisms collected. February and March drift was higher than expected for the winter, perhaps because large amounts of anchor ice disturbed bottom sediments.

4.3.5 Fish and Fisheries

4.3.5.1 Sampling Methods

Fisheries investigations at MNGP were divided into pre-operational and operational phases. The preoperational phase covered the period from 1968 through June 1971; and the operational phase gathered data from June 1971 through early April 1977. The studies were directed by Dr. Alfred J. Hopwood of St. Cloud College between 1968 and 1974 and by NSP in 1975 and 1976.

4.3.5.1.1 Electrofishing

Electrofishing, a technique selective for larger fish, has been conducted since 1968 on a section of the river approximately 7 km (4.4 mi) long. The study area was divided into five sectors (Figure 4.3.1). Sector A was adjacent to and upstream of the plant site and included the plant intake structure. Sector B was below the plant and included the discharge canal and the thermal discharge zone. Sectors C through E were downstream of MNGP. Flow characteristics, substrate types and sounding range locations are described in the Section 316(a) Demonstration for MNGP (NUS 1975). All sectors were sampled between 1968 and 1973; from 1974 to 1976, only sectors A and B were sampled. Electrofishing methods used from 1968 through 1974 are described by Hopwood

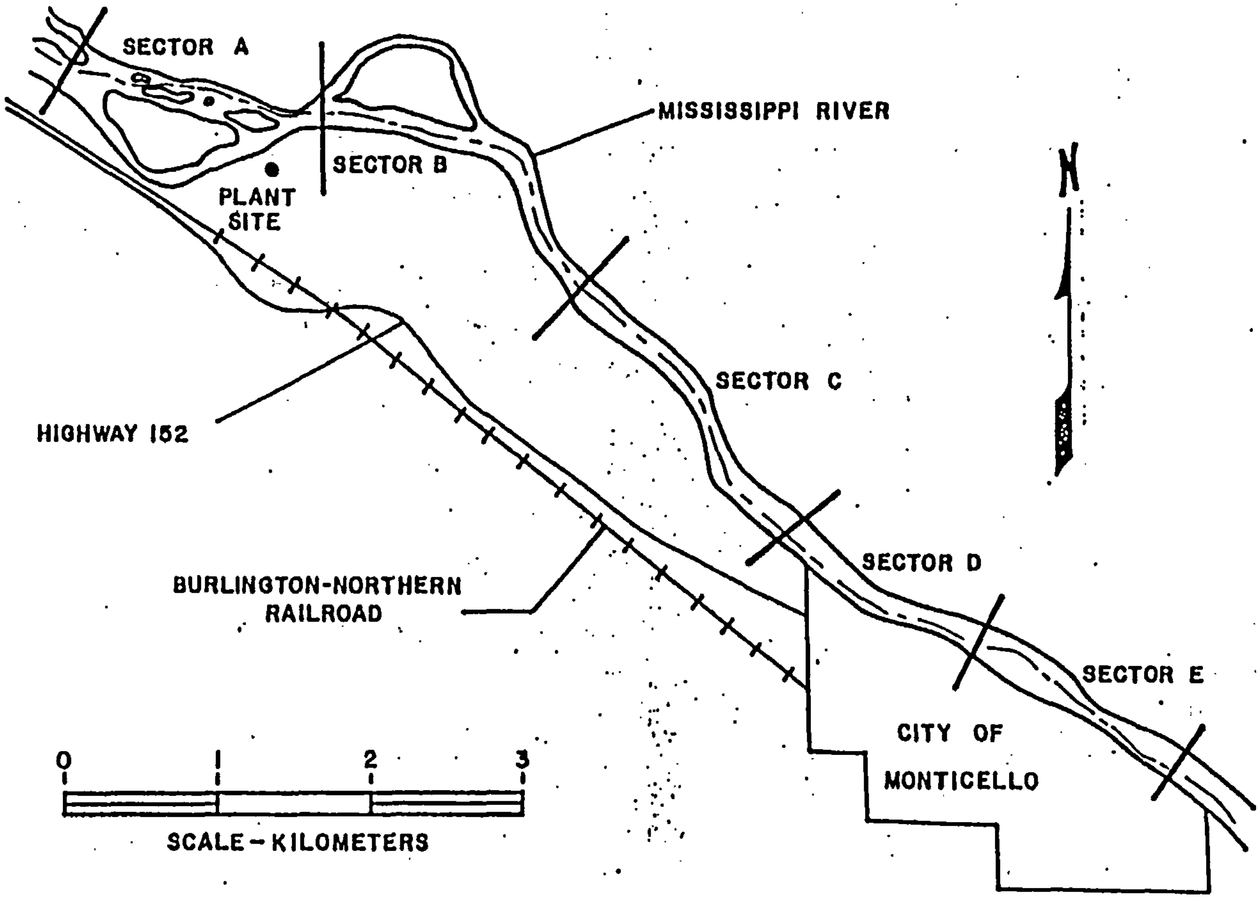


FIGURE 4.3-1

ELECTROFISHING SECTORS NEAR MNGP
(From Hopwood 1974c)

(1974c). The techniques used by NSP between 1975 and 1976 were similar to those of Hopwood (1974c) except for two important changes. In 1975 the AC electrofishing gear was replaced by a pulsed DC unit. The effects of this change on catch and species composition of the catch were not quantified. In 1976 the timing system was changed from total run time to the actual time the electrodes were energized. This reduction in the overall time for each run may have resulted in higher catches-per-unit-effort (CPUE) than in previous years.

Electrofishing was conducted consistently in the summer months (June, July and August) and sporadically in the spring and fall. CPUE (fish/electrofishing hour) was calculated and reported for most years. Percent composition was calculated from CPUE values and reported for each year.

4.3.5.1.2 Seining

Seining was conducted in both preoperational and operational years. A 6 m (20 ft) beach seine with 3.2 mm or 6.4 mm (1/8 or 1/4 inch) mesh was used. Preoperational seining was conducted from May to November 1970 at two stations above and four stations below MNGP (Figure 4.3-2). Detailed descriptions of these stations are given by Morgenweck (1971). Seining after MNGP began operation was first conducted from June 1972 to July 1973 at four stations upstream

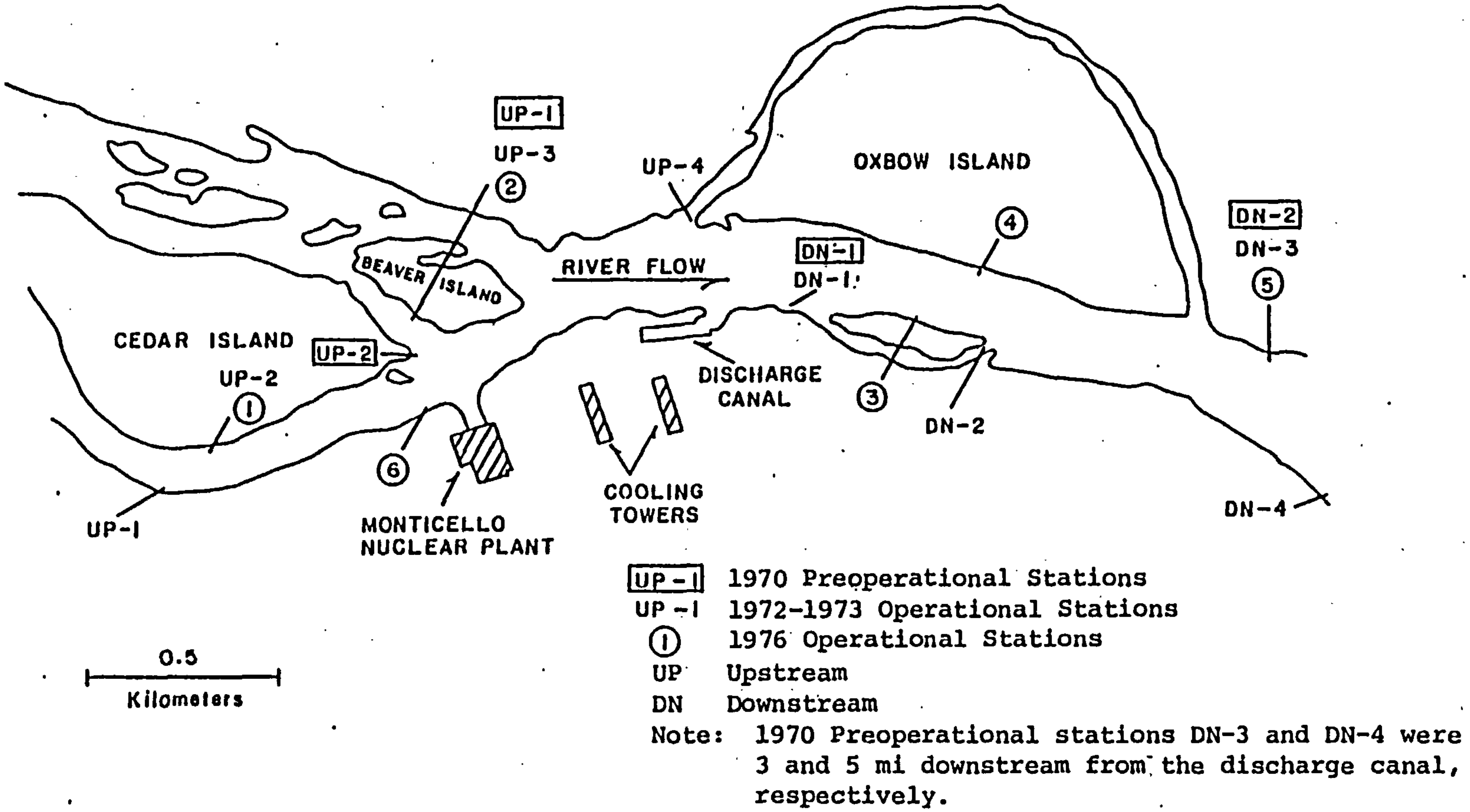


FIGURE 4.3-2

SEINING STATIONS NEAR MNGP, 1970-1973, 1976
(From Morganweck 1971, Ott 1973 and present study)

and four downstream of MNGP (Figure 4.3-2). Detailed descriptions of these stations are reported in Ott (1973). Preoperational stations Upstream-1, Downstream-1 and Downstream-2 were identical to operational stations Upstream-3, Downstream-1 and Downstream-3, respectively.

Special seining studies were conducted in 1973 and 1974 to monitor abundance and growth of young-of-the-year fish in heated and non-heated areas. The stations sampled are shown in Figure 4.3-3 . Heberling (1975) gives detailed descriptions of the stations sampled.

The present study was designed to monitor the species composition and relative abundance of shore zone fishes near MNGP between April 30 and November 20, 1976. Ice cover prevented sampling after November 20. Sampling was resumed on April 1 and was continued to the scheduled termination of the program on April 8, 1977. The gear and stations were chosen to be as similar as possible with those used in several other programs previously conducted near MNGP by Morgenweck (1971), Ott (1973) and Heberling (1975). Samples were collected weekly at six stations (Figures 4.3-2 and 4.3-4).

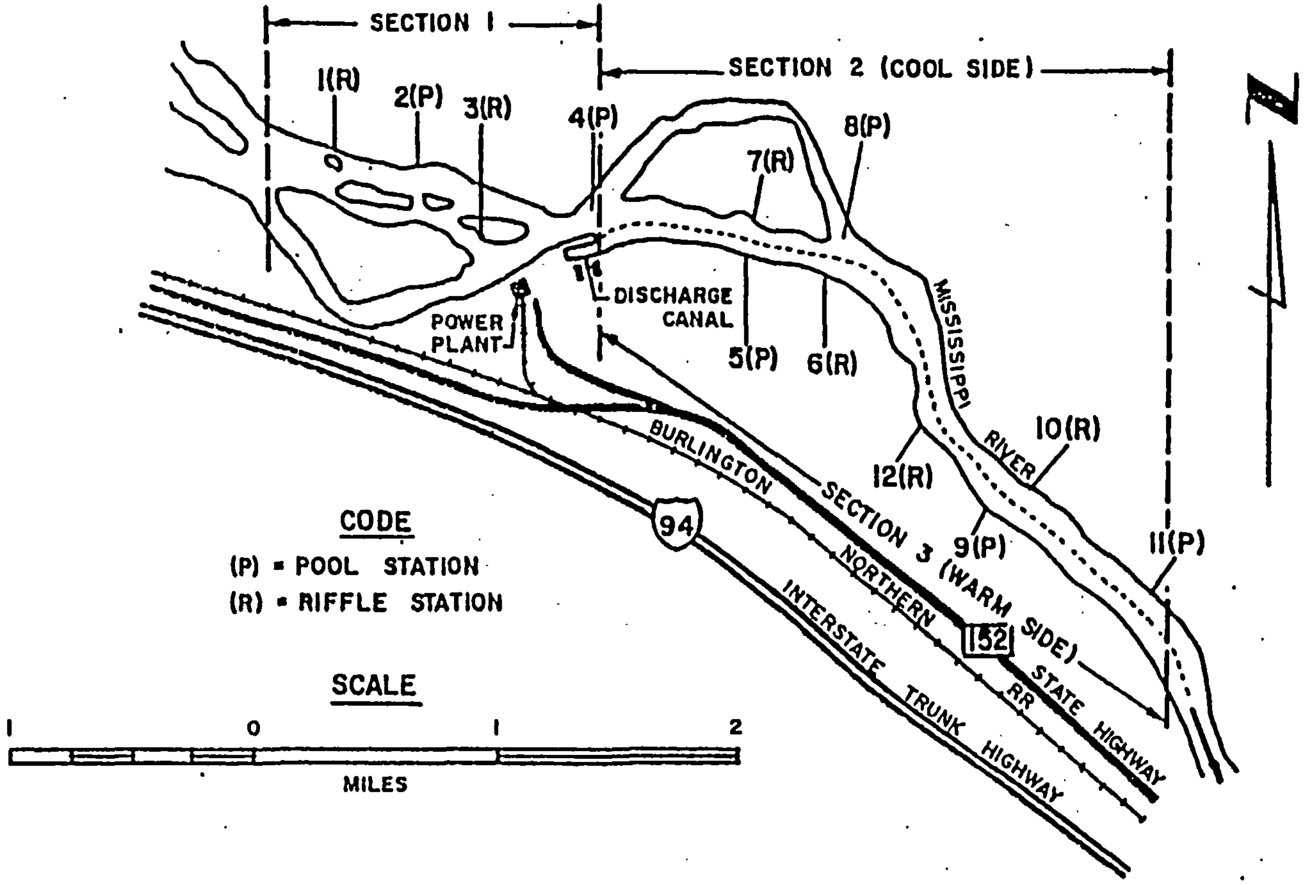


FIGURE 4.3-3

SEINING STATIONS NEAR MNGP, 1973-1974
(From Heberling 1975)

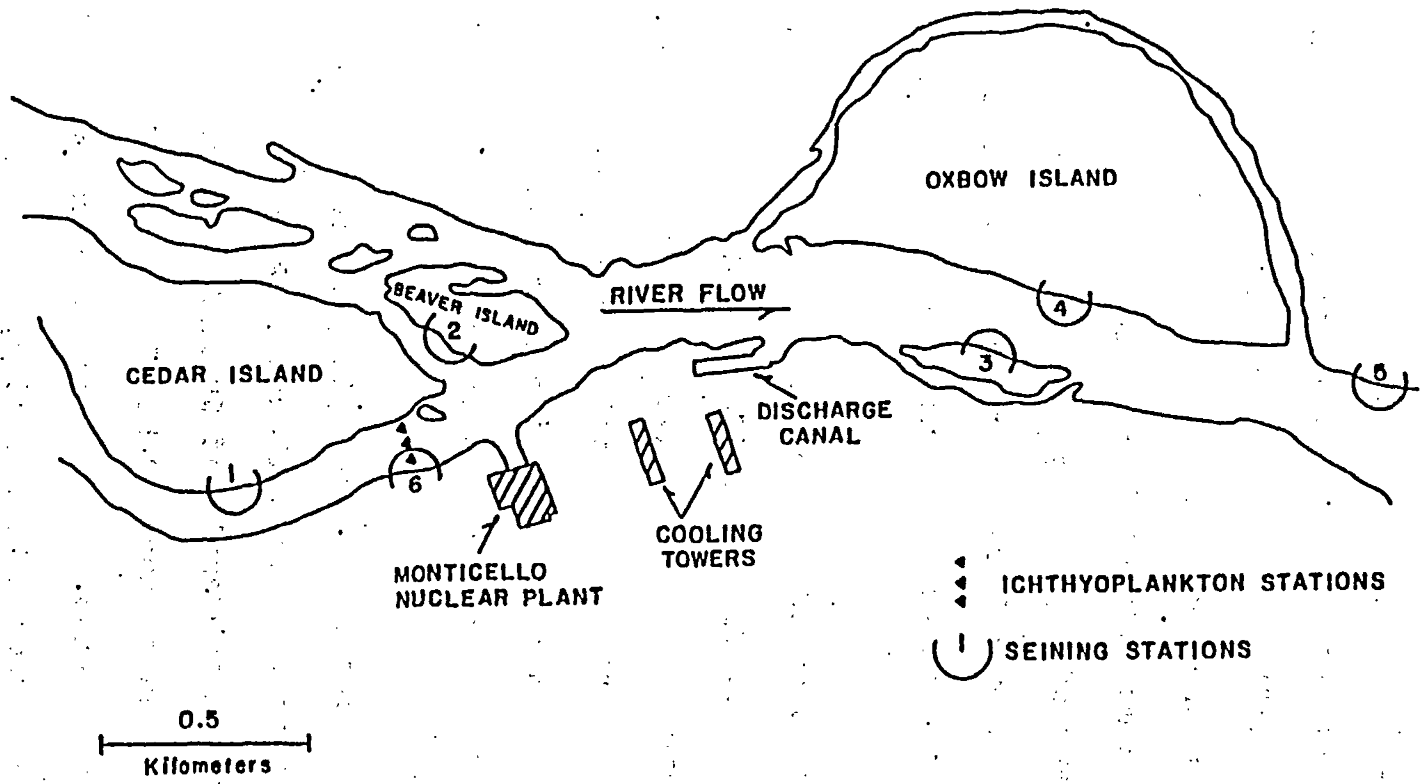


FIGURE 4.3-4

ICHTHYOPLANKTON AND SEINING STATIONS NEAR MNGP, 1976-1977

Fish were collected with a 6.1 m x 1.8 m (20 x 6 ft) straight seine of 3.1 mm (1/8 in.) mesh. Seine hauls were made perpendicular to shore and each haul covered approximately 35 m^2 (375 ft^2). The number of seine hauls at each station depended on the number of fish captured, i.e., enough seine hauls (to a maximum of four) were made to collect at least 50 specimens of any one species. Fewer hauls were generally made at station 6 because it was very difficult to seine there due to the swift current and steep, rocky shore.

All specimens collected were preserved in 10% formalin. In the laboratory, fish were identified, counted and measured to the nearest millimeter (total length and standard length) and to the nearest gram (fish weighing more than 300 g) or tenth of a gram (fish weighing less than 300 g). Weights and lengths of all game and panfish were measured.

For forage species, a subsampling procedure was employed when more than 50 were collected. After identification and enumeration, a subsample of 50 fish was taken if the total number was greater than 50 but less than 500. If greater than 500, a subsample of 10% of the total was taken. The subsample was chosen by spreading the fish over a grid and randomly selecting blocks of the grid until the appropriate number of fish was chosen. Each fish in the subsample was measured. All fish of a given taxon were then weighed as a batch. As the samples were processed, it became clear that a smaller subsample could be chosen and still retain an acceptable level of accuracy. Therefore, for each sample, an initial subsample of 20 fish was selected and the mean length and standard deviation calculated. These data were entered into the following formula to determine optimum sample size:

$$N = \frac{St_a}{a\bar{y}}^2$$

where S = standard deviation of the lengths

t_a = Student's-t for the number of degrees of freedom in the subsample and the level of confidence chosen

a = accuracy with which the mean is to be estimated

$\bar{y}$ = mean length

N = estimated number of measurements needed to obtain a mean within 10% of the true mean at the 95% confidence interval.

If N was greater than 20, an additional subsample was chosen and the statistics were recalculated. If N was less than or equal to 20, no additional subsample was necessary.

The taxonomic keys used to aid in the identification of fishes collected included Becker and Johnson (1970), Eddy (1969), Eddy and Underhill (1974), Hubbs and Lagler (1958), Lutterbie (1975), Pflieger (1975), Scott and Crossman (1973) and Trautman (1957).

4.3.5.1.3 Drift of Fish Eggs and Young

The drift of fish eggs and young (larvae and juveniles, i.e. fish less than one year old) in the Mississippi River near MNGP was monitored weekly between April 16 and September 4, 1976. On each sampling trip, samples were collected once every four hours for 24 hours. Samples were normally collected between 8:00 AM Friday and 8:00 AM Saturday.

Three sampling stations were established on a transect located approximately 100 to 150 m (328 to 492 ft) upstream of the MNGP intake at the downstream end of a riffle (Figure 4.3-4). Surface and bottom samples were collected on the plant side of the river while a single sample was collected at each of the two other stations.

A combination of sampling gear and techniques was used during the first quarter (April through June) because of the extreme variations in river level. Two types of nets were used: bridled conical plankton nets (0.5 m diameter mouth) and staked plankton nets (0.4 x 0.5 m mouth). Both types of nets were constructed of 0.5 mm mesh nylon gauze. The circular nets were 2 m long with an open area ratio of approximately four; the rectangular nets were 1.8 m long with an open area ratio of about five. A General Oceanics flowmeter with either a standard three-blade rotor or a Model R-2 low speed rotor was rigged in the mouth of each net to measure the volume of water filtered. Use of the standard three-blade impeller was not considered a problem as water velocities were always above the threshold (≈ 5 to 20 cm/sec) of the standard rotor. Volumes filtered averaged 86 m^3 (standard deviation = 42 m^3).

Initially, 0.5 m nets were towed from the intake upstream because the water was too deep and swift to set drift nets. As the river level decreased, towing the nets became increasingly difficult because of the shallowness of the area immediately upstream of the intake. After May 21, 1976, stationary drift nets were set on a transect 100 to 150 m (328 to 492 ft) upstream of the intake. Between May 21 and June 4, a combination of circular 0.5 m nets and rectangular 0.4 m x 0.5 m plankton nets was used, depending on the water depth and velocity at the sampling station. After June 4, staked rectangular 0.4 m x 0.5 m nets with low speed impellers were used.

Because of rapidly dropping river levels in May, it was necessary to move the midriver and farshore (the shore opposite the plant) stations weekly. The stations were generally moved toward the center of the channel and upstream so as to keep the stations located in water deep enough to cover the nets and of sufficient velocity to permit efficient sample collection. River levels appeared to stabilize by early June and stations were not moved thereafter. The final location of the transect was at the base of the second riffle area, approximately 130 to 150 m (427 to 492 ft) upstream of the intake. This is the approximate area indicated on the figure in the original Study Proposal submitted to MPCA on February 26, 1975.

The nets were fished from 5 to about 45 minutes, depending on river level and sampling location. The nets were washed down with a hose after each net was fished and the material collected was concentrated in pre-labeled 950 ml plastic jars that were used as catch buckets. Samples were preserved in 5 to 10% formalin dyed with rose bengal.

The original study design estimated that 600 samples would be collected during the 25-week study period. A total of 483 quantitative samples (81% of the estimated number) were actually collected. The remainder of the samples were either not collected or were considered qualitative, mostly because of the low river levels in 1976. Several samples throughout the course of the study were missed or considered qualitative because of boat or equipment problems. The river program was terminated on September 3-4, 1976. As with the intake programs, samples from the last date were considered qualitative because the nets could no longer be completely submerged.

In the laboratory, samples were sorted to remove the fish eggs, larvae and juveniles. To verify sorting accuracy, a randomly-chosen 10% of the samples were resorted by someone other than the original sorter. Sorted specimens were identified to the lowest possible taxon and developmental stage and counted. A maximum of 20 individuals of each taxon/developmental phase were measured to the nearest 0.5 mm total length. References used to aid in identification included Fish (1932), Hogue, Wallus and Kay (1976), Lippson and Moran (1974), Mansueti and Hardy (1967), May and Gasaway (1967), Swor (unpublished) and Taber (1969).

The total number of fish eggs, larvae and juveniles of each taxon estimated to have drifted past the MNGP intake during the study period was calculated as follows:

$$N_i = \sum_{j=1}^{20} X_{ij} \cdot V_j$$

where N_1 = the total number of eggs, larvae or juveniles of taxon i drifting past the intake

X_{ij} = the mean density of taxon i during week j

V_j = the total volume of water passing the intake for period j

j = the sampling period corresponding to the designated sampling date, i.e., April 16, April 23...August 27.

4.3.5.2 Community Structure

4.3.5.2.1 Species Composition and Abundance

The diversity of the fish community in the vicinity of MNGP is rather limited. A total of 41 species have been collected in approximately nine years of study (Table 4.3-1). Eddy, Moyle and Underhill (1963) reported that 65 species of fish occur above St. Anthony Falls. They felt that before 1963, when the St. Anthony Lock and Dam project was completed, the 23 m (75 ft) drop at the falls was an effective barrier to upstream migration of fishes. However,

TABLE 4.3-1

FISHES COLLECTED AT MNGP, 1968-1976

Common Name[a]	Indigenous[b]	RIS[c]	Electrofishing	Seining
Bowfins				
Bowfin	x		x	
Pikes				
Northern pike	x	x	x	x[d]
Muskellunge	x		x	x
Minnows and Carps				
Carp	x		x	x[d]
Brassy minnow	x			x
Hornyhead chub	x			x
Golden shiner	x			x
Common shiner	x			x
Bigmouth shiner	x			x
Blacknose shiner	x			x
Spottail shiner	x			x
Spotfin shiner	x			x
Sand shiner	x			x
Mimic shiner	x			x
Northern redbelly dace	x			x
Bluntnose minnow	x			x
Fathead minnow	x			x
Blacknose dace	x			x
Longnose dace	x			x
Creek chub	x			x

TABLE 4.3-1 (Continued)

	Indigenous[b]	RIS[c]	Electrofishing	Seining
Suckers				
White sucker	x	x	x	x
Northern hogsucker			x	
Bigmouth buffalo	x			x
Silver redhorse	x		x	x
Shorthead redhorse	x		x	x
Freshwater Catfishes				
Black bullhead	x		x	x
Yellow bullhead	x		x	
Trout-Perches				
Trout-perch	x	x	x	x
Codfishes				
Burbot	x		x	
Killifishes				
Banded killifish	x			x
Sunfishes				
Rock bass	x		x	x
Pumpkinseed	x		x	
Bluegill	x	x	x	x
Smallmouth bass	x	x	x	x
Largemouth bass	x	x	x	x
White crappie	x		x	
Black crappie	x	x	x	x

TABLE 4.3-1 (Continued)

	Indigenous[b]	RIS[c]	Electrofishing	Seining
Perches				
Johnny darter	x			x
Yellow perch	x	x		x
Logperch	x			x[d]
Walleye	x	x	x	x

[a]See Appendix 4 for scientific names

[b]Considered indigenous to this section of the river by MPCA (1975)

[c]RIS = Representative Important Species (MPCA 1975)

[d]Those captured in 1972-73 were released immediately and are not included in the data analysis.

since 1963, three additional species (northern hogsucker, white crappie and golden redhorse) have been collected above the falls (Schneider 1966, Hopwood 1974c).

Of the 41 species collected near MNGP, all except the northern hogsucker are considered indigenous to this section of the river and nine are considered Representative Important Species (RIS) by MPCA (1975) (Table 4.3-1). None of the species collected from the MNGP area are listed as threatened or endangered by the U.S. Fish and Wildlife Service (1974) or by the Minnesota Department of Natural Resources (1974).

4.3.5.2.1.1 Electrofishing Catch

Since various seasons and locations were sampled during the nine-year study, data sets which were comparable were selected for analysis. Sectors A and B were the only two locations sampled consistently; therefore only data from these sets were used for analysis. Similarly, June, July and August were the only months sampled consistently. Fluctuations in the mean CPUE (catch-per-unit-effort) and percent composition for June, July and August were similar to those in the annual mean CPUE's for the years studied (Tables 4.3-2 and 4.3-3). These similarities are not unexpected since annual means are strongly influenced by catch rates during the

TABLE 4.3-2

CPUE (Fish/hr) AND PERCENT COMPOSITION OF THE ELECTROFISHING CATCH FOR SECTORS A AND B[a] IN THE MISSISSIPPI RIVER NEAR MNGP, 1968-1976
(From Hopwood 1969, Hopwood and Sherer 1970, Hopwood, 1971, 1972, 1973, 1974a, 1974b, Heberling and Weinhold 1976b, 1977b)

Year	Carp		Shorthead redhorse		Silver redhorse		White sucker		Black crappie		Smallmouth bass		Walleye		Miscellaneous	
	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
1968	38.4	40.4	43.1	45.3	3.3	3.5	6.3	6.6	0.3	0.3	0.8	0.8	2.3	2.4	0.6	0.6
1969	b	27.0	b	51.8	b	7.9	b	4.6	b	4.0	b	1.9	b	1.9	b	1.0
1970[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	b	26.3	b	36.4	b	8.5	b	9.7	b	1.0	b	10.1	b	7.0	b	1.5
1972	48.3	39.2	41.2	33.4	11.4	9.2	5.4	4.4	6.4	5.2	7.8	6.3	1.7	1.4	1.1	0.9
1973	31.2	32.5	39.2	40.8	11.8	12.3	4.8	5.0	4.2	4.4	2.3	2.4	0.8	0.8	1.8	1.9
1974	62.2	46.6	28.3	21.2	20.8	15.6	10.8	8.1	6.6	4.4	1.6	1.2	0.4	0.3	2.7	2.0
1975	30.8	47.1	20.6	31.8	6.4	9.9	2.0	3.1	1.9	2.9	1.3	2.0	0.7	1.1	1.0	1.6
1976	72.2	36.1	77.5	38.8	25.1	12.6	4.8	2.4	0.9	0.5	13.4	6.7	2.9	1.5	2.9	1.5
Mean	48.9	40.7	41.3	34.3	13.1	10.9	5.7	4.7	3.4	2.8	4.5	3.7	1.5	1.2	1.7	1.4

[a] See Figure 4.3-1
[b] CPUE data not available
[c] No electrofishing conducted

TABLE 4.3-3

CPUE (Fish/hr) AND PERCENT COMPOSITION OF THE ELECTROFISHING CATCH FOR SECTORS A AND B[a] IN THE MISSISSIPPI RIVER NEAR MNGP IN JUNE, JULY AND AUGUST FROM 1972 TO 1976 (From Hopwood 1973, 1974a, 1974b, Heberling and Weinhold 1976b, 1977b)

Year	Total Hours Sampled	Carp		Shorthead redhorse		Silver redhorse		White sucker		Black crappie		Smallmouth bass		Walleye		Miscellaneous	
		CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
1972	13.4	41.7	38.4	33.7	31.0	9.8	9.0	6.8	6.3	6.1	5.6	6.1	5.6	1.3	1.2	3.2	2.9
1973	18.0	29.1	31.5	40.9	44.2	7.4	8.0	2.8	3.0	6.0	6.5	3.2	3.5	1.1	1.2	1.9	2.1
1974	11.0	72.1	55.2	22.0	16.8	13.6	10.4	8.9	6.8	7.5	5.7	3.6	2.8	0.5	0.4	2.5	1.9
1975[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1976[c]	d	56.7	38.5	64.8	44.1	17.8	12.1	4.1	2.8	d		2.4	1.6	1.2	0.8	e	

[a]See Figure 4.3-1

[b]Data not reported by month

[c]Percent composition does not include black crappie or miscellaneous fish

[d]Actual hours shocked not available, however shocking conducted once per month

[e]Data not available by month for these species, but average CPUE for the entire sampling period (April to October) for both sectors was only 0.9 fish/hr.

summer, the period of the greatest effort and highest catch. Annual means for the seven years of study were used for data interpretation.

Carp and shorthead redhorse ranked first and second, respectively, in terms of CPUE and percent composition. During the preoperational period, shorthead redhorse were slightly more abundant than carp, with the reverse occurring during operational periods. Overall, these two rough fish species made up 78% of the total catch. The remainder of the catch was made up of silver redhorse, white sucker, smallmouth bass, black crappie, walleye and miscellaneous species (in order of abundance).

The catch (CPUE) of individual species varied somewhat from year to year, but no pronounced trends were evident (Figure 4.3-5). Species composition remained relatively stable over the years (Figure 4.3-5). In 1976, CPUE's were relatively high, probably in part because of factors of sampling technique and river conditions, as explained by Heberling and Weinhold (1977b):

> "In general, catch rates were higher in 1976 than in any other year since 1972. This generalization holds for most species in both sectors. Three factors contributed to these elevated cpe's: 1) The type of

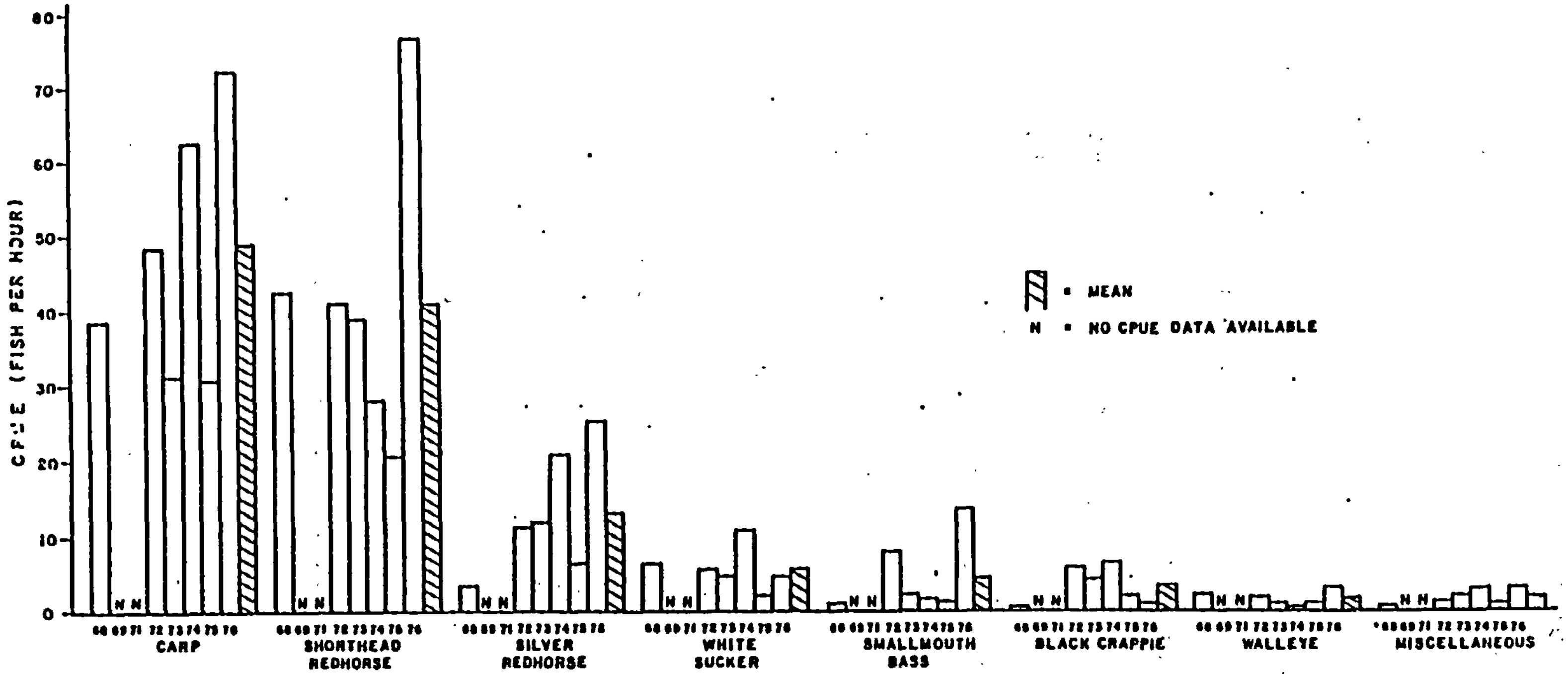


FIGURE 4.3-5

CPUE OF ELECTROFISHING CATCH, SECTORS A AND B COMBINED, 1968-1976
(From Hopwood 1969, Hopwood and Sherer 1970, Hopwood 1971, 1972, 1973, 1974a, 1974b, Heberling and Weinhold 1976b, 1977b)

electrofishing equipment used was new and appeared exceptionally efficient for capturing most species. This new mode of sampling created a problem, whereby most of the previous data could not be compared with 1976 data, 2) elapsed shocking time was recorded differently in 1976. This new method resulted in shorter sampling times being recorded for equivalent shocking runs of previous years. This change, therefore, contributed to the computation of higher catch rates in 1976, and 3) the low river level concentrated fish and made them more vulnerable to sampling."

The most abundant species taken was carp (CPUE = 48.9 fish/hr) which composed 40.7% of the total catch. The CPUE for carp varied widely, from 30.8 in 1975 to 72.2 in 1976. Percent composition ranged from 26.3% in 1971 to 47.1% in 1975. CPUE and percent composition were both somewhat higher during the operational years (1971 to 1976) than in previous years.

Shorthead redhorse were nearly as abundant as carp, producing an overall CPUE of 41.3 fish/hr and composing 34.3% of the catch. CPUE was lowest in 1975 (20.6 fish/hr) and highest in 1976 (77.5 fish/hr). Percent composition ranged from 51.8% in 1969 to 21.2% in 1974. CPUE and percent composition decreased during the operational period, except in 1976, when the CPUE was nearly four times as large as in 1975. This increase may be due in part to the sampling technique, as explained earlier.

Silver redhorse were considerably less abundant than carp or shorthead redhorse and composed only 10.9% of the total catch. The mean CPUE was 13.1 fish/hr. CPUE increased from 1968 (3.3 fish/hr) to 1976 (25.1 fish/hr), except in 1975 when only 6.4 fish/hr were taken. The percent composition ranged from 3.5% to 15.6%.

White suckers made up only 4.7% of the catch (CPUE = 5.7 fish/hr). No trend in abundance for this species was apparent.

The remaining species of fish were all gamefish and included black crappie, smallmouth bass and walleye. Together these three species made up only 7.7% of the catch. A few northern pike were also caught in the MNGP area. In general, the CPUE was lower in 1968 than during operational years (1972 to 1976) but no major trends in abundance were apparent. A large number of smallmouth bass were caught in the fall of 1976, which substantially increased the CPUE for that year, but this high CPUE was not evident in the means calculated from the June, July and August data set. Gamefish are much less abundant than rough fish in the MNGP area.

4.3.5.2.1.2 Seine Catch

During the preoperational seining study conducted from October 1969 to November 1970, a total of 7,248 fish were collected, representing 20 species (Table 4.3-4). The most abundant species were bigmouth shiner (27.3% of the total catch), spotfin shiner (21.1%), sand shiner (18.4%) and bluntnose minnow (12.7%). Morgenweck (1971) describes the distribution as follows:

> "The bigmouth shiner, bluntnose minnow, common shiner, hornyhead chub, johnny darter, sand shiner, smallmouth bass, spotfin shiner, and white sucker had the most widespread distribution. They were found at each station. The longnose dace and redhorse sucker were collected at five of six stations. The blacknose dace was collected at four stations; the creek chub at three; the black bullhead at two; the black crappie, golden shiner, and rock bass were each collected at one station."

The initial operational seine study, conducted from June 1972 to July 1973, yielded 7,599 fish of 23 species (Table 4.3-5). The most abundant of these were spotfin shiner (23.5%), bigmouth shiner (21.8%), sand shiner (21.6%) and bluntnose minnow (16.2%).

TABLE 4.3-4

TOTAL NUMBER AND PERCENT COMPOSITION OF FISH SEINED DURING THE PREOPERATIONAL STUDY AT MNGP, OCTOBER 1969 TO NOVEMBER 1970
(From Morgenweck 1971)

Species[b]	Station[a] UP-1		UP-2		D-1		D-2		D-3		D-4		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Bigmouth shiner	830	49.4	297	27.4	177	12.5	318	23.0	121	11.8	234	35.7	1,977	27.3
Black bullhead	-	-	-	-	-	-	1	0.07	-	-	1	0.1	2	0.02
Black crappie	-	-	-	-	-	-	2	0.1	-	-	-	-	2	0.02
Blacknose dace	-	-	4	0.4	11	0.8	-	-	6	0.6	9	1.4	30	0.4
Common shiner	6	0.4	7	0.6	84	6.0	19	1.4	29	2.8	64	9.8	209	2.9
Creek chub	-	-	1	0.09	20	1.4	-	-	4	0.4	-	-	25	0.3
Golden shiner	-	-	-	-	-	-	-	-	1	0.1	-	-	1	0.01
Hornyhead chub	4	0.2	8	0.7	57	4.0	7	0.5	127	12.4	25	3.8	228	3.1
Johnny darter	14	0.8	87	8.0	90	6.4	90	6.5	26	2.5	56	8.5	363	5.0
Longnose dace	53	3.2	4	0.4	14	1.0	-	-	152	14.8	1	0.1	224	3.1
Redhorse sucker	1	0.06	-	-	6	0.4	2	0.14	10	1.0	1	0.1	20	0.3
Rock bass	-	-	-	-	-	-	1	0.07	-	-	-	-	1	0.01
Sand shiner	614	36.5	303	27.7	96	6.8	253	18.3	33	3.2	34	5.2	1,333	18.4
Smallmouth bass	34	2.0	32	2.9	17	1.2	3	0.2	4	0.4	31	4.7	121	1.7
Spotfin shiner	48	2.9	231	21.1	429	30.4	461	33.3	264	25.8	95	14.5	1,528	21.1
Spottail shiner	4	0.2	3	0.3	23	1.6	3	0.2	34	3.3	8	1.2	75	1.0
White sucker	20	1.2	27	2.5	66	4.7	37	2.7	14	1.4	20	3.1	184	2.5
Bluntnose minnow	53	3.2	89	8.1	321	22.7	187	13.5	199	19.4	76	11.6	925	12.7
Total	1,681	23.2	1,093	15.1	1,411	19.5	1,384	19.1	1,024	14.1	655	9.0	7,248	99.9

[a]See Figure 4.3-2

[b]Logperch and trout-perch, of which two specimens of each were collected, were considered incidental to the catch and were not included in the analysis.

TABLE 4.3-5

TOTAL NUMBER AND PERCENT COMPOSITION OF FISH SEINED DURING THE INITIAL OPERATIONAL STUDY AT MNGP, JUNE 1972 TO JULY 1973 (From Ott 1973)

Species[b]	Station[a] Up-1		Up-2		Up-3		Up-4		D-1		D-2		D-3		D-4		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Spotfin shiner	42	15.8	106	38.4	193	9.8	129	30.2	830	33.6	168	36.9	271	17.5	47	26.3	1,786	23.5
Bigmouth shiner	107	40.1	4	1.4	612	30.9	19	4.5	274	11.0	20	4.4	608	39.3	12	6.7	1,656	21.8
Sand shiner	45	16.9	94	34.1	754	38.0	12	2.8	404	16.4	69	15.2	249	16.1	14	7.8	1,641	21.6
Bluntnose minnow	21	7.9	31	11.2	117	5.9	73	17.1	506	20.5	137	30.1	320	20.7	24	13.4	1,229	16.2
Common shiner	21	7.9	2	0.7	52	2.6	5	1.2	122	4.9	18	4.0	26	1.7	9	5.0	255	3.4
Hornyhead chub	10	3.7	14	5.1	22	1.1	5	1.2	43	1.7	2	0.4	23	1.5	7	3.9	126	1.7
Johnny darter	8	3.0	2	0.7	49	2.5	8	1.9	84	3.4	7	1.6	24	1.6	14	7.8	196	2.6
Fathead minnow	1	0.4	--	--	2	0.1	17	4.0	34	1.4	1	0.2	6	0.4	5	2.8	66	0.9
Spottail shiner	1	0.4	1	0.4	20	1.0	1	0.2	24	1.0	10	2.2	4	0.3	1	0.6	62	0.8
Creek chub	3	1.1	--	--	--	--	--	--	3	0.1	--	--	--	--	--	--	6	0.1
Longnose dace	--	--	--	--	42	2.1	--	--	3	0.1	--	--	--	--	11	6.1	56	0.7
Blacknose dace	1	0.4	--	--	19	1.0	1	0.2	4	0.2	--	--	--	--	--	--	25	0.3
Redhorse spp.	2	0.8	21	7.6	4	0.2	1	0.2	7	0.3	2	0.4	5	0.3	7	3.9	49	0.6
White sucker	--	--	1	0.4	33	1.7	121	28.3	105	4.2	8	1.8	9	0.6	18	10.1	295	3.9
Smallmouth bass	1	0.4	--	--	41	2.1	9	2.1	17	0.7	2	0.4	--	--	9	5.0	79	1.0
Largemouth bass	--	--	--	--	--	--	2	0.5	3	0.1	2	0.4	--	--	--	--	7	0.1
Logperch	2	0.8	--	--	--	--	6	1.4	4	0.2	--	--	--	--	--	--	12	0.2
Trout-perch	1	0.4	--	--	12	0.6	2	0.5	4	0.2	9	2.0	--	--	--	--	28	0.4
Brassy minnow	--	--	--	--	8	0.4	15	3.5	--	--	--	--	--	--	1	0.6	24	0.3
Northern redbelly dace	--	--	--	--	--	--	1	0.2	--	--	--	--	--	--	--	--	1	<0.1
Total	266		276		1,980		427		2,471		455		1,545		179		7,599	

[a] See Figure 4.3-2

[b] Carp, northern pike and walleye were also captured, but they were released immediately and were not included in the analysis

The second operational seining study, conducted from April 1976 to April 1977, yielded 39,006 fish of at least 24 species (Appendix 5). The most abundant species were bluntnose minnow (23.4%), spotfin shiner (23.4%), redhorse (silver and shorthead) (16.9%), sand shiner (13.8%) and bigmouth shiner (12.4%) (Table 4.3-6). None of the remaining species made up more than 2.5% of the total catch. Several species, including blacknose shiner, mimic shiner and an unidentified buffalo, were caught at the site for the first time in 1976-1977.

The four most abundant species in all the studies were spotfin shiner, bigmouth shiner, sand shiner and bluntnose minnow, each ranking first at some time (Table 4.3-7). At station Pre/Up-1 there was an increase from 1970 to 1976 in the percentage of spotfin shiner (2.9% to 12.7%) and a major increase in the percentage of bluntnose minnow (3.2% to 32.3%) from 1970 to 1976. Bigmouth shiner decreased somewhat (49.4% to 26.3%) and sand shiner decreased substantially (36.5% to 3.0%) over the same period. At station Pre/D-1 changes were minor, except for sand shiner which increased from 6.8% to 16.4% between 1970 and 1972. Changes were larger at Pre/D-2, where spotfin shiner first declined from 33.3% during 1970 to 17.5% in 1972 and then increased to 25.1% by 1976. Conversely, bigmouth shiner first increased

TABLE 4.3-6

CPUE (Fish/Haul) AND PERCENT COMPOSITION OF FISH SEINED DURING THE SECOND OPERATIONAL STUDY AT MNGP, APRIL 30, 1976 TO APRIL 1, 1977

	Station[a]													
	1		2		3		4		5		6		Mean	
Species[b]	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%	CPUE	%
Bluntnose minnow	1.04	2.5	78.4	32.3	2.4	7.2	0.3	2.0	50.4	26.1	0.1	0.6	22.1	23.4
Spotfin shiner	23.6	57.8	30.9	12.7	12.3	36.4	2.4	15.2	59.7	25.1	0.9	4.2	21.6	23.4
Redhorse[b]	7.5	18.3	33.3	13.6	4.0	11.9	6.9	44.1	34.4	14.5	18.3	81.0	16.0	16.9
Sand shiner	2.0	4.8	7.2	3.0	9.7	28.7	2.4	15.1	62.3	26.2	0.6	2.7	14.0	15.3
Bigmouth shiner	1.0	2.5	63.8	26.3	2.7	8.0	0.3	2.2	11.0	4.6	0.4	1.6	11.2	12.4
White sucker	1.1	2.7	5.5	2.3	1.4	4.1	1.8	11.3	3.5	1.5	0.4	1.9	2.2	2.5
Longnose dace	0.5	1.2	12.0	4.9	0.1	0.3	0.2	1.3	c	c	0.1	0.6	1.8	2.0
Johnny darter	2.1	5.2	2.4	0.1	0.3	0.9	0.3	1.7	1.6	0.7	0.6	2.8	1.1	1.3
Fathead minnow	c	0.1	3.4	1.4	0	0	0.5	3.1	0.1	c	0	0	0.6	0.6
Carp	0.3	0.6	1.9	0.8	0.2	0.5	0.1	0.3	0.9	0.4	c	0.1	0.5	0.5
Smallmouth bass	0.1	0.3	1.9	0.8	0.1	0.2	0.2	1.3	c	c	0.2	0.9	0.4	0.4
Logperch	1.0	2.5	0	0	c	0.1	0.3	1.9	0.5	0.2	0.1	0.2	0.3	0.4
Shiners (unidentified)	0.3	0.6	0.7	0.3	c	c	0	0	0.8	0.3	0	0	0.3	0.3
Hornyhead chub	0.1	0.1	1.3	0.5	c	c	c	c	0.1	c	0.1	0.5	0.1	0.2
Common shiner	c	0.1	0.2	0.1	0.1	0.3	0	0	0.7	0.3	0	0	0.2	0.2
Catostomidae	0.1	0.2	0	0	0.4	1.1	0.1	0.4	0	0	0	0	0.1	0.1
Mimic shiner	0.1	0.3	0.1	c	c	c	c	0.1	0	0	0.2	0.9	0.1	0.1
Blacknose dace	c	0.1	0	0	c	c	0	0	0	0	0.4	1.9	c	c
Bluegill	0	0	c	c	c	0.1	0	0	0	0	0	0	c	c
Buffalo sp.	c	0.1	0	0	0	0	0	0	0	0	0	0	c	c
Spottail shiner	c	c	0	0	0	0	c	c	c	c	0	0	c	c
Cyprinidae	0	0	0	0	0	0	0	0	c	c	0	0	c	c
Brassy minnow	0	0	c	c	0	0	0	0	0	0	0	0	c	c
Blacknose shiner	0	0	c	c	0	0	0	0	0	0	0	0	c	c
Black crappie	0	0	0	0	0	0	0	0	0	0	c	c	c	c
Muskellunge	0	0	0	0	c	c	0	0	0	0	0	0	c	c
TOTAL CPUE	40.8		242.9		33.8		15.7		237.8		22.6		90.1	
TOTAL NUMBER OF HAULS	77		58		96		96		68		38		433	

[a] See Figure 4.3-4

[b] See Appendix 4 for scientific names

[c] Silver and shorthead redhorse

TABLE 4.3-7

PERCENT COMPOSITION OF PREOPERATIONAL AND OPERATIONAL FISH POPULATIONS SEINED NEAR MNGP
(Adapted from Hopwood 1974c)

	Station[a]							
	Island Channel Stations			Downstream South Shore Stations		Downstream North Shore Stations		
	1970[b]	1972[c]	1976[d]	1970[e]	1972[f]	1970[g]	1972[h]	1976[i]
Spotfin shiner	2.9	9.8	12.7	30.4	33.6	33.3	17.5	25.1
Bigmouth shiner	49.4	30.9	26.3	12.5	11.0	23.0	39.3	4.6
Sand shiner	36.5	38.0	3.0	6.8	16.4	18.3	16.1	26.2
Bluntnose minnow	3.2	5.9	32.3	22.7	20.5	13.5	20.7	26.1
Common shiner	0.4	2.6	0.1	6.0	4.9	1.4	1.7	0.3
Hornyhead chub	0.2	1.1	0.5	4.0	1.7	0.5	1.5	j
Johnny darter	0.8	2.5	0.1	6.4	3.4	6.5	1.6	0.7
Spottail shiner	0.2	1.0	0	1.6	1.0	0.2	0.3	j
Creek chub	-	-	0	1.4	0.1	-	-	0
Longnose dace	3.2	2.1	4.9	1.0	0.1	-	-	j
Blacknose dace	-	1.0	0	0.8	0.2	-	-	0
Redhorse (unidentified)	0.06	0.2	13.6	0.4	0.3	0.14	0.3	14.5
White sucker	1.2	1.7	2.3	4.7	4.2	2.7	0.6	1.5
Smallmouth bass	2.0	2.1	0.8	1.2	0.7	0.2	-	j

[a]See Figure 4.3-2
[b]Morgenweck (1971) Pre/UP-1
[c]Ott (1973) Op-1/UP-3
[d]Current study Op-2/2
[e]M[illegible]genweck (1971) Pre/D-1
[f]Ott (1973) OP-1/D-1
[g]Morgenweck (1971) Pre/D-2
[h]Ott (1973) OP-1/D-3
[i]Current Study Op-2/5
[j] 5%

from 23.0% to 39.3% and then dropped to 4.6% in the same period. From 1970 to 1976, percentages of sand shiner and bluntnose minnow increased moderately.

The abundance of redhorse, the third most numerous taxon in 1976, also changed. Percent composition was low during the preoperational and early operational studies, ranging from 0.06% to 0.4%, but increased during the 1976 operational study to 14.5%.

4.3.5.2.2 Population Densities

In 1968 and 1969 a tag-recapture study was conducted by Hopwood and Scherer (1970) in conjunction with electrofishing to provide a basis for the estimation of population size for the study area shown in Figure 4.3-1. Spaghetti tags were used for marking the fish. The Schnabel method was used to calculate population estimates; however, due to the low number of tag returns for most species, the following variation, as explained by Hopwood and Scherer (1970), was used:

> "Since the tag return rate for the redhorse is greater than that of the other species, and since the number of redhorse captured was greater than that of other fishes, a modification of the calculations so as to obtain population numbers as proportions may yield

better estimates of populations. Thus for carp:

$$\frac{\text{Estimated number of redhorse by the Schnabel method}}{\text{Actual total number of captured redhorse}} = \frac{X}{\text{Actual total number of captured carp}}$$

or

$$\frac{33{,}376}{1{,}867} = \frac{X}{1{,}212}$$

$$X = 21{,}666$$

This figure for X (estimated population size relative to the population size of redhorse) closely approximates the estimated number of carp computed by the Schnabel method (20,093).

Extending this procedure to other species:

Common Name	Estimated number
Carp	21,666
Silver redhorse	3,576
Black crappie	2,360
White sucker	2,270
Walleye	1,609
Smallmouth bass	1,359
Rock bass	608
Bullhead	179
Northern pike	161
Burbot	143
Perch	54
Bowfin	18

Certain limitations should be realized when examining these population estimates. These are described by Hopwood and Scherer (1970): 1) the movement of marked and unmarked fish in the study area (Figure 4.3-1), and 2) the physical effect of the tags on the fish, including changes in health or mortality rates which may affect the susceptibility of these fish for recapture. The effects of these conditions in the population estimates were not studied and are unknown.

In general, the species compositions of the ichthyofauna as described by population estimates and electrofishing were similar. The ranking of the major fish species remained nearly the same: shorthead redhorse, carp, silver redhorse, black crappie, white sucker and smallmouth bass. Black crappie and walleye ranked slightly lower in the electrofishing data than in the population estimate data.

4.3.5.3 Spawning and Nursery Potential

4.3.5.3.1 Reproductive Strategies

Much of the available information concerning the reproduction of the fish in the Mississippi River near MNGP is summarized in Appendix 6. Information on the spawning and nursery potential of the area is provided from studies at the MNGP site by Morgenweck (1971), Eberley (1975), Heberling (1975) and from studies carried out in 1976 in conjunction with the MNGP intake monitoring study.

The fish of the Mississippi River near MNGP employ several spawning strategies and utilize a variety of habitats. Several species release their eggs into the water column or broadcast them over the substrate. These species do not provide parental care or build nests, although some species (e.g. redhorses) may clean the substrate of debris and fine sediment prior to spawning. These species are characterized by high fecundities and low egg and larval survival rates. This group includes northern pike, carp, silver redhorse, shorthead redhorse and walleye.

Other fish, such as the bullheads, bluegill, smallmouth bass, black crappie and johnny darter, utilize nests and provide some degree of parental care. This group is characterized by medium fecundities and relatively high egg survivals.

Forage species, such as the minnows, trout-perch and logperch, represent a third group. These species tend to mature early, to reproduce only once or twice, to be short-lived and to have low fecundities (usually less than 2,000-3,000 eggs per female). They do not normally provide parental care or construct nests, although some minnows may utilize sunfish nests. Little is known of the survival rates of their eggs and larvae, but survival is presumed to be rather high since many of these species can be quite abundant.

4.3.5.3.2 Spawning Habitats

A variety of habitat types are available for spawning in the Mississippi River near MNGP. Backwater areas are the preferred spawning locations for species such as northern pike, carp and bullheads. These areas are characterized by minimal current which prevents the premature downstream displacement of young, and by abundant protective macrophyte cover which is generally absent in the mainstream of the river. Eberley (1975), in a study of spawning activities of carp near MNGP, found that carp spawned in the late spring and early summer (when water levels were highest) in backwaters and inundated areas (Figure 4.3-6). No information was available on the use of those areas by northern pike, a species with similar reproductive habits.

Species such as rock bass, bluegill, smallmouth bass and black crappie generally prefer protected shallows with minimal current for spawning. Cover, such as aquatic vegetation, fallen trees and large rocks, may be important, depending on the species. Since these species build nests, a moderately hard substrate of gravel, small stones or rocks is required for egg attachment; however, this hard substrate may be covered with a thin layer of silt or detritus which is swept away prior to nesting. No centrarchid nests were observed in the MNGP study area in 1976. However, Hopwood

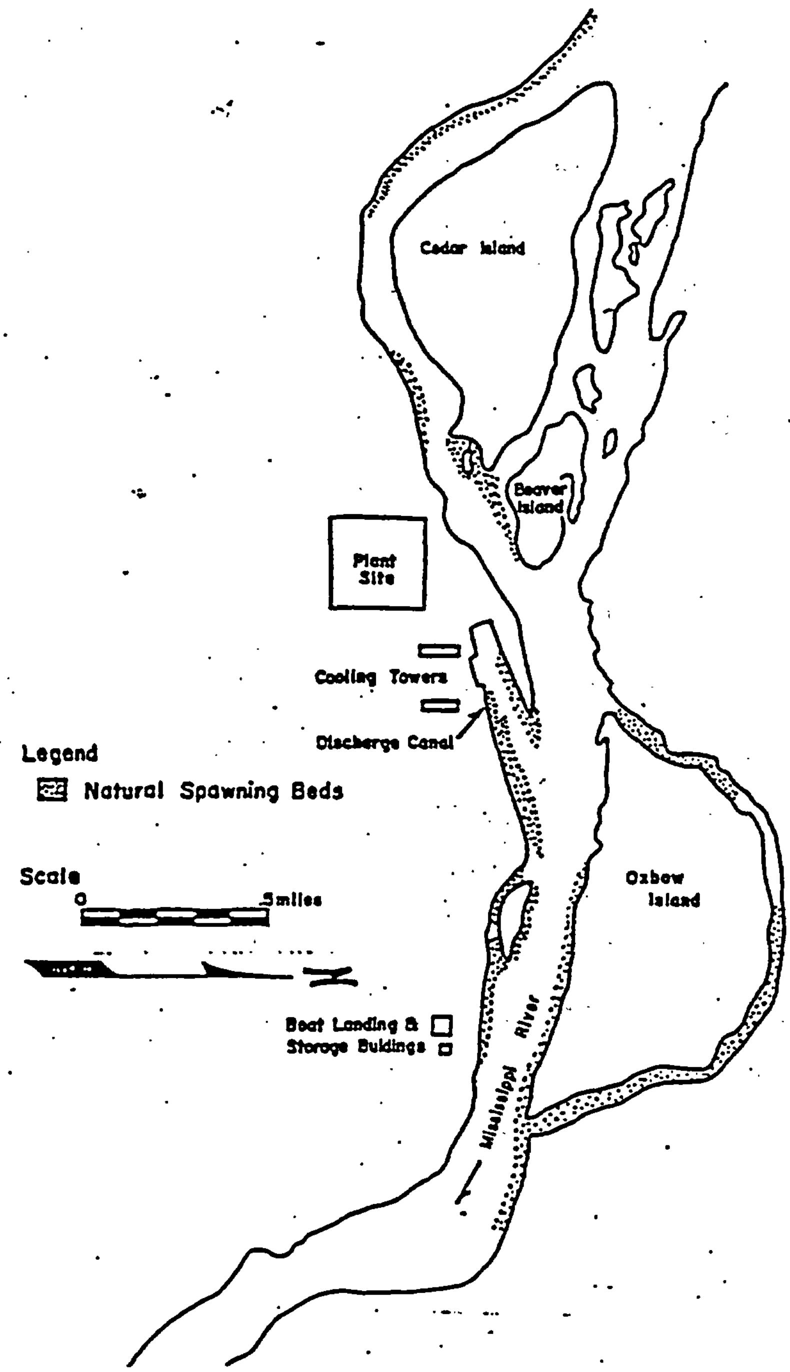


FIGURE 4.3-6

CARP SPAWNING AREAS OBSERVED NEAR MNGP
(Adapted from Hopwood 1974a and Eberley 1975)

(1974a) reported that black crappie probably spawned in several protected areas downstream of MNGP in 1973 (Figure 4.3-7). No information on smallmouth bass spawning in the vicinity of MNGP was available, but suitable habitat exists throughout the area, especially in the river channel to the north of Cedar Island.

Silver redhorse, shorthead redhorse, white sucker and walleye spawn in rivers and streams where the water is flowing and the substrate is usually sand, gravel and/or rock. The eggs of these species are demersal (deposited on the bottom) and usually become lodged in the crevices of the substrate until hatching. The currents in such areas provide a means of downstream dispersal for newly-hatched larvae, a dispersal which tends to balance the upstream spawning migrations of these species. No information is available on spawning movements of these four species in the MNGP area although Hopwood (1973) and Eberley (1975) have determined the spawning areas of white sucker and the redhorses (Figure 4.3-8). All three species used the same riffle areas for spawning, but the white sucker and redhorses were segregated by time and location. White suckers spawned first (April and early May) and at the lower end of riffles where the substrates were mainly fine pebbles and gravel. Redhorses spawned later in May and utilized the upper end of

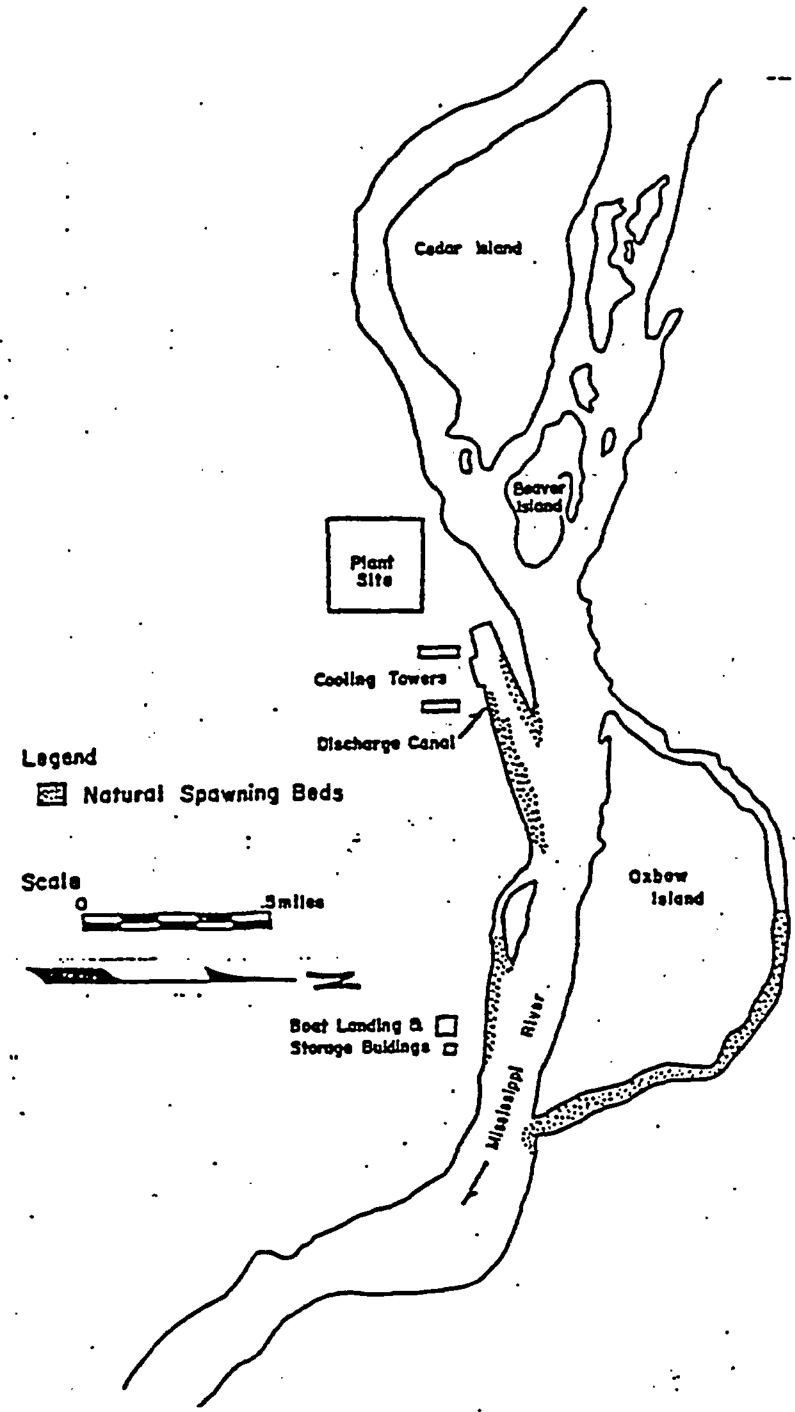


FIGURE 4.3-7

BLACK CRAPPIE SPAWNING AREAS OBSERVED NEAR MNGP
(Adapted from Hopwood 1974a)

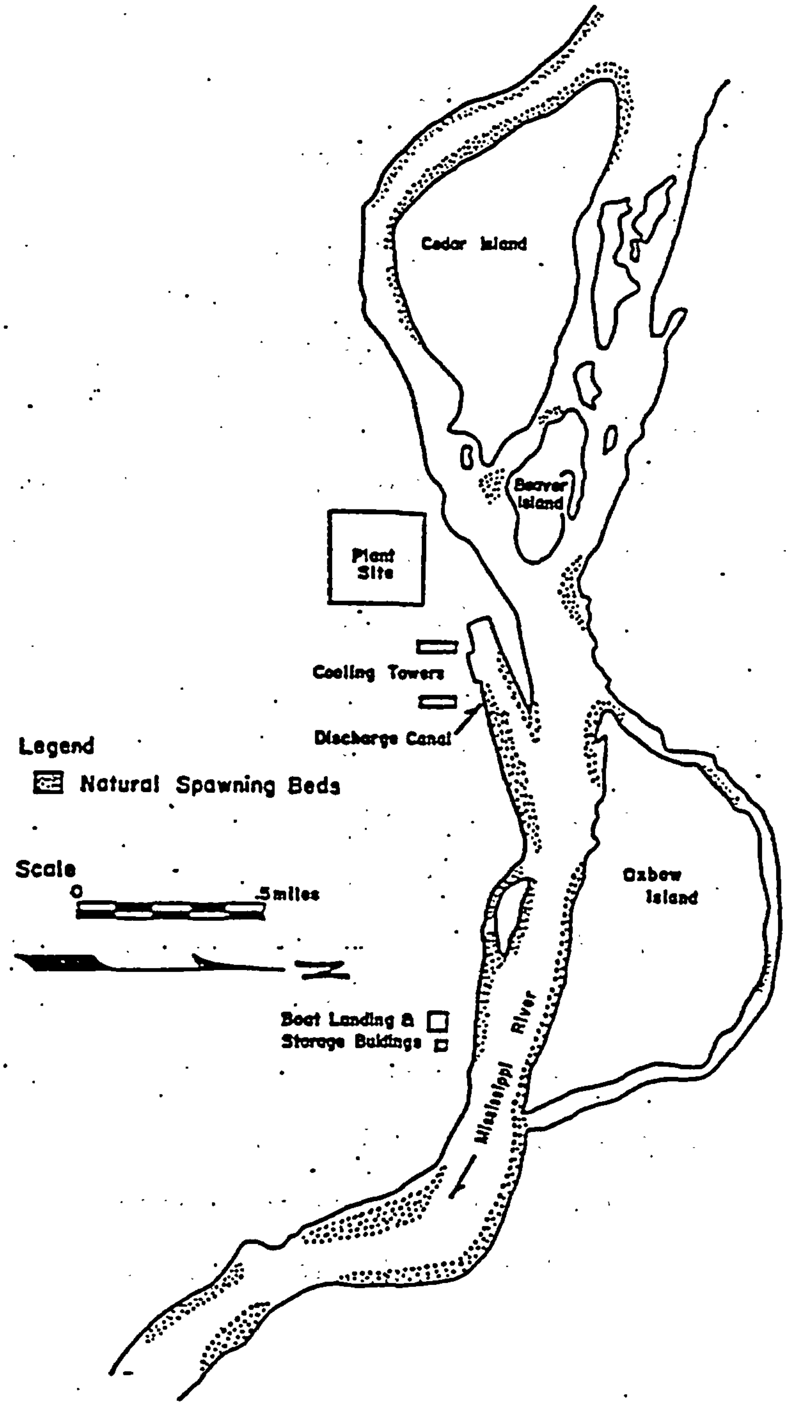


FIGURE 4.3-8

WHITE SUCKER AND REDHORSE SPAWNING AREAS NEAR MNGP
(Adapted from Hopwood 1974 a and Eberley 1975)

riffle areas where the substrate consisted primarily of pebbles. No walleye spawning areas in the vicinity of MNGP have been identified in any of the fisheries studies to date.

4.3.5.3.3 Drifting Eggs and Larvae

Little information on the drift of fish eggs and larvae near MNGP was available before Knutson et al. (1975) studied the entrainment of drifting young fishes at MNGP (the results of this work are discussed in Section 5.5.1.2).

As part of an intake monitoring study in 1976, drift samples were collected in an area just upstream of the MNGP intake. Between early April and late August 1976, an estimated 866,000 fish eggs and 9,788,000 larval, juvenile and older fish drifted past the MNGP intake. A total of 18 taxa of young (larvae and juveniles less than one year old), representing seven families and at least 11 genera, were identified (Table 4.3-8). Young which were too damaged to identify accounted for less than 3% of the estimated total number of young.

More than 52% of the young drifting past the MNGP intake were suckers (primarily redhorses). Logperch was the next most abundant taxon in the drift, accounting for 21% of the total number. These two taxa, along with darters (7.3%),

TABLE 4.3-8

ESTIMATED NUMBER, PERCENT COMPOSITION AND DEVELOPMENTAL STAGE OF YOUNG FISH DRIFTING PAST MNGP, APRIL-AUGUST 1976

Scientific Name	Common Name	Number ($x10^5$)	Percent Composition	Stage of Development[a]					
				E	YL	EL	LL	J	O
Cyprinus carpio	Carp	1.27	1.3		x	x		x	
Notropis dorsalis	Bigmouth shiner	0.28	0.3						x
Notropis spp.	Unidentified shiners	0.28	0.3					x	
Pimephales promelas	Fathead minnow	1.40	1.4						x
Rhinichthys atratulus	Blacknose dace	0.45	0.5					x	
Rhinichthys cataractae	Longnose dace	0.05	b					x	
Cyprinidae	Unidentified minnows	6.42	6.6		x	x	x		
Catostomus commersoni	White sucker	8.43	8.6		x	x			
Moxostoma anisurum	Silver redhorse	0.96	1.0					x	
Moxostoma macrolepidotum	Shorthead redhorse	30.01	30.7				x	x	
Moxostoma spp.	Unidentified redhorse	10.97	11.2		x	x	x		
Catostomidae	Unidentified suckers	0.80	0.8		x		x		
Noturus gyrinus	Tadpole madtom	1.87	1.9				x	x	
Percopsis omiscomaycus	Trout-perch	0.11	0.1		x				
Ambloplites rupestris	Rock bass	4.00	4.1			x			
Lepomis spp.	Unidentified sunfish	0.31	0.3			x			
Centrarchidae	Unidentified sunfish	0.25	0.2			x			
Etheostoma nigrum	Johnny darter	0.10	0.1					x	x
Etheostoma spp.	Unidentified darters	7.05	7.2		x	x			
Percina caprodes	Logperch	20.42	20.9		x	x	x		
Unidenfiable larvae[c]		2.46	2.5						
	Total	97.88	100						

[a] E = Egg
YL = Yolk larva
EL = Early larva
LL = Late larva
J = Yearling or older

[b] <0.05%

[c] Too badly damaged to identify

unidentified minnows (6.6%), rock bass (4.1%) and tadpole madtoms (1.9%), represented over 90% of the fish in the drift. Adult bigmouth shiner, fathead minnow and johnny darter accounted for less than 2% of the identifiable fish drifting by the MNGP intake.

Adult fathead minnows and fish eggs were present in the drift on April 16, 1976, the first date sampled. The eggs could not be positively identified but, based on their size, they were probably sucker eggs. Several peaks in the number of young fish in the drift were apparent in 1976 (Table 4.3-9, Figure 4.3-9). The first peak (1,283,000 fish/week) occurred in the week of May 28 and was made up primarily of redhorse yolk larvae, darter yolk larvae and logperch yolk and post-yolk larvae. The second and highest peak (an estimated 3,143,000 fish/week) occurred during the week of June 18. Post-yolk larvae and juveniles of shorthead redhorse constituted over 95% of the drift of young fishes during the second peak. After June 18, rock bass and minnow larvae were the primary components of the young fish collected at MNGP.

The temporal succession of sucker young in the drift corresponds well with the data reported by Eberley (1975) for the

TABLE 4.3-9

TOTAL NUMBER OF FISH EGGS AND YOUNG (X 10^5) DRIFTING PAST MNGP BETWEEN APRIL 21 AND AUGUST 31,1976

Taxon[b]	Density During 7-day Period[a]																				
	Apr 16	Apr 23	Apr 30	May 7	May 14	May 21	May 28	June 4	June 11	June 18	June 25	July 2	July 9	July 16	July 23	July 30	Aug 6	Aug 13	Aug 20	Aug 27	Total
EGGS																					
Unidentified	4.09	0	0	0	0.80	0.24	0.10	2.78	0	0	0	0	0.38	0	0	0	0.19	0.07	0	0	8.66
LARVAE AND JUVENILES																					
Unidentifiable	0	1.21	0	0	0	0.45	0.26	0.24	0	0	0	0.25	0	0	0.05	0	0	0	0	0	2.46
Cyprinidae	0	0	0	0	0	0.16	0	0	0	0	0.22	1.58	1.00	0.70	1.61	0.34	0.20	0.28	0.11	0.21	6.42
Cyprinus carpio	0	0	0	0	0	0	0.16	0.24	0.35	0.31	0.21	0	0	0	0	0	0	0	0	0	1.27
Notropis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0.28	0	0	0	0	0	0	0	0.28
Notropis dorsalis	0	0	0	0	0	0	0	0	0.28	0	0	0	0	0	0	0	0	0	0	0	0.28
Pimephales promelas	1.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.40
Rhinichthys atratulus	0	0	0	0	0	0	0	0	0	0	0	0	0.39	0	0	0	0	0.06	0	0	0.45
Rhinichthys cataractae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0.05
Catostomidae	0	0	0	0.38	0	0.16	0	0	0	0.27	0	0	0	0	0	0	0	0	0	0	0.80
Catostomus commersoni	0	0	0	3.93	2.35	1.39	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	8.43
Moxostoma spp.	0	0	0	0	0	0	5.69	2.60	0	2.67	0	0	0	0	0	0	0	0	0	0	10.97
Moxostoma anisurum	0	0	0	0	0	0	0	0	0	0.09	0	0.70	0	0	0	0.05	0	0.11	0	0	0.96
Moxostoma macrolepidotum	0	0	0	0	0	0	0	0	1.25	26.63	1.60	0.25	0.13	0	0.10	0.05	0	0	0	0	30.01
Noturus gyrinus	0	0	0	0	0	0	0	0	0	0.62	0	0.48	0	0.42	0.35	0	0	0	0	0	1.87
Percopsis omiscomaycus	0	0	0	0	0	0	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11
Centrarchidae	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0	0	0	0	0	0.25
Ambloplites rupestris	0	0	0	0	0	0	0	0	0.90	0.84	1.54	0.72	0	0	0	0	0	0	0	0	4.00
Lepomis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0.26	0	0.05	0	0	0	0	0	0.31
Etheostoma spp.	0	0	0	0	3.13	0.89	1.34	0.99	0.59	0	0	0.10	0	0	0	0	0	0	0	0	7.05
Etheostoma nigrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05	0	0	0	0	0.10
Percina caprodes	0	0	6.65	1.39	0	6.91	4.50	0.96	0	0	0	0	0	0	0	0	0	0	0	0	20.42
TOTAL EGGS	4.09	.0	0	0	0.80	0.24	0.10	2.78	0	0	0	0	0.38	0	0	0	0.19	0.07	0	0	8.66
TOTAL LARVAE AND JUVENILES	1.40	1.21	6.65	5.71	5.48	9.97	12.83	5.03	3.37	31.43	3.57	4.33	2.06	1.12	2.25	0.49	0.20	0.46	0.11	0.21	97.88
RIVER DISCHARGE (10^6 m^3)	152.8	134.2	94.0	71.1	51.3	40.5	35.3	30.3	32.1	32.6	34.7	41.8	34.8	27.3	24.8	23.3	22.8	19.5	20.1	17.8	

[a]Date shown is first day of two sampling dates centered on 7-day period

[b]See Appendix 4 for common names

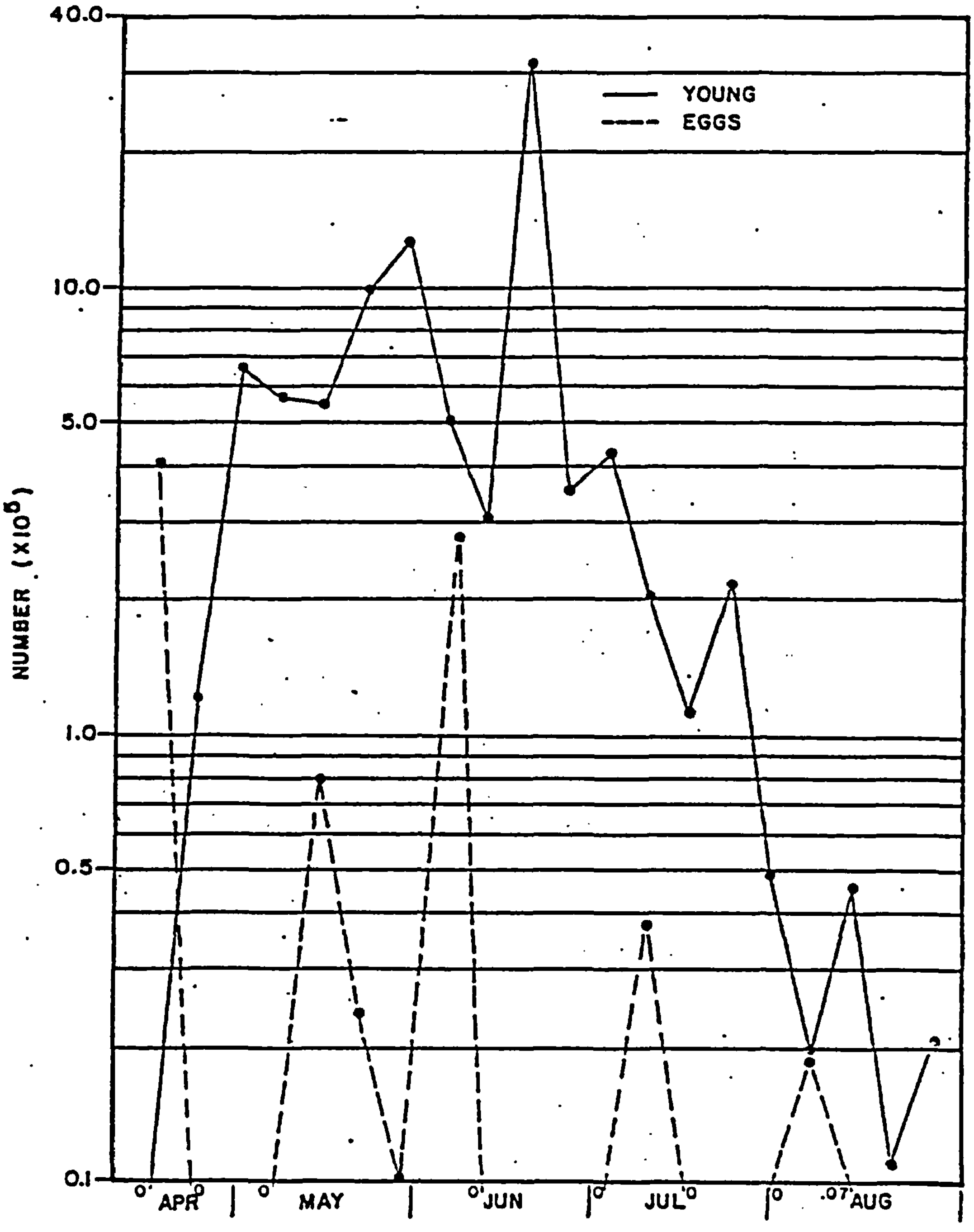


FIGURE 4.3-9

NUMBER OF FISH EGGS AND YOUNG DRIFTING PAST MNGP EACH WEEK, APRIL 16-AUGUST 27, 1976 sequence of sucker spawning (Figure 4.3-10). White suckers, the earliest spawners, appeared in early May. Redhorses, which peaked later in May and in mid-June, apparently spawn later. No consistent diel patterns in drift were evident for young white sucker or redhorse in 1976 (Table 4.3-10). Young redhorse were generally most abundant at midriver; but they were often almost as numerous near the surface on the plant side of the river. No consistent pattern in spatial distribution was evident for white sucker (Table 4.3-10).

Logperch were one of the earliest spawners in the MNGP area, based on the occurrence of yolk larvae in the drift; however, logperch were only present in the drift for six weeks (April 30 to June 4) (Table 4.3-9). The greatest numbers were projected to have drifted past the plant during the week of April 30 (665,000/week) and May 21 (691,000/week). Each peak was made up primarily of yolk larvae. Logperch young were generally most abundant in the drift after sunset, between 8:00 PM and 4:00 AM, and in surface collections on the plant side of the river (Table 4.3-10).

Darter larvae (probably johnny darter) were present in the drift concurrently with logperch (Table 4.3-9). The estimated peak number of 313,000 larvae occurred during the

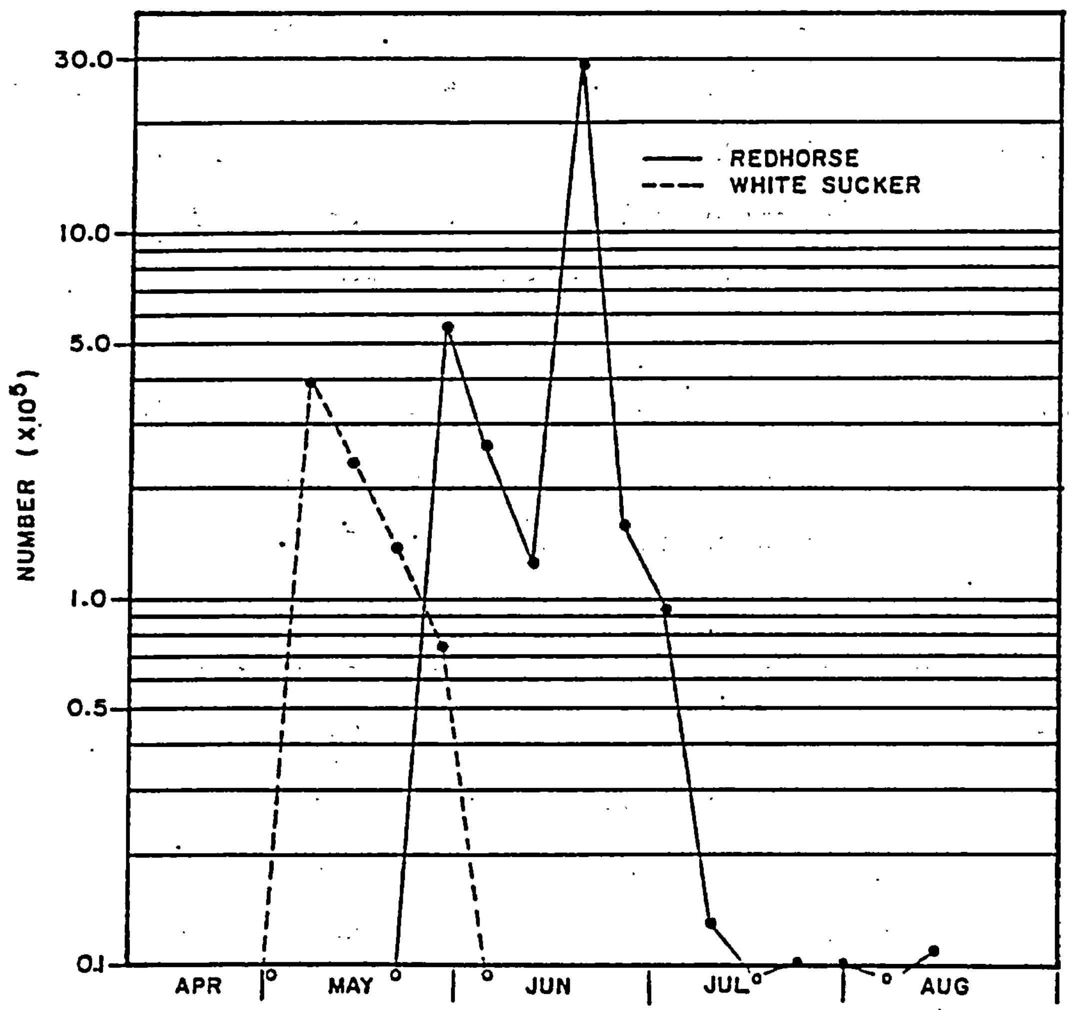


FIGURE 4.3-10

NUMBER OF YOUNG WHITE SUCKER AND REDHORSE DRIFTING PAST MNGP EACH WEEK, APRIL 16-AUGUST 27, 1976

TABLE 4.3-10

DENSITIES (No./100 m^3) OF YOUNG WHITE SUCKERS, REDHORSES (SILVER AND SHORTHEAD), DARTERS AND LOGPERCH DRIFTING PAST MNGP PER 4-HR PERIOD IN 1976

Station[a]	Collection Time							Collection Time						
	0800	1200	1600	2000	2400	0400	Mean	0800	1200	1600	2000	2400	0400	Mean
	White Sucker							Redhorses						
RIS	0	0	0.	0	1.75	0.82	0.39	1.09	2.34	1.45	2.21	2.99	1.08	1.99
RIB	0.62	0	0.34	0	0.70	0.42	0.63	0.77	0	0	0.63	1.41	0.29	0.52
R2	0	0	0	0.37	0.42	0	0.14	4.87	3.84	2.57	1.16	3.23	1.05	2.79
R3	0.88	0	0	2.04	0.55	0.62	0.72	0.62	0.30	0.41	0.29	0.36	0.29	0.38
Mean	0.41	0	0.09	0.60	0.86	0.47		2.04	1.62	1.06	1.07	2.00	0.68	
	Darters							Logperch						
RIS	0.18	0	0	1.81	0.82	0	0.47	0.56	0.44	0.56	2.23	3.57	0.83	1.29
RIB	0	0	0	1.05	0	0	0.18	0.19	0.57	0.23	0.54	1.00	0.30	0.45
R2	0	0	0	0	0	0	0	0.33	1.28	0.25	0.37	0.86	0	0.53
R3	0	0	0	2.11	1.06	0	0.57	0.27	0	0.43	0.22	0.71	0.58	0.37
Mean	0.04	0	0	1.24	0.47	0		0.36	0.54	0.30	0.84	1.56	0.42	

[a] RIS, RIB - plant side of Mississippi River, surface and bottom, respectively
R2 - Mid-river
R3 - Side opposite MNGP

week of May 14, which was also their initial appearance in the drift collections (Table 4.3-9). Similar to logperch, darters were only present in the drift for a short period of about six weeks. Nearly all the drifting larvae possessed yolk-sacs. Darter larvae were almost exclusively captured at night between 8:00 PM and midnight (Table 4.3-10). No darter larvae were collected at mid-river.

Rock bass were only present in the drift for four weeks, June 11 to July 2, with an estimated peak number of 154,000 occurring in the week of June 25 (Table 4.3-9). The spawning season of rock bass at MNGP appears to have been short. Most larvae appeared to have recently absorbed their yolk-sacs, indicating they had recently left nest areas upstream of MNGP.

Larvae of the important game species, such as northern pike, smallmouth bass or walleye, did not appear to be part of the young fish drift near the MNGP intake. This is not unexpected for northern pike and smallmouth bass, considering the spawning habitat of adults and the behavior and rapid growth of young. However, if walleye spawning had occurred in the channel immediately upstream of the MNGP intake, young should have been collected. Neither Hopwood (1974a) nor Eberley (1975) located walleye spawning concentrations in the vicinity of MNGP. This, along with the lack of young in the 1976 drift net collections, seems to indicate that this species does not spawn in the area immediately upstream of the MNGP intake.

4.3.5.3.4 Abundance of Young Fish

In addition to the present study, seine studies have been conducted in the vicinity of MNGP by Morgenweck (1971), Ott (1973) and Heberling (1975). The data collected in 1976 and in Heberling's study, covering 1973 and 1974, are the most useful in examining the abundance and distribution of young fishes.

Heberling (1975) examined the abundance of young white sucker and smallmouth bass in 1973 and 1974. Unpublished data on the abundance of redhorse and carp were also available. These data are summarized in Table 4.3-11 along with abundance estimates for 1976. Heberling (1975) thought that the lower abundance of white sucker in 1974, as compared to 1973, was due to weaker year classes being produced in 1974. He attributed the weaker 1974 year class to low water temperatures in the spring of 1974. The 1976 year classes of redhorse, white sucker and carp appeared to be stronger than those of 1973. The 1976 year class of smallmouth bass was intermediate in size.

TABLE 4.3-11.

MEAN MONTHLY ABUNDANCE (No./ha) OF REDHORSE (SILVER AND SHORTHEAD), WHITE SUCKER, SMALLMOUTH BASS AND CARP NEAR MNGP IN 1973, 1974 AND 1976

	Redhorse	White Sucker	Smallmouth Bass	Carp
1973[a]				
June	-	4,590	201	161
July	1,243	832	291	36
August	663	373	224	9
September	231	37	87	0
1974[a]				
June	-	-	71	-
July	-	443	834	-
August	-	65	365	-
September	-	3	55	-
1976[b]				
June	26,460	5,365	346	79
July	11,793	630	92	675
August	266	6	60	57
September	774	3	43	0

[a] Data from Heberling (1975) and NSP unpublished data

[b] Based on an average area seined of 35 m^2

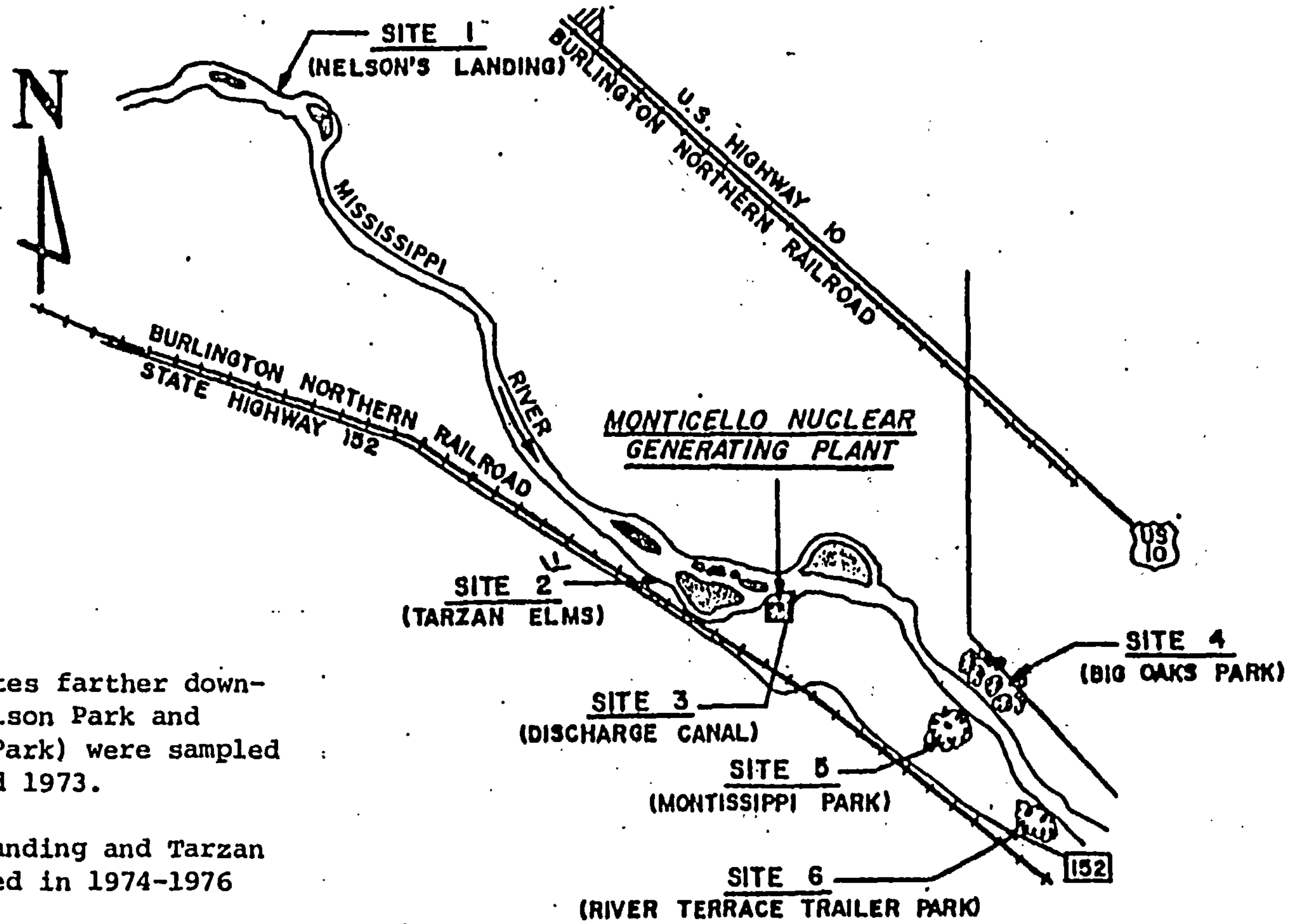
Dash = No data given

4.3.5.4 Sport Fishery

The segment of the Mississippi River located near the MNGP provides a sport fishery utilized primarily by fishermen from the Twin Cities and Monticello areas. This segment of the river is considered to be exploited far below its sustained yield capacity, primarily because of limited public access. The swift current in this stretch of the river discourages boat fishing.

A stratified random creel survey (Neuhold and Lu 1957) was conducted during the primary sportfishing months (May to November) from 1972 to 1976. During 1972 and 1973, six sites, between from the plant discharge canal and the town of Monticello approximately 6 km (3.7 mi) downstream, were monitored. From 1974 to 1976, two of the least productive sites in terms of fishing pressure (Elison Park and Municipal Park) were discontinued and two new stations upstream from the plant were added (Nelson's Landing and Tarzan Elms) (Figure 4.3-11). Both of these new locations were known to be popular fishing areas.

Throughout the survey period, a sharp increase in fishing pressure was observed (Table 4.3-12). Total man-hours spent fishing more than doubled from 2,570 hours in 1972 to 5,772 hours in 1976. This increase can in part be attributed



Note: Two sites farther downstream (Elison Park and Municipal Park) were sampled in 1972 and 1973.

Nelson's Landing and Tarzan Elms sampled in 1974-1976 only.

FIGURE 4.3-11

CREEL SURVEY SAMPLING STATIONS
(From Heberling 1976)

TABLE 4.3-12

CATCH RATE (FISH PER MAN-HOUR) AND PERCENT COMPOSITION IN CREEL SURVEY AT MNGP, 1972-1976
(From NSP 1973, 1974; Heberling and Weinhold 1975b, Heberling 1976, 1977a)

	1972		1973		1974		1975		1976	
Species[a]	Fish/hr	%	Fish/hr	%	Fish/hr	%	Fish/hr	%	Fish/hr	%
Walleye	0.005	1.3	0.031	6.1	0.083	14.6	0.010	1.6	0.010	6.5
Smallmouth bass	0.081	21.3	0.078	15.3	0.050	8.8	0.185	27.8	0.078	50.3
Northern pike	0.006	1.6	0.150	29.5	0.023	4.0	0.008	1.2	0.006	3.9
White sucker	0.006	1.6	0.018	3.5	0.003	0.5	0	0	0	0
Black crappie	0.014	3.7	0.101	19.9	0.104	18.3	0.280	43.5	0.010	6.5
Carp	0.202	53.0	0.078	15.4	0.087	15.3	0.103	16.0	0.049	31.6
Rock bass	0.005	1.3	0	0	0.003	0.5	0.003	0.5	0	0
Black bullhead	0.062	16.3	0.053	10.4	0.200	35.2	0.026	4.0	0	0
Shorthead redhorse	0	0	0	0	0.003	0.5	0.021	3.3	0.003	1.9
Silver redhorse	0	0	0	0	0	0	0.008	1.2	0	0
TOTAL FISH/hr	0.381		0.508		0.568		0.643		0.155	
FISHING PRESSURE (Man Hours)	2,570		2,418		3,700		4,929		5,772	
CATCH RATE (Fish Per Hour)	0.381		0.508		0.568		0.643		0.155	
HARVEST[b]	-		-		1,560		2,370		481	
TOTAL CATCH[c]	980		1,190		2,101		3,169		894	

[a] See Appendix 4 for scientific names

[b] Includes only fish retained by fishermen

[c] Includes all fish taken by fishermen

to two factors: 1) sampling sites were changed in 1974 to include more heavily fished areas and 2) the participation of the general public in outdoor recreation, such as camping and hiking, has increased in recent years. Many of the public fishing sites sampled were campgrounds, with fishing taking on a secondary role to other camping activities.

The most popular species sought were smallmouth bass (11% to 25% of the anglers interviewed), walleye (1% to 12%), northern pike (0% to 14%), black crappie (1% to 8%), carp (0% to 2.3%) and black bullhead (0% to 1%). An additional 53% to 71% of the fishermen listed "anything" (any species) as their preference.

Catch rates (fish/man-hr) indicate that no single species dominated the catch throughout the sampling period. The most frequently caught fish for each year were carp (1972), northern pike (1973), black bullhead (1974), black crappie (1975) and smallmouth bass (1976) (Table 4.3-12). The catch rate for any one species varied and no major trends were observed.

The overall catch rate for all species combined increased steadily from 0.381 fish/hr in 1972 to 0.643 fish/hr in

1975, indicating that fishermen were using more efficient techniques, or that the general population of fishes had increased. A catch rate of 0.5 fish/hr is considered "good" by the MDNR (Krosch 1970). In 1976, the catch rate dropped to 0.155 fish/hr, its lowest level for the survey period. This sharp decline was probably due to the low river levels which severely limited the effectiveness of bank fishing, the major type of fishing practiced. Those few fishermen who were able to find the deeper holes had substantially higher catch rates. The decline was similar for all species.

The annual estimated harvests (annual catch rate in fish/man-hr.x annual fishing pressure in man-hr) are presented in Table 4.3-13. The overall total harvest for all species combined increased steadily from 980 fish in 1972 to 2,370 fish in 1975; however, the corresponding total weights of fish caught decreased from 869 kg in 1972 to 523 kg in 1975. This may be because the species composition of the catch, made up principally larger fish (carp) in 1972, changed to black crappie, a much smaller fish, in 1975. In 1976, both number and weight of fish dropped considerably, probably again because of low river levels.

The annual estimated harvest of walleye increased from 13 fish in 1972 to 307 fish in 1974 and then declined to 36 and

TABLE 4.3-13

ESTIMATED ANNUAL HARVEST (NUMBER AND TOTAL WEIGHT OF FISH)
TAKEN BY FISHERMEN NEAR MNGP, 1972-1976
(From NSP 1973, 1974; Heberling and Weinhold 1976b, Heberling 1976, 1977a)

Species[a,b]	1972[c]		1973[c]		1974[c]		1975[d]		1976[d]	
	Total No.	Total Wt(kg)	Total No.	Total Wt(kg)	Total No.	Total Wt(kg)	Total No.	Total Wt(Kg)	Total No.	Total Wt(kg)
Walleye	13	6.0	49	56.3	307	-	36	16.1	54	36.4
Smallmouth bass	209	127.9	168	60.8	185	-	662	195.0	168	34.3
Northern pike	16	6.2	365	261.5	85	-	3	-	25	11.7
White sucker	15	6.7	44	31.6	11	-	21	21.7	-	-
Black crappie	35	14.7	245	55.7	385	-	1,554	233.7	64	14.3
Carp	519	673.9	190	149.5	322	-	63	52.8	143	180.0
Black bullhead	160	9.6	129	61.3	777	-	34	4.0	-	-
TOTAL	980	869.1	1,190	676.8	1,560	-	2,370	523.5	481	292.3

[a] See Appendix 4 for scientific names

[b] Includes only major species taken

[c] Includes all fish taken by fishermen

[d] Includes only those fish retained by fishermen

54 in 1975 and 1976, respectively. The estimated harvest of smallmouth bass was relatively stable from 1972 to 1974 (168 to 209 fish), however, it more than tripled in 1975 (662 fish) before returning to earlier levels in 1976 (168 fish). The catch of northern pike ranged from 3 fish to 85 fish for all years except 1973, when 365 fish were harvested. The harvest of white suckers was low for all years (0 to 44 fish). The catch of black crappie varied from 35 fish in 1972 to 1,554 fish in 1975 and 64 fish in 1976. The catch of carp ranged from 63 to 519 fish.

A comparison of this section of the Mississippi River to the Red Cedar River in Wisconsin indicates that the catch rates for smallmouth bass were similar in both areas. In the Red Cedar River, 0.07 fish/hr were caught (Paragamian and Coble 1975) compared with 0.05 to 0.18 during the present study.

4.3.5.5 Commercial Fishery

There is no known commercial fishery in the Mississippi River near MNGP.

5 INTAKE STUDIES

5.1 ENTRAINMENT

5.1.1 Entrainment Monitoring Methods

Entrainment monitoring studies were conducted at MNGP between April 23 and September 4, 1976. Samples were collected concurrently with the drift sampling program for fish eggs and young (described in Section 4.3.5.11).

Two sampling station locations immediately in front of the bar racks were used throughout the study (Figure 3.2-1). Initially, surface, mid-depth and bottom samples were collected at each location; however, as the river level dropped, it became necessary to eliminate the mid-depth samples. From June 4 to the completion of the study, only surface and bottom samples were collected.

All samples were collected with 0.5 m plankton nets fished as stationary drift nets. The nets were the same as those described in Section 4.3.5.1 except that they had no bridle. Initially, flowmeters were fitted with the standard three-blade rotor because of limited availability of the newly manufactured R-2 low speed rotor; however, intake velocities were generally above the threshold (15 to 20 cm/sec) of the standard rotor during its usage. Estimates of the volume filtered were obtained by the method described in Section 4.3.5.1. The average volume filtered was 114 m^3 (4,000 ft^3; standard deviation = 95 m^3 or 3,354 ft^3). Nets were generally fished between 20 and 30 minutes.

Sample handling and analysis procedures were the same as those described in Section 4.3.5.1.3 for drift samples.

The total number of fish eggs, larvae and juveniles of each taxon estimated to be entrained was calculated as follows:

$$N_i = \sum_{j=1}^{18} X_{ij} \cdot V_j$$

where N_i = the total number of eggs, larvae or juveniles taxon i entrained

X_{ij} = the mean density of taxon i during week j

V_j = the total circulating water volume for period j

j = the sampling period corresponding to the designated sampling date, i.e., April 23, April 30...August 27.

Sampling was terminated before the planned September 30, 1976 completion date because water velocities in the intake bays were too low (17 to 30 cm/sec) to collect an adequate sample. Because of these difficulties and the observed low densities of young fish in the river, the sampling program was terminated ahead of schedule.

No samples were collected on April 16-17 because of difficulties in sampling at the originally planned location between the traveling screens and circulating water pumps. On August 6-7, no samples were collected because the plant was down for maintenence. Several samples were missed because of boat or equipment problems.

Most of the qualitative samples resulted from the whole or partial obstruction of the net mouth by a sill which extends along the bottom for the width of the intake bay. When the nets were fished near the bottom, they were often pulled behind the sill by the intake current. This problem was rectified in late May by slightly altering the net set.

Methods for other entrainment-related studies at MNGP are detailed by Knutson (1975).

5.1.2 <u>Entrainment of Fish Eggs and Young</u>

Between April 23 and August 27, 1976, 1,076,000 eggs and 2,827,000 young (less than one year old) were estimated to have been entrained at MNGP (Table 5.1-1). Sampling indicated

TABLE 5.1-1

ESTIMATED NUMBER OF FISH EGGS AND YOUNG (X 10^5) ENTRAINED AT MNGP
APRIL 21-AUGUST 31, 1976

Taxon[b]	Density During 7-day Period[a] Apr 23	Apr 30	May 7	May 14	May 21	May 28	Jun 4	Jun 11	Jun 18	Jun 25	Jul 2	Jul 9	Jul 16	Jul 23	Jul 30	Aug 13	Aug 20	Aug 27	Total
EGGS																			
Unidentified	0	0	0.01	0.94	0.74	0.18	6.20	0.79	0	0	0.28	0.06	0.32	0.26	0.39	0.38	0.12	0	10.67
Cyprinidae	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0.06	0	0	0	0	0.10
LARVAE AND JUVENILES																			
Unidentifiable	0	0	0.01	0.02	0	0.07	0	0	0	0	0	0.04	0	0	0	0	0	0	0.15
Cyprinidae	0	0	0	0	0.12	0	0.06	0.37	0.08	0	0.41	0.19	0.14	0.55	0.60	0.29	0.25	0.02	3.08
Cyprinus carpio	0	0	0	0	0	0	0.05	0.14	0.11	0	0	0	0	0	0	0	0	0	0.30
Rhinichthys atratulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0	0	0	0.09
Catostomidae	0	0	0.05	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0.10
Catostomus commersoni	0	0	0.76	0.57	0.17	0	0	0	0	0	0	0	0	0	0	0	0	0	1.50
Moxostoma spp.	0	0	0	0	0.11	1.31	0.31	0.37	0.09	0	0	0	0	0	0	0	0	0	2.19
Moxostoma anisurum	0	0	0	0	0	0	0	0.24	0	0	0	0.12	0	0	0.03	0	0	0	0.40
Moxostoma macrolepidotum	0	0	0	0	0	0	0	0.58	4.64	1.01	0.04	0.18	0	0	0.03	0	0	0	6.33
Ictalurus melas	0	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0.17
Ictalurus nebulosus	0	0	0	0	0	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0.10
Noturus gyrinus	0	0	0	0	0	0	0	0	0.10	0	0	0	0	0	0	0	0	0	0.10
Percopsis omiscomaycus	0	0	0.01	0.02	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08
Ambloplites rupestris	0	0	0	0	0	0	0	0.32	0.29	0.09	0.08	0.10	0	0	0	0	0	0	0.87
Lepomis spp.	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0.07
Percidae	0	0	0	0	0.03	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0.07
Etheostoma spp.	0	0	0	2.17	0.89	0.40	0.13	0.29	0	0	0	0	0	0	0	0	0	0	3.88
Percina caprodes	0	1.61	0.39	0.58	4.05	1.70	0.45	0	0	0	0	0	0	0	0	0	0	0	8.79
TOTAL EGGS	0	0	0.01	0.94	0.74	0.18	6.20	0.79	0	0	0.28	0.10	0.32	0.31	0.39	0.38	0.12	0	10.76
TOTAL LARVAE AND JUVENILES	0	1.75	1.22	3.36	5.44	3.51	0.99	2.37	5.30	1.27	0.53	0.51	0.14	0.64	0.64	0.29	0.25	0.06	28.27
INTAKE VOLUME (10^5 m^3)	9.9	9.9	9.7	9.7	8.0	10.0	9.5	9.0	9.0	9.4	9.5	9.7	9.7	9.8	9.7	8.9	8.5	6.9	

[a] Date shown is first day of two sampling dates centered on 7-day period. Circulating pumps did not operate during the week of August 6 so no data collected.

[b] See Appendix 4 for common names.

that no eggs were entrained before the week of May 7 or after the week of August 20, 1976. There were several apparent peaks in egg entrainment; the greatest number (620,000 or 58% of the total) were entrained during the week of June 4 (Figure 5.1-1). Young fish were entrained between the weeks of April 30 and August 27. The greatest estimated number of young were entrained between April 30 and June 25, when nearly 90% of the total were entrained. Most young fish entrained during this period were suckers (primarily redhorse) and logperch. A secondary peak in entrainment occurred in late July. No estimate of the potential number of eggs and young entrained during the week of August 6 was made because the plant was down and the circulating water pumps were not operating. However, service water pumps were operating and some young fish probably were entrained. Considering the low volume of water withdrawn during this period ($3.45 \times 10^6 m^3$), it is not likely that entrainment during the week of August 6 significantly contributed to the total number of eggs and young entrained at MNGP during 1976.

Suckers (mainly redhorse), which also dominated river drift (Section 4.3.5.3.2), and perch (mainly logperch) made up the largest portion of the fish entrained, accounting for more than 80% of the total young entrained (Table 5.1-1). In contrast, perch constituted a larger portion of the total than the

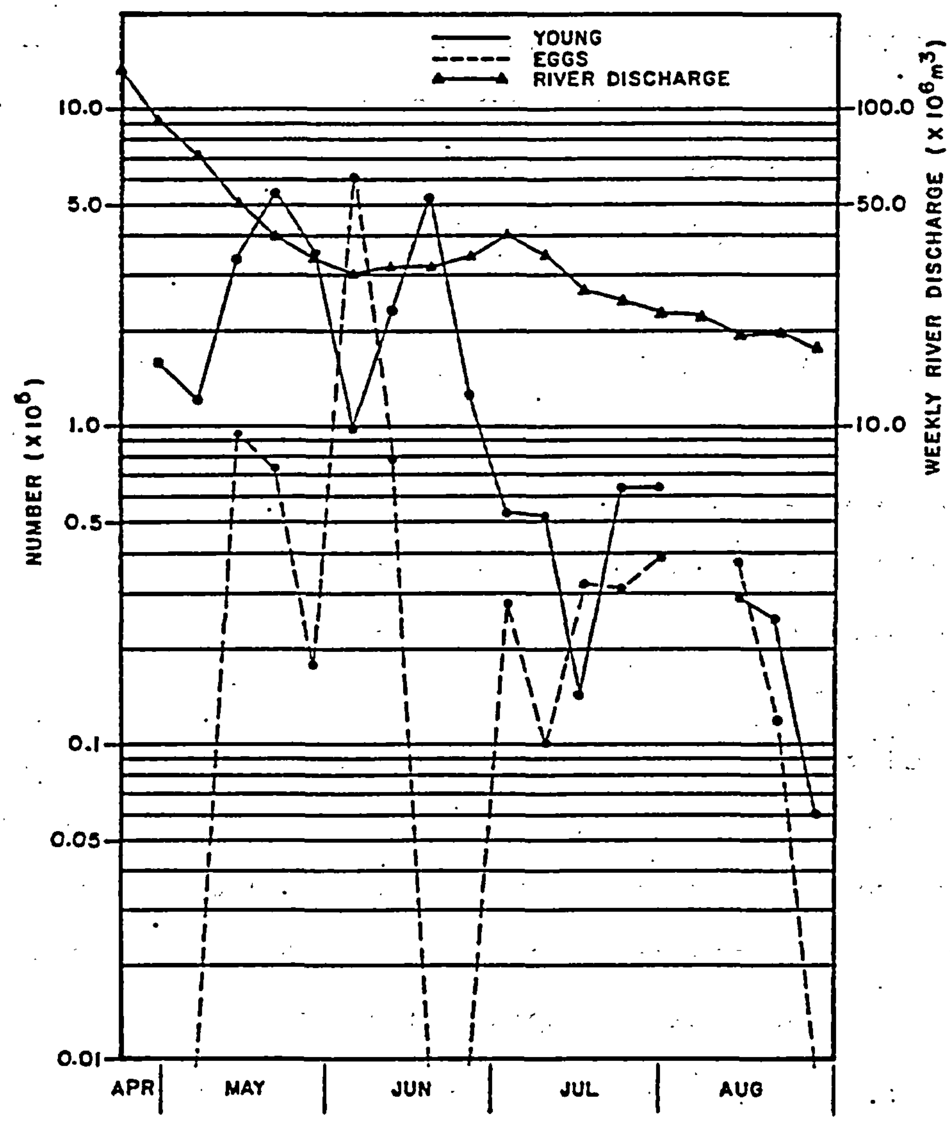


FIGURE 5.1-1

ESTIMATED NUMBERS OF FISH EGGS AND YOUNG ENTRAINED EACH WEEK AT MNGP, APRIL 16-AUGUST 27, 1976 suckers (45.7 vs. 37.2%, respectively, for entrained fish and 28.2% vs. 52.3% for young fish in the river).

Minnows (10.9%), rock bass (3.1%) and carp (1.1%) were the only other taxa that accounted for more than 1% of the estimated total number of young entrained (Table 5.1-2). Minnow eggs, the only eggs identified, accounted for 0.9% of the total number of eggs entrained.

Logperch young were the first to be collected during the study period (Table 5.1-1). There appeared to be two peaks in entrainment, the first during or before the week of April 23 and the second larger peak in the week of May 21 (Figure 5.1-2). At both times, most of the young entrained were yolk larvae. The estimated number of young logperch entrained was generally related to their abundance in the drift. However, no young were taken in the drift during the week of May 14, although approximately 60,000 were estimated to have been entrained in this week. This difference was likely the result of incomplete sampling because of equipment failure on the designated sampling date (See Section 4.3.5.1).

Estimated densities of entrained suckers paralleled their densities in the drift (Figure 5.1-3). White suckers were first entrained during the week of May 7, when they also

TABLE 5.1-2

ESTIMATED TOTAL NUMBER, PERCENT COMPOSITION AND DEVELOPMENTAL STAGE OF YOUNG FISH ENTRAINED AT MNGP, APRIL-AUGUST 1976

Scientific Name	Common Name[a]	Estimated Number Entrained ($x 10^5$)	Percentage of Total Entrained	Stage of Development[b]				
				YL	EL	LL	J	O
Cyprinus carpio	Carp	30,000	1.1	x	x			
Rhinichthys atratulus	Blacknose dace	9,000	0.3				x	
Cyprinidae	Unidentified minnow	308,000	10.9	x	x	x		
Catostomus commersoni	White sucker	150,000	5.3	x	x			
Moxostoma anisurum	Silver redhorse	40,000	1.4			x	x	
Moxostoma macrolepidotum	Shorthead redhorse	633,000	22.4			x	x	
Moxostoma spp.	Unidentified redhorse	219,000	7.7	x	x	x		
Catostomidae	Unidentified suckers	10,000	0.4	x		x		
Ictalurus melas	Black bullhead					x	x	x
	Juvenile	3,000	0.1					
	Yearling or Older	14,000	0.5					
Ictalurus nebulosus	Brown bullhead	10,000	0.4			x		
Noturus gyrinus	Tadpole madtom	10,000	0.4		x	x		
Percopsis omiscomaycus	Trout-perch	8,000	0.3	x				
Ambloplites rupestris	Rock bass	87,000	3.1	x	x			
Lepomis sp.	Unidentified sunfish	7,000	0.2	x				
Percina caprodes	Logperch	879,000	31.8	x	x	x		
Etheostoma sp.	Unidentified darter	388,000	13.7	x				
Percidae	Unidentified perch	7,000	0.2	x				
	Unidentified larvae	15,000	0.5					
Total		2,827,000	100.0					

[a] Nomenclature follows American Fisheries Society (1970)

[b] YL = Yolk larva
EL = Early larva
LL = Late larva
J = Juvenile
O = Yearling or older

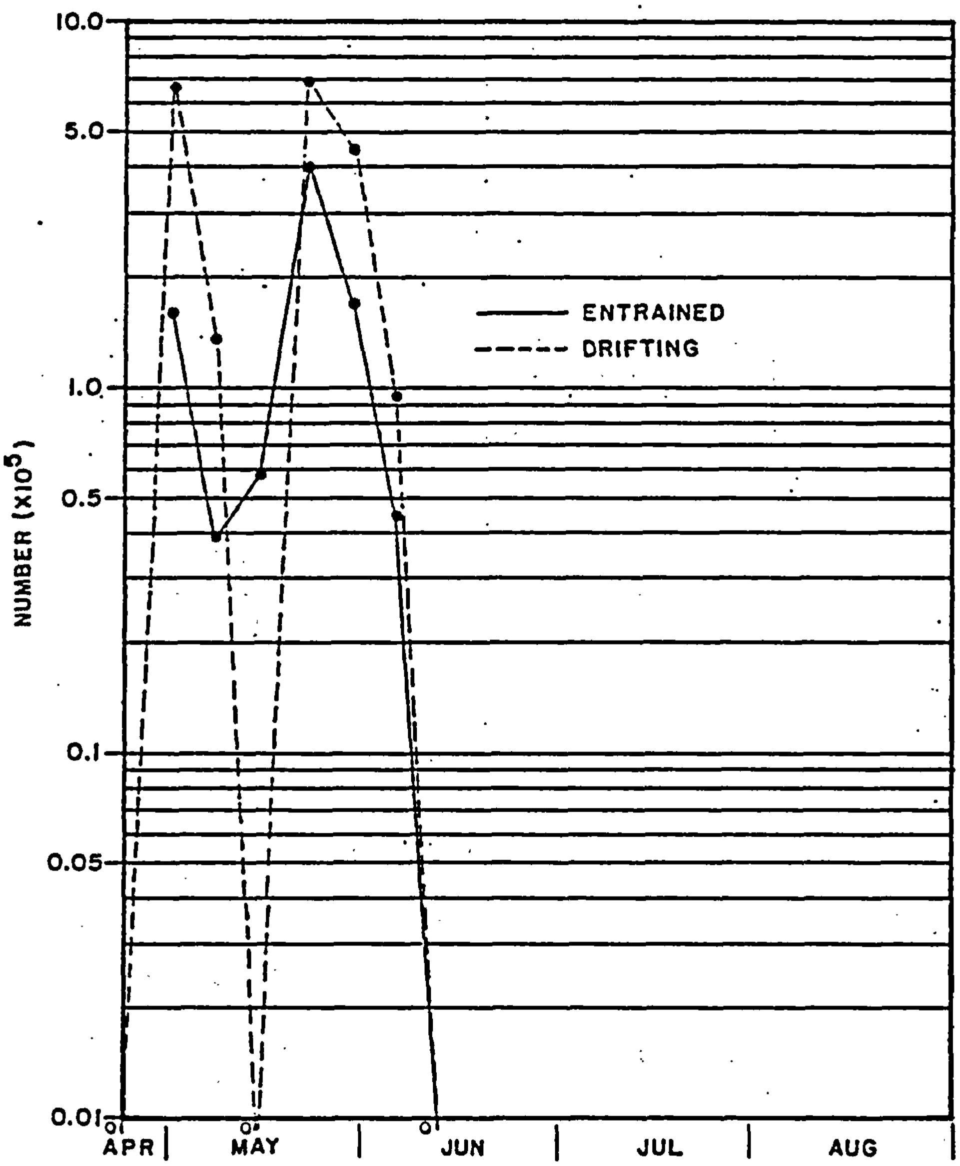


FIGURE 5.1-2

ESTIMATED NUMBERS OF LOGPERCH DRIFTING PAST, AND ENTRAINED BY, MNGP, APRIL 16-AUGUST 27, 1976

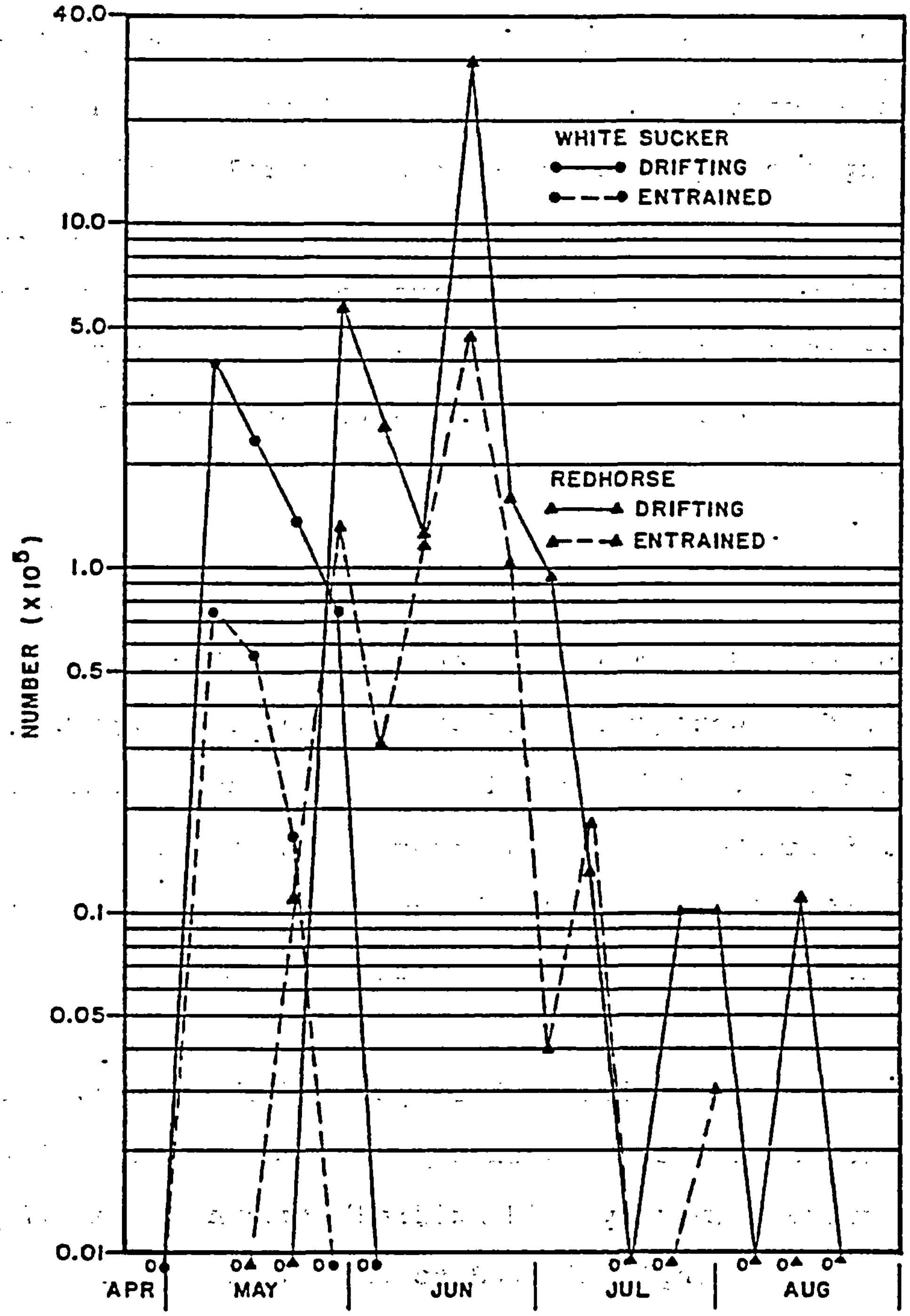


FIGURE 5.1-3

ESTIMATED NUMBERS OF SUCKERS DRIFTING PAST, AND ENTRAINED BY, MNGP, APRIL 16-AUGUST 27, 1976 reached peak abundance. No white suckers were projected to have been entrained after May 28. Redhorses, on the other hand, apparently were not entrained until May 21. An estimated 131,000 redhorses (mostly yolk larvae) were entrained during the week of May 28 and an estimated 473,000 during the week of June 18 (Table 5.1-1). During the week of June 18, most of the young redhorse collected were larval shorthead redhorse.

Knutson (1975) studied the entrainment of young fishes at MNGP between September 1973 and August 1974. Nearly all (99.3%) fish were entrained between May and August 1974 (Table 5.1-3). This period was similar to that examined in the 1976 intake monitoring program. A direct comparison of the studies is precluded by significantly different sampling gear and sampling locations in the two studies.

In 1974, more than 6.3 million young fish were estimated to have been entrained between May and August (Table 5.1-4). Young suckers (mostly unidentified) accounted for 97.8% of the total young estimated to have been entrained during this period; walleye (0.9%),black crappie (0.7%), unidentified shiners (0.3%) and burbot (0.1%) accounted for most of the other young entrained.

TABLE 5.1-3

ESTIMATED NUMBER OF YOUNG ENTRAINED AT MNGP BETWEEN SEPTEMBER 12, 1973 AND AUGUST 18, 1974
(Adapted from Knutson 1975)

Taxon[a]	Sept. 12	Oct. 15	Oct. 22	Nov. 5	Nov. 19	Dec. 17	Jan. 18	Feb. 17	Mar. 13	May 22	May 30	June 12	June 20	June 28	July 14	July 21	July 28	Aug. 4	Aug. 18
Number of Days in Period	34	21	11	14	21	30	31	27	30	4	10.5	10.5	8	12	11.5	7	7	10.5	14
Bowfin											1,491								
Northern pike										336									
Carp		1,827																	
Blacknose dace									1,830										
Fathead minnow	1,394																		
Spotfin shiner							3,658												
Spottail shiner	714		451	1,190			1,209												
Sand shiner	714	1,218		588	2,121	7,710													
Common shiner								1,485						696					
Bigmouth shiner		1,218				2,580	1,209												
Unidentified shiner		609	451									19,992				763	756		
White sucker							1,209												
Silver redhorse	1,394									336									
Shorthead redhorse														1,404	2,749		1,512		
Unidentified suckers										50,736	599,760	4,733,300	266,880	513,672	15,813	5,327	7,938	5,754	742
Yellow bullhead																1,904	378	578	
Burbot										1,008		2,352							
Banded killifish						1,290													
Brook silverside												1,176							
Rock bass		1,218	451																
Bluegill																		1,722	
Smallmouth bass		1,218	2,244													385			
Black crappie	714	3,045												1,404	26,117	4,186	1,512	9,209	1,484
Walleye												28,224	26,688	1,404					
Johnny darter		609					1,209												
Total	4,930	10,962	3,597	1,778	2,121	11,580	8,494	1,485	1,830	52,416	601,251	4,785,144	293,568	518,580	44,679	12,565	12,096	17,263	2,226

[a]See Appendix 4 for scientific names

TABLE 5.1-4.

ESTIMATED NUMBER AND PERCENT COMPOSITION OF YOUNG FISH ENTRAINED AT MNGP BETWEEN SEPTEMBER 12, 1973 AND AUGUST 18, 1974 (Adapted from Knutson 1974)

	September 1973 to August 1974		May to August 1974	
Taxon[a]	Total Number	Percent Composition	Total Number	Percent Composition
Bowfin	1,491	b	1,491	b
Northern pike	336	b	336	b
Carp	1,827	b	0	0
Blacknose dace	1,830	b	0	0
Fathead minnow	1,394	b	0	0
Spotfin shiner	3,658	0.1	0	0
Spottail shiner	3,564	0.1	0	0
Sand shiner	12,351	0.2	0	0
Common shiner	2,181	b	696	b
Bigmouth shiner	5,007	0.1	0	0
Unidentified shiner	22,571	0.4	21,511	0.3
White sucker	1,243	b	0	0
Silver redhorse	1,696	b	336	b
Shorthead redhorse	5,665	0.1	5,665	0.1
Unidentified sucker	6,200,022	97.1	6,200,022	97.8
Yellow bullhead	2,860	b	2,860	b
Burbot	3,360	0.1	3,360	0.1
Banded killifish	1,290	b	0	0
Brook silverside	1,176	b	1,176	b
Rock bass	1,669	b	0	0
Bluegill	1,722	b	1,722	b
Smallmouth bass	3,047	b	385	b
Black crappie	47,671	0.7	43,912	0.7
Walleye	56,316	0.9	56,316	0.9
Johnny darter	1,818	b	0	0
Total	6,386,565	100.0	6,339,788	100.0

[a] See Appendix 4 for scientific names

[b] Less than 0.05%

Young were collected in the intake on all dates between May 22 and August 18, 1974. There were three peaks in entrainment (Figure 5.1-4). The first and largest peak occurred on June 12 and was due mainly to sucker young; however, walleye and shiners were also entrained in considerable numbers (Table 5.1-3). The second smaller peak occurred on June 20 and was again dominated by sucker young. The final and smallest peak occurred on August 4 when black crappie accounted for 53% of the young estimated to have been entrained and suckers composed 33% of the young entrained.

Suckers were entrained throughout the May to August 1974 study period and were most abundant on June 12. Temporal variations in sucker density at the intake in 1974 were similar to those seen for redhorse in 1976.

It is likely that most of the sucker young entrained after late May were redhorse. The lack of samples from late April and early May due to plant shutdown could account for the absence of white suckers in 1974 collections. This species spawns several weeks earlier than the redhorses and consequently young white suckers were no longer of entrainable size when the first samples were collected.

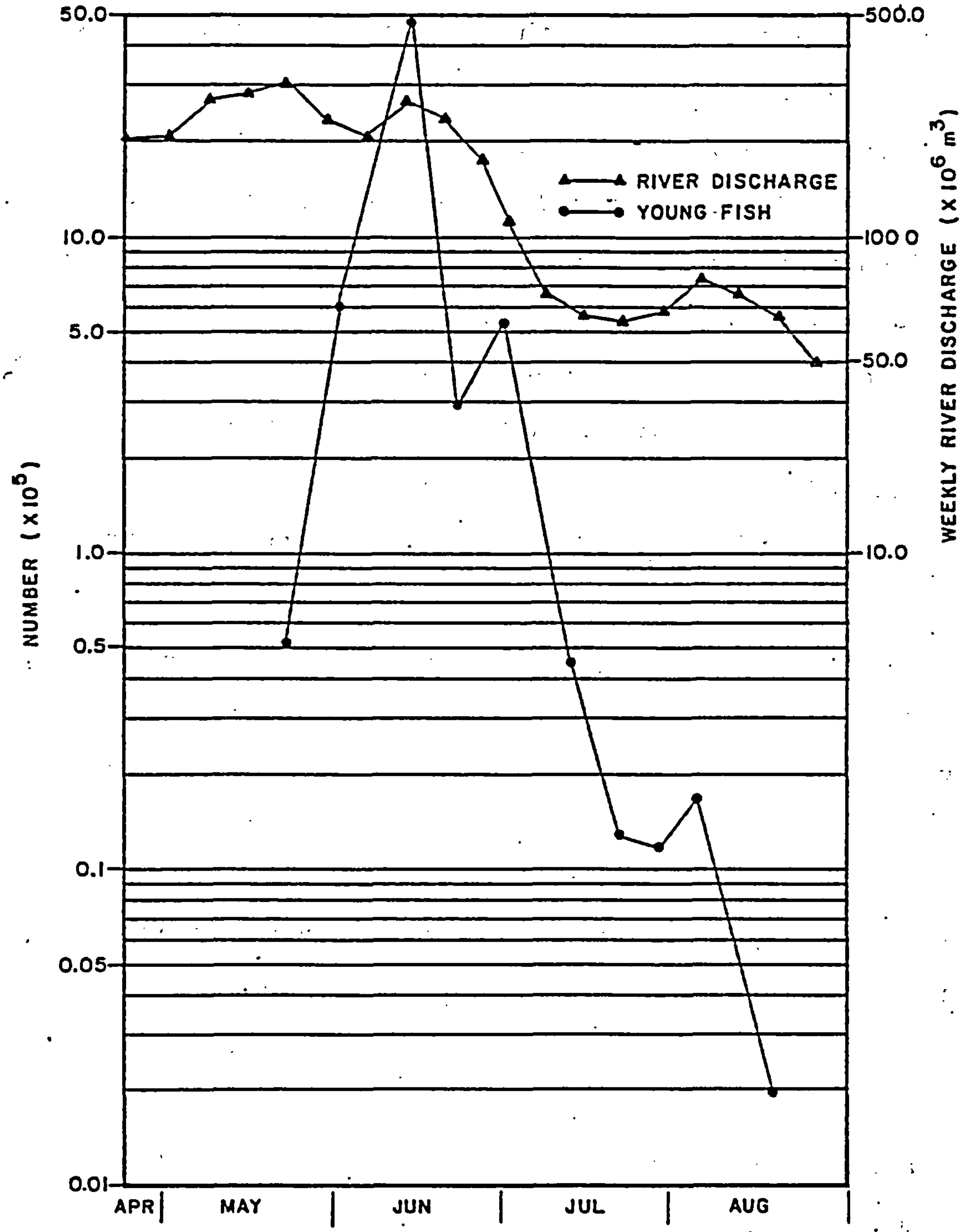


FIGURE 5.1-4

ESTIMATED NUMBER OF YOUNG FISH ENTRAINED EACH WEEK AT MNGP, APRIL 23-AUGUST 25, 1974
(From Knutson 1974)

Walleye accounted for nearly 1% of the young fish entrained in 1974; however, in 1976 no walleye were collected in entrainment samples. A similar situation was observed with black crappie. The absence of walleye and black crappie and the much lower numbers of suckers in 1976, despite more comprehensive sampling, may have been related to considerably lower river flows in 1976 (Figure 5.1-5).

The peaks in the number of young entrained corresponded rather closely with peaks in river discharge in 1974 but not in 1976 (Figures 5.1-1 and 5.1-4).

If a finer mesh collecting device had been used in 1974, the differences in estimated total young entrained in 1974 and 1976 probably would have been larger. The absence of logperch in the 1974 collections, an abundant taxon in 1976, was partially the result of the large mesh size used in 1974 and partially the result of no sampling in late April and early May, 1974.

5.2.1 Impingement Monitoring Methods

An impingement monitoring program was conducted at MNGP between April 16, 1976 and April 8, 1977. One 24-hour period was monitored during each week of the study. The

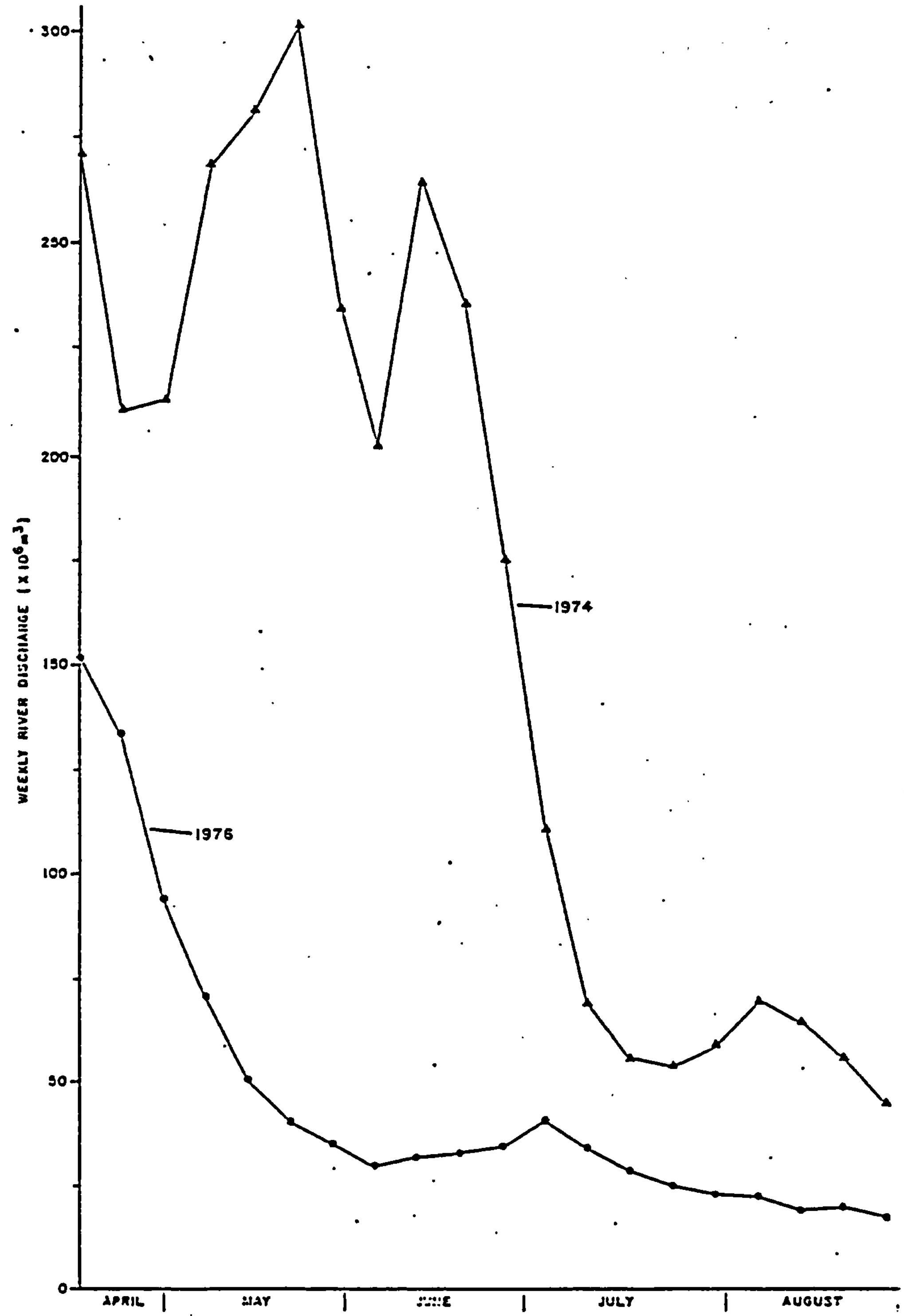


FIGURE 5.1-5

WEEKLY RIVER DISCHARGE AT MNGP, APRIL 16 THROUGH AUGUST 27, IN 1974 AND 1976 period usually extended from 8:00 AM Friday to 8:00 AM Saturday. Fish were generally collected once every 4 hours during the 24-hour period; however, on occasion longer collection periods were needed.

Prior to the start of each 24-hour sampling period, all screens were rotated to clear them of accumulated fish and debris. An effort was made to preserve the normal screen wash schedule when screens did not run continuously. All fish impinged on the traveling screens were collected in a 9.5 mm mesh trash basket located outside the MNGP screenhouse (Figure 3.2-1).

Fish were identified, counted and measured immediately after collection; however, fish whose identification was tentative, as well as most samples from the initial portion of the program, were returned to the laboratory for verification. All game fish were measured and released if still alive. A subsampling procedure similar to that described in Section 4.3.5.5 was employed when more than 50 individuals of a given species were collected.

The total number of fish impinged for the 12-month period was estimated as follows:

$$N_i = \sum_{j=1}^{52} N_{ij} \cdot t_j$$

where N_i = total number of fish of taxon i estimated to be impinged

N_{ij} = number of fish of taxon i impinged in a standardized 24-hour period during week j

t_j = the number of days the plant was in operation in week j

j = the week corresponding to the designated sampling date, i.e., April 16, April 23, 1976,.....April 8, 1977.

Impingement studies were also conducted from 1972 to 1976. Detailed methods employed in these studies may be found in Grotbeck and Bechtold (1975) and Heberling and Weinhold (1975a, 1976a) for study years 1972, 1973-1974 and 1975, respectively.

5.2.2 Impingement Study Results

5.2.2.1 1972-1975 Monitoring

Studies of fish impingement on the vertical traveling screens at MNGP began in June 1972 and continued until September 1972. Counts were made of all fish impinged in 24 hours of plant operation on a sufficient number of days each month to estimate total monthly impingement.

Grotbeck and Bechthold (1975) estimated that 2,952 fish were impinged during this four-month study. Of the impinged fish, 65% were black bullheads and 25.8% were black crappie. Impinged smallmouth bass, northern pike and carp were primarily young-of-year. Black bullhead and black crappie showed lower percentages of young-of-year than did smallmouth bass, northern pike and carp. During the four-month study, 55% of impingement occurred in June (Figure 5.2-1).

In subsequent studies, impinged fish were collected after each screen rinse cycle on 33 dates between July 11, 1973 and December 6, 1974. Heberling and Weinhold (1975a) estimated that 18,030 fish were impinged from July through December 1973 (Figure 5.2-2). Of the fish impinged, 75% were bluegills and 8% were black crappies. Young-of-the-year (including all of the bluegills) made up 94% of the catch.

An estimated 16,343 fish were impinged in 1974 (Heberling and Weinhold 1975), of which 28% were black crappies and 33% were black bullheads. Smallmouth bass and white sucker each composed 4% of the impinged fish. Of the 1974 catch, 52% were young-of-year. Highest impingement rates occurred in late summer and fall in 1973 and 1974, as young-of-year fish grew to impingeable size (Figure 5.2-3).

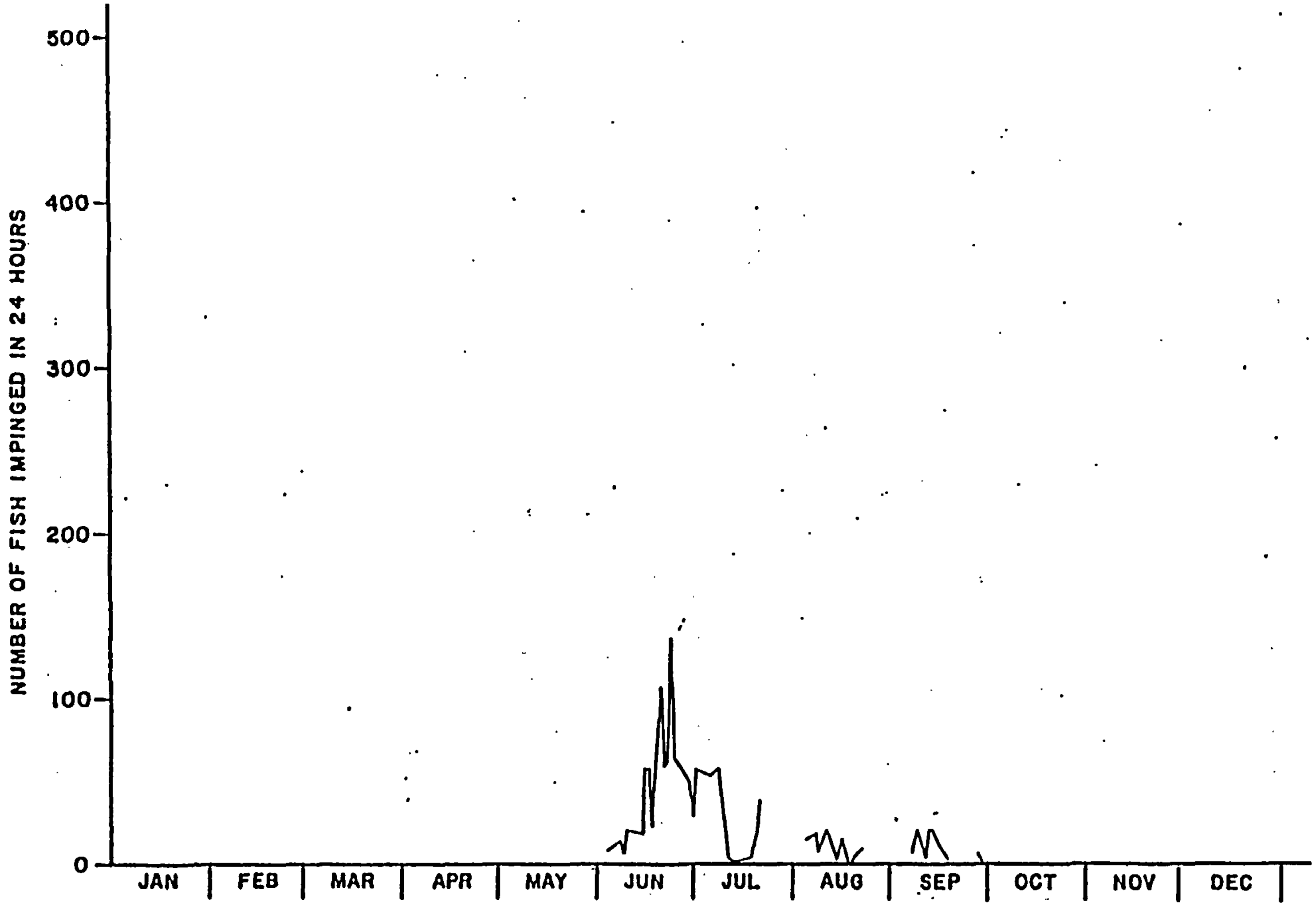


FIGURE 5.2-1

ESTIMATED NUMBER OF FISH IMPINGED DAILY AT MNGP,
JUNE 3 THROUGH SEPTEMBER 29, 1972
(From Grotbeck and Bechthold 1975)

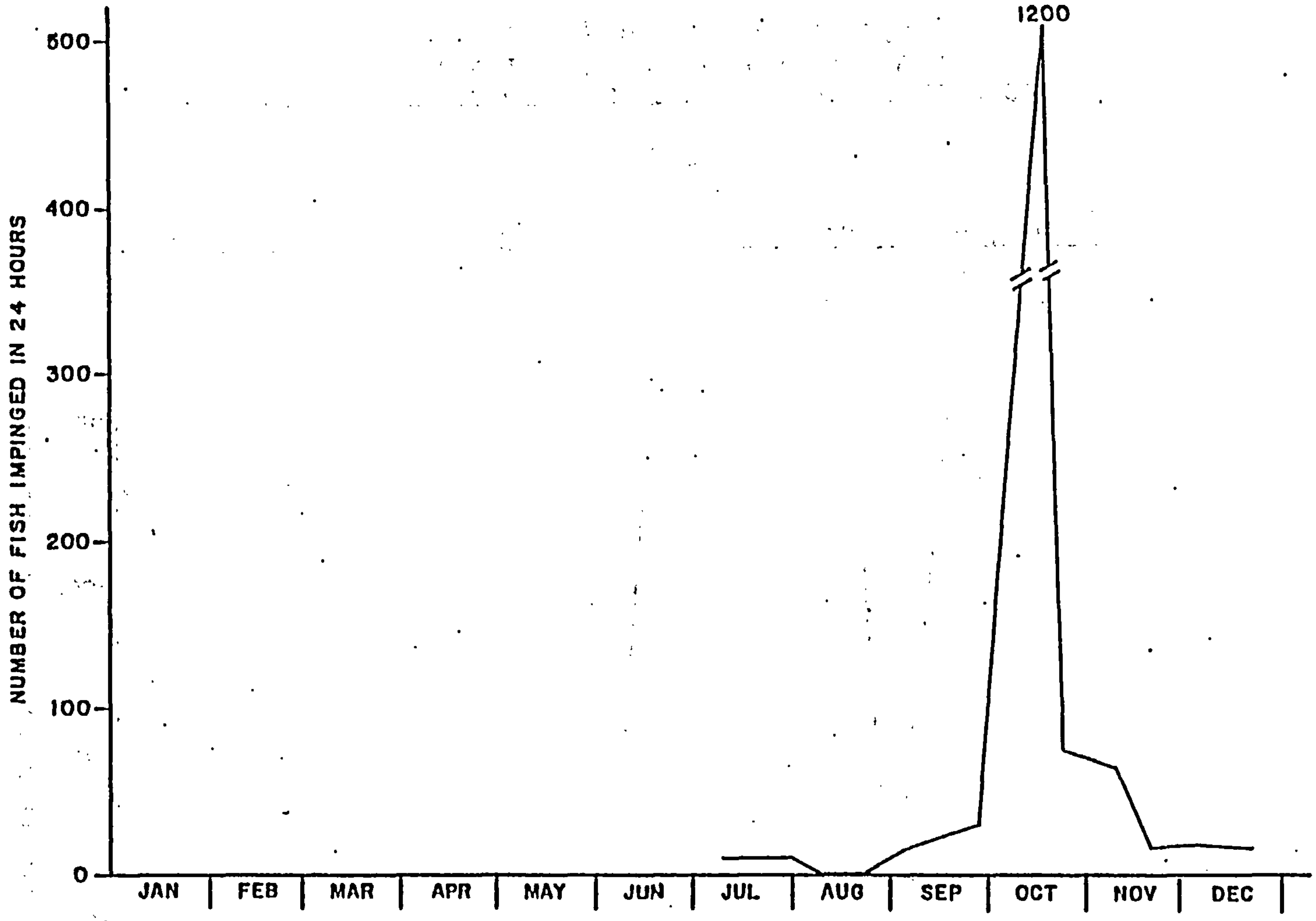


FIGURE 5.2-2

ESTIMATED NUMBER OF FISH IMPINGED DAILY AT MNGP, JULY 11 THROUGH DECEMBER 21, 1973
(From Heberling and Weinhold 1975a)

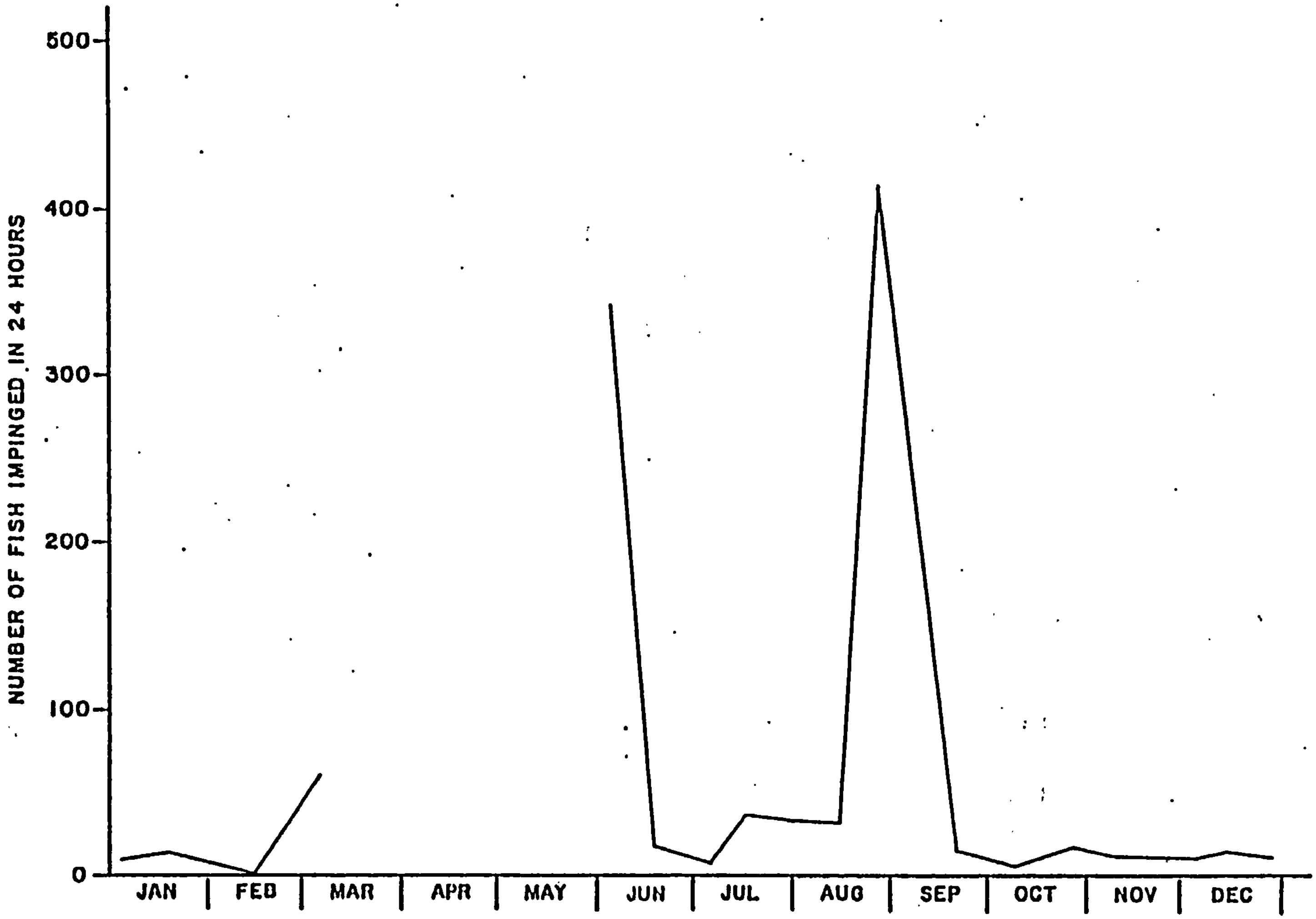


FIGURE 5.2-3

ESTIMATED NUMBER OF FISH IMPINGED DAILY AT MNGP,
JANUARY 4 THROUGH DECEMBER 26, 1974
(From Heberling and Weinhold 1975a)

Impinged fish were collected after each screen rinse cycle on 40 out of 263 plant operating days during 1975. Heberling and Weinhold (1976a) estimated that 34,157 fish were impinged in 1975 (Figure 5.2-4), of which 73% were black bullheads. Carp and black crappies together composed an additional 9%. Only 20% of the fish were young-of-year. The plant was shut down in the fall, when young-of-year impingement is most likely.

5.2.2.2 1976 Monitoring

During the study year, 39,767 fish (719,124 g) were estimated to have been impinged (Table 5.2-1). The upper limit of the 95% confidence interval for this estimate is 75,687 fish (1,437,457 g) while the lower limit is 7,410 fish (110,164 g). An average of 111 fish weighing a total of 2,009 g were estimated to have been impinged on each plant operating day. Plant operating days were considered to be days when water was withdrawn from the river.

At least 33 species of fish were impinged during the study year (Table 5.2-1); 41 species have been identified from the Mississippi River during seven years of ecological studies near MNGP. Eight species of game fish and 10 species of cyprinids (carp and minnows) were identified from the screen-wash samples. Actual numbers and weights of each species

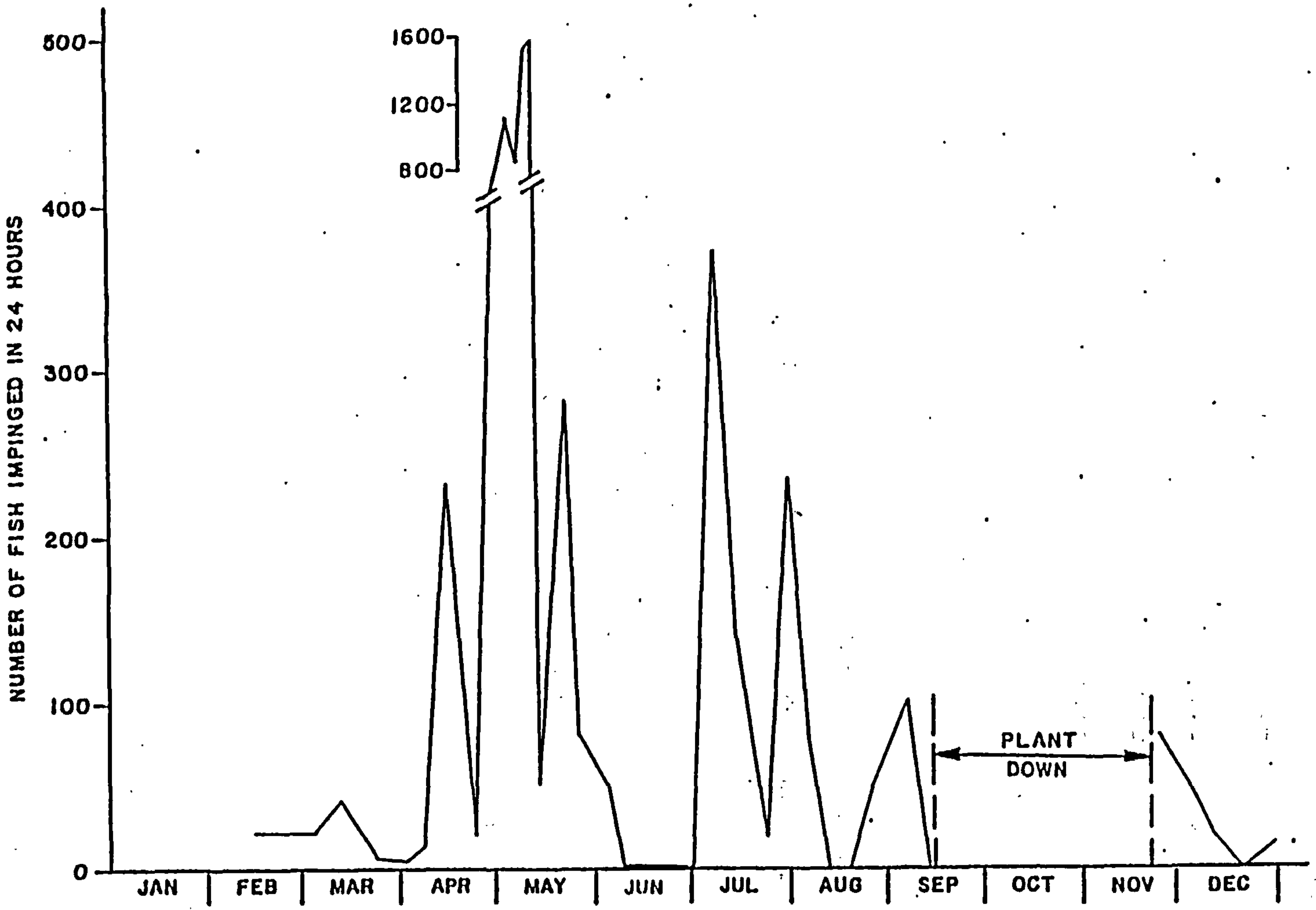


FIGURE 5.2-4

ESTIMATED NUMBER OF FISH IMPINGED DAILY AT MNGP, FEBRUARY-DECEMBER 1975
(From Heberling and Weinhold 1976a)

TABLE 5.2-1

NUMBER AND WEIGHT (GRAMS) OF FISH ESTIMATED TO HAVE BEEN IMPINGED AT MNGP, APRIL 1976 TO APRIL 1977

Species[a]	April 1976 No.	April 1976 Wt.	May 1976 No.	May 1976 Wt.	June 1976 No.	June 1976 Wt.	July 1976 No.	July 1976 Wt.	August 1976 No.	August 1976 Wt.
Cisco					7	28				
Northern pike									7	12614
Carp					14	28	1967	17045	77	1201
Hornyhead chub							7	63	7	105
Golden shiner			7	42	7	35				
Common shiner			21	420	7	112				
Bigmouth shiner	7	7			7	35				
Spottail shiner	7	28	21	84	7	14	21	105		
Spotfin shiner					49	378	210	980	7	28
Sand shiner							7	21		
Shiner									7	14
Bluntnose minnow	49	161					7	35		
Fathead minnow	28	259			14	63	7	21		
Longnose dace			63	546	189	1442	182	1245	91	616
White sucker					21	3948	504	33509	168	7007
Silver redhorse							882	33509	161	546
Shorthead redhorse					21	14539	434	33509	504	16947
Redhorse							7	7245		
Black bullhead	224	21014	770	92946	147	15778	91	4606	140	5061
Yellow bullhead	7	21			7	98	14	231	35	3829
Brown bullhead									7	511
Tadpole madtom	21	154	14	140	21	217	28	245	28	63
Burbot	7	1393					49	6811	7	294
Trout-perch					7	35				
Rock bass							21	910		
Orange-spotted sunfish										
Bluegill									14	21
Smallmouth bass					14	14	21	77		
Largemouth bass										
White crappie										
Black crappie	672	4452	385	2996	539	6013	406	5425	7	49
Johnny darter										
Yellow perch	7	1785								
Logperch			7	133			7	105	7	28
Walleye			7	525	14	21	7	28		
Total	1029	29274	1295	97832	1092	42798	4879	78757	1274	49014

TABLE 5.2-1 (Continued)

Species[a]	September 1976 No.	September 1976 Wt.	October 1976 No.	October 1976 Wt.	November 1976 No.	November 1976 Wt.	December 1976 No.	December 1976 Wt.	January 1977 No.	January 1977 Wt.
Carp	21	483	189	11305	35	197	21	840		
Hornyhead chub			35	140			7	35		
Common shiner							7	14		
Spottail shiner			7	14			7	28	14	42
Spotfin shiner	14	56	7	42	49	133	147	581	28	133
Sand shiner							14	21	7	14
Bluntnose minnow					14	56	7	28		
Fathead minnow			7	21			7	28		
Longnose dace	7	21			14	91				
White sucker	7	140	7	406	7	70	14	112	35	469
Silver redhorse	14	70	287	1400	98	707	2121	11123	1484	8057
Shorthead redhorse	63	252	637	4074	812	8575	5675	29946	2345	14469
Black bullhead	126	4956	21	1533	7	238	14	434	42	1204
Yellow bullhead	14	686	7	266	14	567	28	1400	7	252
Tadpole madtom	21	91	21	238	14	147	49	280	28	203
Burbot	7	693			7	161	98	13811	105	21224
Trout-perch	7	21	7	28	7	42	84	595	7	35
Rock bass	7	350	7	1645	7	35	14	42	28	84
Orange-spotted sunfish					7	21				
Bluegill	7	14	7	14	35	77				
Smallmouth bass	21	1246	7	63	70	1911	63	1876	112	2471
Largemouth bass									14	168
White crappie							28	1232	7	287
Black crappie			35	973	56	539	56	2520	14	413
Johnny darter	7	7					14	28		
Logperch			98	707	56	385	700	5404	63	504
Total	343	9086	1386	22869	1309	14672	7182	70427	4340	50029

TABLE 5.2-1 (Continued)

Species[a]	February, 1977 No.	February, 1977 Wt.	March, 1977 No.	March, 1977 Wt.	April, 1977 No.	April, 1977 Wt.	Totals No.	Totals Wt.
Cisco							7	28
Northern pike							7	12614
Carp	14	6398	112	3276	56	16583	2506	58156
Hornyhead chub							56	343
Golden shiner			7	392			21	469
Common shiner			28	371	56	280	119	1197
Bigmouth shiner			21	56	7	14	42	112
Spottail shiner	7	28	14	49	119	616	224	1008
Spotfin shiner	56	259	385	1981	147	686	1099	5257
Sand shiner	7	28	7	21			42	105
Shiner							7	14
Bluntnose minnow	21	77	14	77	28	140	140	574
Fathead minnow							63	392
Longnose dace			7	28			553	4039
White sucker	28	217	924	12614	406	5089	2121	305655
Silver redhorse	672	3416	1442	9968	224	1862	7385	305655
Shorthead redhorse	280	1827	5194	93625	1330	20671	15295	305655
Redhorse							7	7245
Black bullhead	42	623	98	1603	77	1519	1799	151515
Yellow bullhead			7	420	7	28	147	7798
Brown bullhead			7	119			14	630
Tadpole madtom	7	77	28	196	21	119	301	2170
Burbot	14	1428	42	7356			336	52171
Trout-perch	14	112	21	210			154	1078
Rock bass	63	392	28	119			175	3577
Orange-spotted sunfish							7	21
Bluegill							63	126
Smallmouth bass	154	2681	595	16485	238	7161	1295	33985
Largemouth bass			7	196			21	364
White crappie	14	112					49	1631
Black crappie			35	2394	49	7413	2254	33187
Johnny darter	7	14	7	7			35	56
Yellow perch							7	1785
Logperch	14	231	1085	9492	1344	14210	3381	31199
Walleye							7	21
Total	1414	17920	10115	160055	4109	76391	39767	719124

[a]See Appendix 4 for scientific names

impinged in each collection period and on each collection date are presented in Appendices 7 and 8, respectively.

Shorthead redhorse was the most commonly impinged fish, composing 38.5% of the annual catch (Table 5.2-2). Silver redhorse were the next most numerous fish in the screenwash samples at 18.6% of the annual total. Logperch composed 8.5%, carp 6.3% and black crappies 5.7% of the total collected. Shorthead redhorse was also the most abundant species in the screenwash samples by biomass, at approximately 32% of the annual total. Black bullheads made up only 4.5% of the screenwash catch by numbers but 21.0% by biomass. Sport fish composed 9.8% of the screenwash catch by numbers and 12.2% by biomass.

Figure 5.2-5 shows a peak in impingement in late July, high impingement rates through the winter, and a maximum in late March 1977. Black crappies and black bullheads were the most frequently impinged fish in the spring of 1976, but impingement rates were relatively low. Shorthead redhorse (Figure 5.2-6), silver redhorse (Figure 5.2-7), white sucker and carp were the main components of the July 1976 impingement peak. The two redhorses dominated the screenwash samples for the remainder of the study year (Table 5.2-2)

TABLE 5.2-2

PERCENT COMPOSITION BY NUMBERS AND WEIGHT OF FISH[a] ESTIMATED TO HAVE BEEN IMPINGED AT MNGP, APRIL 1976-APRIL 1977

Species[b]		April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Mean	% Species Composition Near Plant[c]
Carp	% No.	0	0	1.2	40.3	6.0	6.1	13.6	2.7	0.3	0	1.0	1.1	1.4	6.3	40.7
	% Wt.	0	0	*	21.6	2.6	5.3	49.4	6.3	1.2	0	35.7	2.0	21.7	8.1	
White sucker	% No.	0	0	1.9	10.3	13.2	2.0	0.5	0.5	0.2	0.8	2.0	9.1	9.9	5.3	4.7
	% Wt.	0	0	9.0	b	14.3	1.5	1.8	0.5	0.2	0.9	1.2	7.9	6.7	4.7[c]	
Silver redhorse	% No.	0	0	0	18.1	12.7	4.1	20.7	7.5	29.5	34.2	47.5	14.3	5.5	18.6	10.9
	% Wt.	0	0	0	b	1.1	0.8	6.1	4.8	15.8	16.1	19.1	6.2	2.4	5.8[c]	
Shorthead redhorse	% No.	0	0	1.9	8.9	39.6	18.4	46.0	62.0	51.2	54.0	19.8	51.3	32.4	38.5	34.3
	% Wt.	0	0	34.0	b	34.6	2.8	17.8	58.4	42.5	28.9	10.2	58.5	27.1	32.0[c]	
Black bullhead	% No.	21.7	59.4	13.4	1.9	11.0	36.7	1.5	0.5	0.2	1.0	3.0	1.0	1.9	4.5	d
	% Wt.	71.7	95.0	36.9	0.1	10.3	54.5	6.7	1.6	0.6	2.4	3.5	1.0	2.0	21.0	
Smallmouth bass	% No.	0	0	1.2	0.4	0	6.1	0.5	5.3	0.9	2.6	10.9	5.9	5.8	3.3	3.7
	% Wt.	0	0	*	0.1	0	13.7	0.3	13.0	2.7	4.9	15.0	10.3	9.4	4.7	
Black crappie	% No.	65.3	29.7	49.3	8.3	0.5	0	2.5	4.2	0.8	0.3	0	0.3	1.2	5.7	2.8
	% Wt.	15.2	3.0	14.0	6.9	0.1	0	4.3	3.7	7.7	0.8	0	1.5	9.7	4.6	
Logperch	% No.	0	0.4	0	0.1	0.5	0	7.1	4.3	9.7	1.4	1.0	10.7	32.7	8.5	d
	% Wt.	0	0.1	0	0.1	*	0	3.1	2.6	7.7	1.0	1.3	5.9	18.6	4.3	

* Less than 0.1%

[a] Does not include July, 1976 (all suckers weighed together in July-total 42.5 g)

[b] See Appendix 4 for scientific names

[c] From ecological studies near MNGP in 1968-1976

[d] No data available

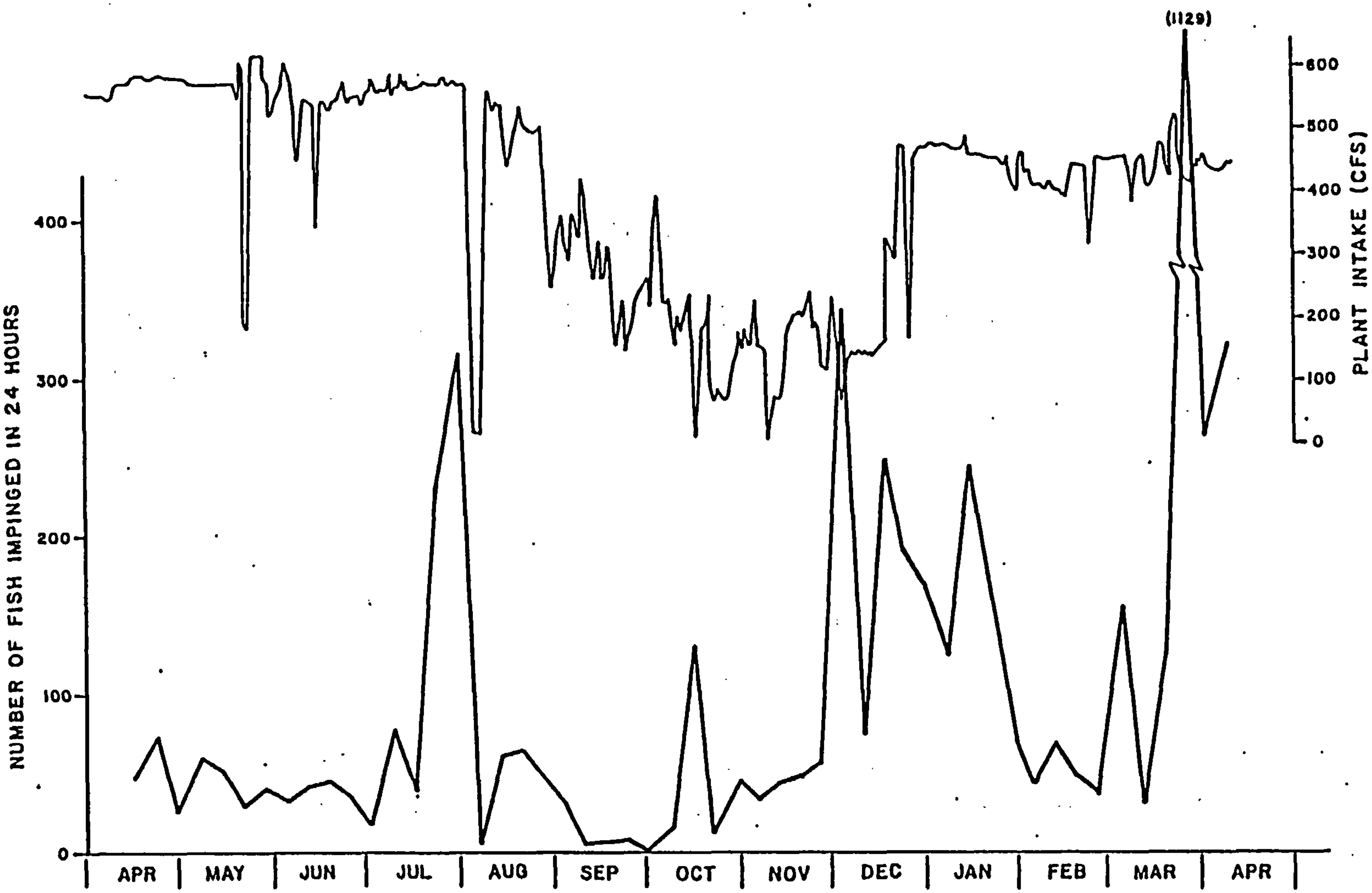


FIGURE 5.2-5

ESTIMATED NUMBER OF FISH IMPINGED DAILY AT MNGP AND INTAKE WATER APPROPRIATION AT MNGP, APRIL 16, 1976-APRIL 9, 1977

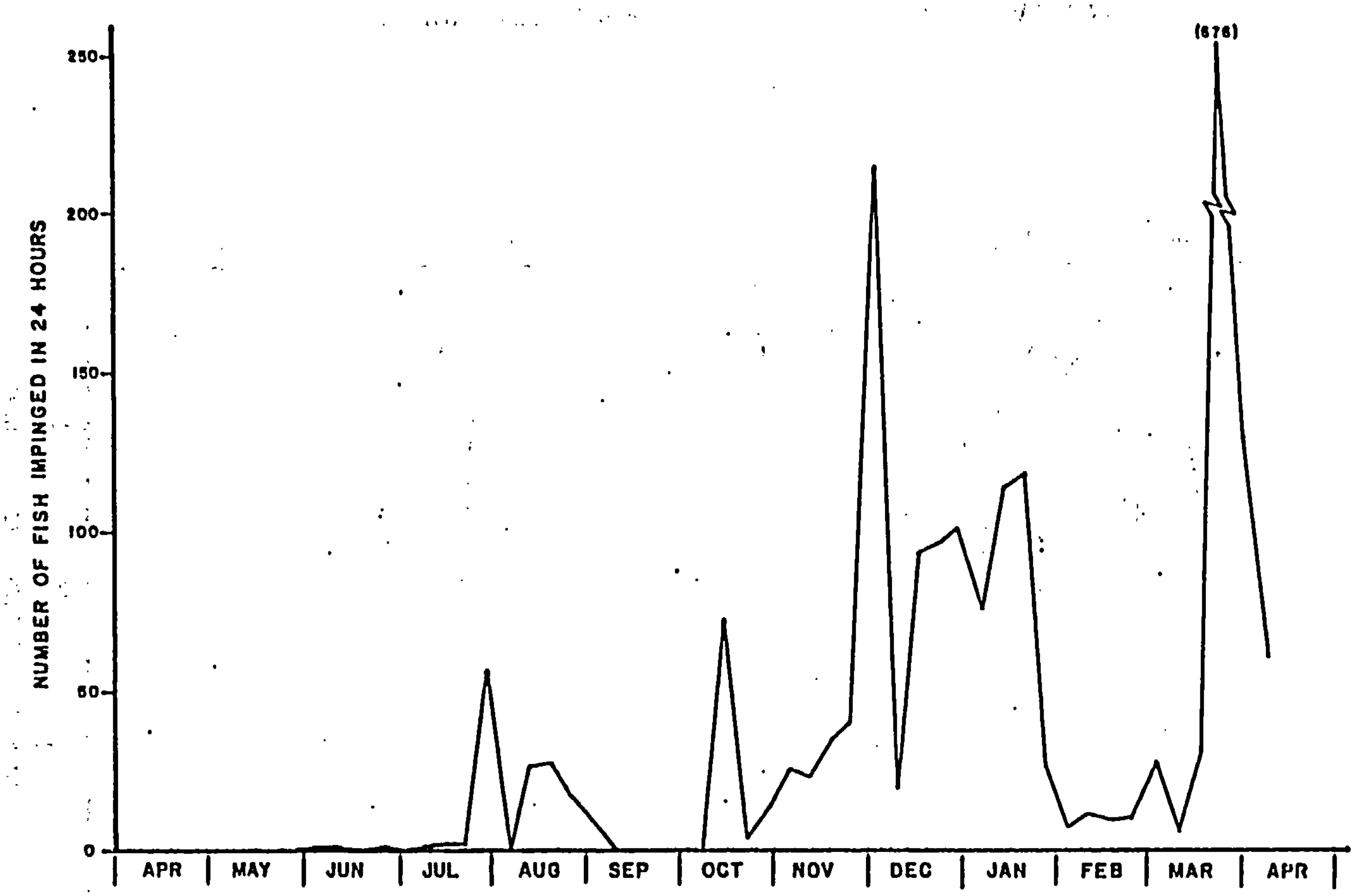


FIGURE 5.2-6

NUMBER OF SHORTHEAD REDHORSE IMPINGED IN 24 HR AT MNGP, APRIL 1976-APRIL 1977

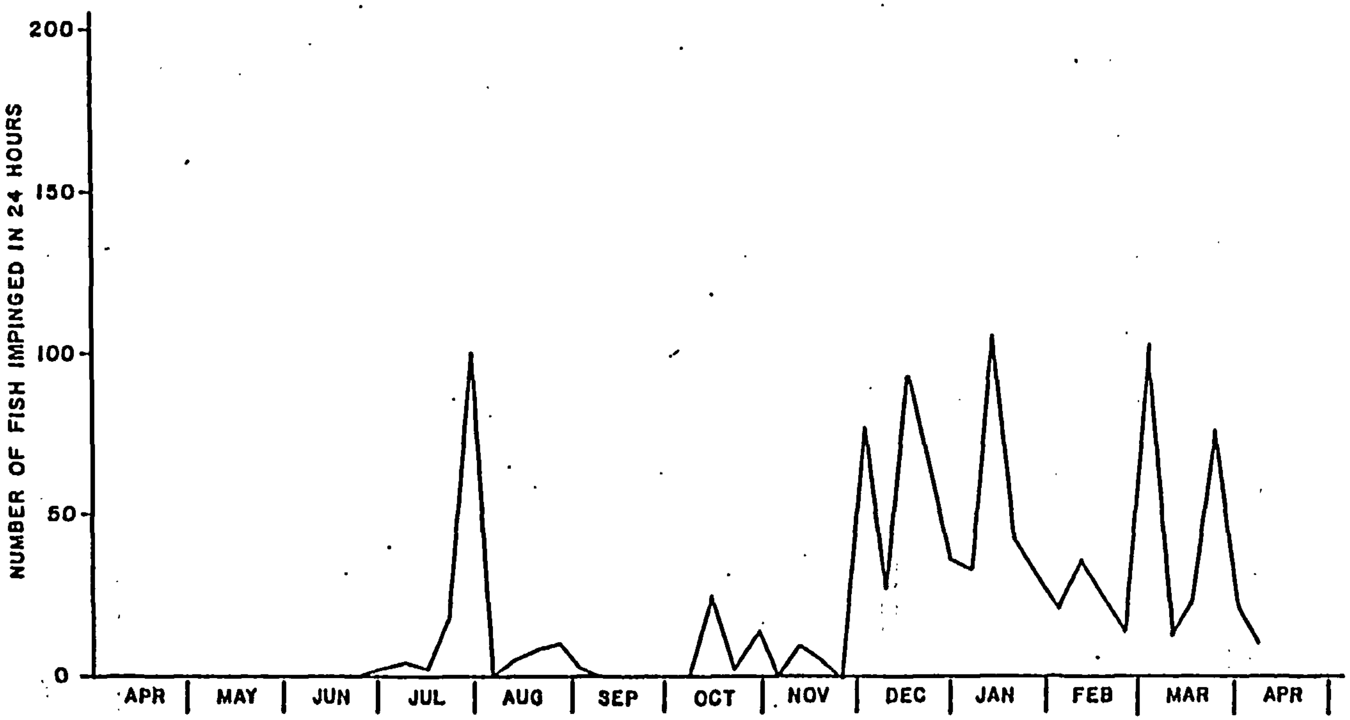


FIGURE 5.2-7

NUMBER OF SILVER REDHORSE IMPINGED IN 24 HR AT MNGP,
APRIL 1976-APRIL 1977

and produced several impingement peaks during the winter months. Smallmouth bass were impinged primarily in the winter and spring (Figure 5.2-8). Shorthead redhorse were impinged in greatest numbers on March 25-26, 1977, when 676 were collected in 24 hours. White suckers, silver redhorse, smallmouth bass and logperch were also collected in high numbers on this date.

Selective impingement of some species of fish is apparent when abundances in screenwash collections are compared to population estimates from the river near the plant. White sucker, shorthead redhorse and smallmouth bass made up about the same proportion of total fish in both the screenwash and river collections (Table 5.2-2). Carp constituted only 6.3% of the impinged fish but made up approximately 40.7% of the fish taken in the river. On the other hand, silver redhorse and black crappie were more common in impingement samples than in the river samples.

Impinged shorthead redhorse were primarily young-of-year (Table 5.2-3). They first appeared in the screenwash samples on July 16 in the 40-69 mm length range. Smaller fish are not retained on the screen. Impinged shorthead redhorse reached an average of 80-89 mm

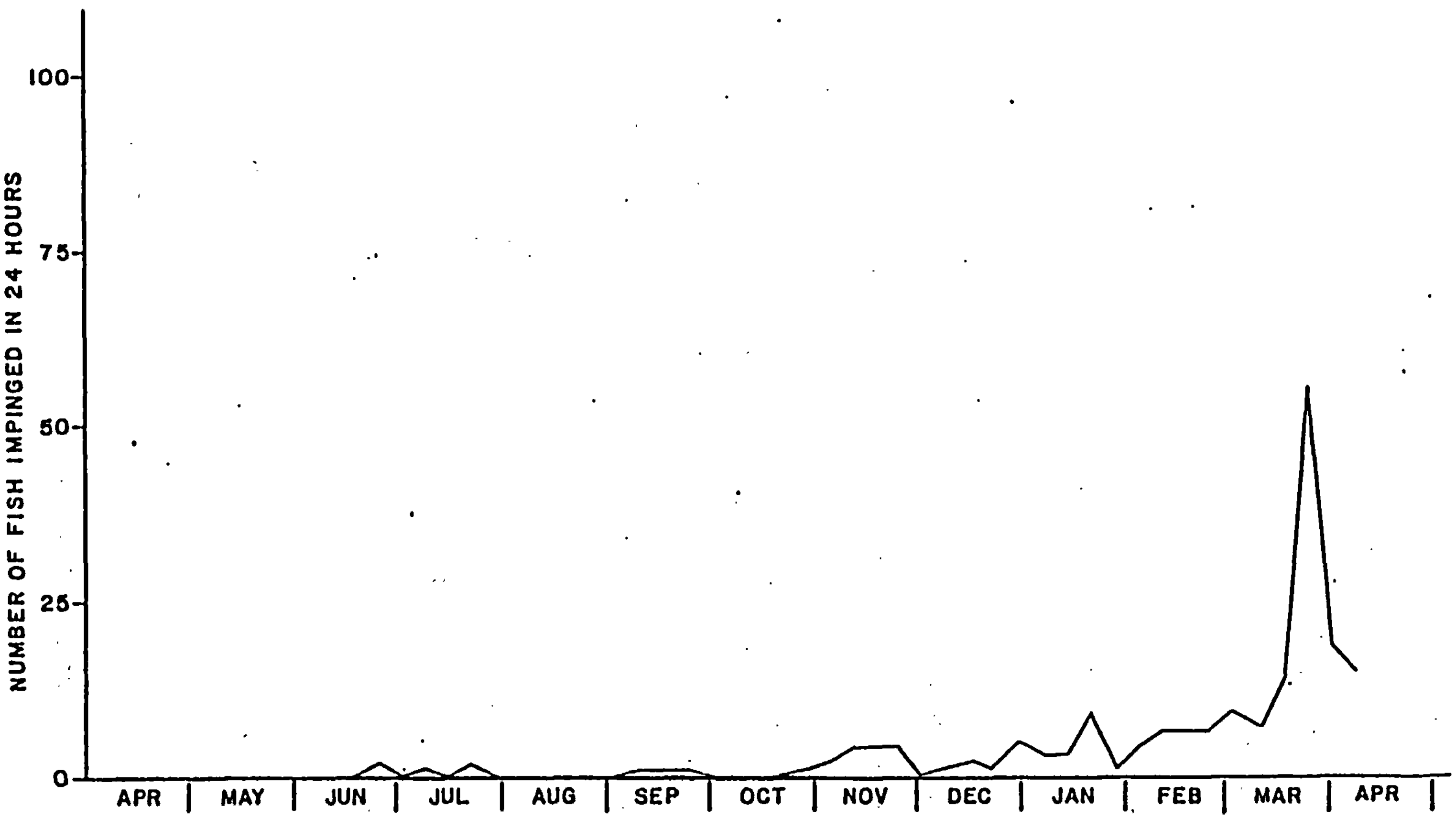


FIGURE 5.2-8

NUMBER OF SMALLMOUTH BASS IMPINGED IN 24 HR AT MNGP, APRIL 1976-APRIL 1977

TABLE 5.2-3

LENGTH FREQUENCY OF SHORTHEAD REDHORSE IMPINGED AT MNGP,
APRIL 16, 1976 TO APRIL 9, 1977

Date	Length Interval (Total Length, mm) 40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	>200	Total Measured	Total Caught
	Number of Fish															
4/16-17/76																
4/23-24/76																
4/30-5/1/76																
5/7-8/76																
5/14-15/76																
5/21-22/76																
5/28-29/76																
6/4-5/76														1	1	1
6/11-12/76														1	1	1
6/18-19/76																
6/25-26/76														1	1	1
7/2-3/76																
7/9-10/76														1	1	1
7/16-17/76	1		1												2	2
7/23-24/76		1		1											2	2
7/30-31/76	1	3	4											2	10	59
8/6-7/76																
8/13-14/76	1	2	7	1	2									1	14	14
8/20-21/76			2	4	1										7	7
8/27-28/76		1	4	7	4	1									17	17
9/3-4/76			5	3	1										9	9
9/10-11/76																
9/17-18/76																
9/24-25/76																
10/1-2/76																
10/8-9/76										1					1	1
10/15-16/76	2	13	9	24	14	6	4		1	1					74	74
10/22-23/76						1	1		1	1					4	4
10/29-30/76				5	2	4	1					2			14	14
11/5-6/76				1	4	4	5	6	4		2				26	26
11/12-13/76			2	3	4	2	1	1	1						14	14
11/19-20/76			1	3	2	13	8	1	4	3					35	35
11/25-26/76		4	5	8	11	7	1	1	3	1					41	41
12/3-4/76				8	16	8	8	5	2		1				48	215

TABLE 5.2-3 (Continued)

Date	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	160-169	>200	Total Measured	Total Caught
	Length Interval (Total Length, mm) Number of Fish															
12/10-11/76			1	2	9	5	1	1	1						20	20
12/17-18/76			2	17	38	19	6	5	2	3			1		93	93
12/23-24/76			2	36	26	15	6	4	2	2	3				96	96
12/30-31/76			4	20	36	22	8	4	3	1	3				101	101
1/7-8/77		1	5	23	27	15	2	2					1		76	76
1/14-15/77		1	5	19	49	27	6	4	2	1	1				115	115
11/21-22/77		1	3	40	48	17	4	1	2	1	1				118	118
1/28-29/77			3	8	8	5	2					1			27	27
2/4-5/77				1	1	4	1								7	7
2/11-12/77		1	2	1	6	2									12	12
2/18-19/77				4	4	1			1						10	10
2/25-26/77				1	4	4		2							11	11
3/4-5/77			2	6	0	7	3	1		1					28	28
3/11-12/77				3	3										6	6
3/18-19/77			1	5	6	5	4	1	4	3				1	30	30
3/25-26/77		1	9	11	30	36	47	54	48	51	37	8			332	676
4/1-2/77			1	8	2	9	6	15	4	6	9	6	1		67	129
4/8-9/77			3	2	7	8	4	12	2	5	7	1			51	61
Total	5	29	83	275	373	247	129	120	87	81	64	18	3	8	1522	2154

by November 1976 and the fish did not appear to grow over the winter. Only eight shorthead redhorse impinged during the study year were longer than 200 mm.

Impinged silver redhorse were also mainly young-of-year. They first appeared in the screenwash samples on July 2 in the 30-59 mm total length range and reached an average size in the 70-79 mm range by December (Table 5.2-4). Only one fish over 160 mm was collected during the study year.

White suckers were first taken from the collection basket on June 25. They reached an average size of 100-109 mm by the following April (Table 5.2-5). Only five fish over 170 mm were collected during the year.

Smallmouth bass were first collected in June of 1976 (Table 5.2-6). The majority of bass impinged were young-of-year, although some year class 1 and older fish were present in the catch. The average length reached 95-109 mm by April 1977.

At least two distinct year classes of black bullheads were impinged (Table 5.2-7). The majority of the bullheads impinged in the spring of 1976 were in the 170-240 mm length

TABLE 5.2-4

LENGTH FREQUENCY OF SILVER REDHORSE IMPINGED AT MNGP,
APRIL 16, 1976 TO APRIL 9, 1977

Date	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	160-169	Total Measured	Total Caught
	Length Interval (Total Length, mm) / Number of Fish														
4/16-17/76															
4/23-24/76															
4/30-5/1/76															
5/7-8/76															
5/14-15/76															
5/21-22/76															
5/28-29/76															
6/4-5/76															
6/11-12/76															
6/18-19/76															
6/25-26/76															
7/2-3/76	1		1											2	2
7/9-10/76		2	2											4	4
7/16-17/76		2												2	2
7/23-24/76		1	12	4	1									18	18
7/30-31/76		1	12	11	1	1								26	101
8/6-7/76															
8/13-14/76			1	2										3	5
8/20-21/76															
8/27-28/76			1	7	2									10	10
9/3-4/76															
9/10-11/76															
9/17-18/76															
9/24-25/76															
10/1-2/76															
10/8-9/76															
10/15-16/76				14	12	1								27	27
10/22-23/76									1	1				2	2
10/29-30/76															
11/5-6/76															
11/12-13/76			1	2	2	2	2							9	9
11/19-20/76					3		1		1					5	5

TABLE 5.2-4 . (Continued)

Date	Length Interval (Total Length, mm) 30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	160-169	Total Measured	Total Caught
	Number of Fish														
11/25-26/76															
12/3-4/76				4	8	5	1	1	2	1				22	77
12/10-11/76				3	11	9	3	1						27	27
12/17-18/76				27	43	18	5							93	93
12/23-24/76				7	33	23	5		1	1				70	70
12/30-31/76				7	12	16	1							36	36
1/7-8/77			1	6	12	12	2							33	33
1/14-15/77				17	41	37	8	2						105	105
1/21-22/77				9	17	11	5							42	42
1/28-29/77				5	16	9	2							32	32
2/4-5/77				4	9	6		1	1					21	21
2/11-12/77			2	5	20	5	1	3						36	36
2/18-19/77				7	11	6	1							25	25
2/25-26/77				1	5	6	2							14	14
3/4-5/77				13	52	32	6							103	103
3/11-12/77					3	5	1	2		1				12	12
3/18-19/77			1	3	8	5	4	1	1				1	24	24
3/25-26/77				2	24	11	5	14	9	1		1		67	67
4/1-2/77					5	8	5	2	1		1			22	22
4/8-9/77					2	4	1	2	1					10	10
Total	1	6	34	160	353	232	61	29	18	5	1	1	1	902	1034

TABLE 5.2-5

LENGTH FREQUENCY OF WHITE SUCKER IMPINGED AT MNGP, APRIL 16, 1976 TO APRIL 9, 1977

Date	Length Interval (Total Length, mm) 50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	>170	Total Measured	Total Caught
	Number of Fish													
4/16-17/76														
4/23-24/76														
4/30-5/1/76														
5/7-8/76														
5/14-15/76														
5/21-22/76														
5/28-29/76														
6/4-5/76														
6/11-12/76														
6/18-19/76												1	1	1
6/25-26/76	1	1											2	2
7/2-3/76														
7/9-10/76		3	2										5	5
7/16-17/76	1												1	1
7/23-24/76	3	10	6	1									20	20
7/30-31/76	6	3	8	11	4	1						2	35	46
8/6-7/76														
8/13-14/76	1			2	1	1						1	6	6
8/20-21/76			3	4	3	2	1	1					14	14
8/27-28/76				1									1	1
9/3-4/76														
9/10-11/76														
9/17-18/76														
9/24-25/76									1				1	1
10/1-2/76														
10/8-9/76														
10/15-16/76												1	1	1
10/22-23/76														
10/29-30/76														
11/5-6/76														
11/12-13/76														
11/19-20/76						1							1	1
11/25-26/76														
12/3-4/76				1									1	1

TABLE 5.2-5 (Continued)

Date	Length Interval (Total Length, mm) 50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139	140-149	150-159	>170	Total Measured	Total Caught
	Number of Fish													
12/10-11/76														
12/17-18/76						1							1	1
12/23-24/76														
12/30-31/76														
1/7-8/77														
1/14-15/77							1						1	1
1/21-22/77														
1/28-29/77					1		2						3	3
2/4-5/77														
2/11-12/77				1		1							2	2
2/18-19/77					1								1	1
2/25-26/77					1								1	1
3/4-5/77							1						1	1
3/11-12/77														
3/18-19/77					1	9	4	11	9	2			36	36
3/25-26/77				14	22	24	22	4	4	3	2		95	95
4/1-2/77			1	7	1	9	4	5	1	3	1		32	32
4/8-9/77			1	4	5	8	5	1	2				26	26
Total	12	17	21	46	40	57	40	23	16	8	3	5	288	299

TABLE 5.2-6

LENGTH FREQUENCY OF SMALLMOUTH BASS IMPINGED AT MNGP, APRIL 16, 1976 TO APRIL 9, 1977

	Length Interval (Total Length, mm)												
Date	50-64	65-79	80-94	95-109	110-124	125-139	140-154	155-169	170-184	185-199	200-214	>215	Total Caught
					Number of Fish								
4/16-17/76													
4/23-24/76													
4/30-5/1/76													
5/7-8/76													
5/14-15/76													
5/21-22/76													
5/28-29/76													
6/4-5/76													
6/11-12/76													
6/18-19/76													
6/25-26/76	1												1
7/2-3/76													
7/9-10/76	1												1
7/16-17/76													
7/23-24/76	2												2
7/30-31/76													
8/6-7/76													
8/13-14/76													
8/20-21/76													
8/27-28/76													
9/3-4/76													
9/10-11/76				1									1
9/17-18/76											1		1
9/24-25/76					1								1
10/1-2/76													
10/8-9/76													
10/15-16/76													
10/22-23/76													
10/29-30/76			1										1
11/5-6/76				1		1							2
11/12-13/76					3			1					4
11/19-20/76													
11/25-26/76				2	1		1						4

TABLE 5.2-6 (Continued)

Date	Length Interval (Total Length, mm) 50-64	65-79	80-94	95-109	110-124	125-139	140-154	155-169	170-184	185-199	200-214	>215	Total Caught
	Number of Fish												
12/3-4/76													
12/10-11/76					1								1
12/17-18/76				1			1						2
12/23-24/76							1						1
12/30-31/76			1	1		2				1			5
1/7-8/77					1	1		1					3
1/14-15/77				1	2								3
1/21-22/77			1	5	2							1	9
1/28-29/77					1								1
2/4-5/77			1	1	2								4
2/11-12/77				2	3	1							6
2/18-19/77				4	2								6
2/25-26/77			1	3		2							6
3/4-5/77			1	1	4	2		1					9
3/11-12/77			1	3	2	1							7
3/18-19/77			2	3	7		2						14
3/25-26/77			10	16	11	5	4	3	3		2	1	55
4/1-2/77			1	2	6	6	3	1					19
4/8-9/77				7		2	2	2	1	1			15
Total	4		20	54	49	23	14	9	4	2	3	2	184

TABLE 5.2-7

LENGTH FREQUENCY OF BLACK BULLHEAD IMPINGED AT MNGP,
APRIL 16, 1976 TO APRIL 9, 1977

Date	Length Interval (Total Length, mm) 35-49	50-64	65-79	80-94	95-109	110-124	125-139	140-154	155-169	170-184	185-199	200-214	215-229	230-244	245-259	260-274	Total Caught
	Number of Fish																
4/16-17/76		2					1			2	1	2	1				10
4/23-24/76		1	1					2	2	2	4	1	2				15
4/30-5/1/76			1				1		2	2	1	3	2	2	1		14
5/7-8/76			1					2		1	5	5	6	6	4	3	33
5/14-15/76									1	2	5	8	5	8	2	1	32
5/21-22/76			1								3	6	5	2	1	1	19
5/28-29/76		1			1							2	6	3	2		15
6/4-5/76										1	1	3	1	2			8
6/11-12/76			1														1
6/18-19/76						1			1		1		3		1		7
6/25-26/76		1		1								1	2				5
7/2-3/76														1			1
7/9-10/76																	
7/16-17/76				2	1											1	4
7/23-24/76	1												1				2
7/30-31/76		1		1													2
8/6-7/76		1															1
8/13-14/76		1	3	2								1		1			8
8/20-21/76			2	3													5
8/27-28/76			1	3													4
9/3-4/76			1	3	1					1					1		7
9/10-11/76					2												2
9/17-18/76				2				1				1					4
9/24-25/76		1		2	1												4
10/1-2/76																	
10/8-9/76						1											1
10/15-16/76														1			1
10/22-23/76				1													1
10/29-30/76																	
11/5-6/76																	
11/12-13/76																	
11/19-20/76																	
11/25-26/76								1									1

TABLE 5.2-7. (Continued)

Date	Length Interval (Total Length, mm) 35-49	50-64	65-79	80-94	95-109	110-124	125-139	140-154	155-169	170-184	185-199	200-214	215-229	230-244	245-259	260-274	Total Caught
	Number of Fish																
12/3-4/76				1					1								2
12/10-11/76																	
12/17-18/76																	
12/23-24/76																	
12/30-31/76																	
1/7-8/77			1	1						1							3
1/14-15/77			1														1
1/21-22/77																	
1/28-29/77				1						1							2
2/4-5/77			1				1										2
2/11-12/77				2													2
2/18-19/77				1													1
2/25-26/77				1													1
3/4-5/77			1														1
3/11-12/77			1							1							2
3/18-19/77			2	1													3
3/25-26/77		1		2	1	2				1							7
4/1-2/77			2	1	1												4
4/8-9/77		1	1	1	3							1					7
Total	1	11	22	32	11	4	3	6	7	15	21	34	34	26	12	6	245

range and were probably two-year old fish. Black bullheads impinged during the remainder of the study year were smaller, primarily in the 60-110 mm range.

The length frequency distribution of black crappies was similar to that of black bullheads. Most black crappies were impinged in the spring and early summer of 1976 and were between 75 and 100 mm in length (Table 5.2-8). These fish, probably young-of-the-year, showed substantial growth over the first three months of the study. Several crappies, possibly young-of-the-year, were impinged in July. Very few crappies appeared in the collection basket after July.

Fish impingement at the mouth of a cooling water intake is a complex problem influenced by a host of factors which are often difficult to measure and site-specific. Physical factors influencing impingement include intake canal configuration, pumping rates, water velocities, river level, water temperature, dissolved oxygen and light. Biotic factors specific to impinged organisms include sustainable cruising speed, burst speed, metabolic processes controlling muscle fatigue, schooling tendencies, foraging activities, habitat preferences, spawning movements and rheotactic responses.

TABLE 5.2-8

LENGTH FREQUENCY OF BLACK CRAPPIE IMPINGED AT MNGP,
APRIL 16, 1976 TO APRIL 9, 1977

Date	Length Interval (Total Length, mm) — Number of Fish: 40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100-104	105-109	110-114	115-119	120-124	125-129	130-134	>135	Total Caught
4/16-17/76				1	1	8	7	5	6	3											31
4/23-24				2		7	12	20	7	9	6	1	1								65
4/30-5/1/76						1		3	6												10
5/7-8/76					1	3	3	1	3	1			2								14
5/14-15/76							3	5	3	1		1	1						1		15
5/21-22/76							1		2	2	1		1								7
5/28-29/76							2	1	6	4		2									15
6/4-5/76							2	1	5	3	1	2									14
6/11-12/76								3	6	5	6	6									26
6/18-19/76									7	5	2	6	3	3	1	1					28
6/25-26/76									1		2	2	2	1	1						9
7/2-3/76											1	1									2
7/9-10/76	1								1	1	5	7	6	5	5	4	2	2			39
7/16-17/76		5	1							1	1	1	3	2				1			15
7/23-24/76				1									1								2
7/30-31/76												1									1
8/6-7/76																					
8/13-14/76																					
8/20-21/76																					
8/27-28/76									1												1
9/3-4/76																					
9/10-11/76																					
9/17-18/76																					
9/24-25/76																					
10/1-2/76																					
10/8-9/76																				1	1
10/15-16/76																				1	1
10/22-23/76																					
10/29-30/76								1	1										1		3
11/5-6/76								1	2							1	1				5
11/12-13/76									1												1
11/19-20/76									2												2
11/25-26/76																					

TABLE 5.2-8 (Continued)

Date	Length Interval (Total Length, mm) 40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100-104	105-109	110-114	115-119	120-124	125-129	130-134	>135	Total Caught
	Number of Fish																				
12/3-4/76																					
12/10-11/76																				2	2
12/17-18/76							1												1	2	4
12/23-24/76																				1	1
12/30-31/76																				1	1
1/7-8/77																					
1/14-15/77																			1	1	2
1/21-22/77																					
1/28-29/77																					
2/4-5/77																					
2/11-12/77																					
2/18-19/77																					
2/25-26/77																					
3/4-5/77															1					1	2
3/11-12/77																				2	2
3/18-19/77																					
3/25-26/77																					
4/1-2/77																				1	1
5/8-9/77								1												5	6
Total	1	5	1	4	2	19	31	42	60	35	25	30	20	11	8	6	3	3	4	18	328

Velocity profiles of the intake canal at MNGP are shown in Figures 3.4-2 and 3.4-3. Velocities vary with pumping rate and river discharge (river level). As was found by Grotbeck and Bechthold (1975) and illustrated in Figures 3.4-2 and 3.4-3, most of the water appears to enter the downstream side of the canal under the log boom, with greatest velocities 1.2 to 1.5 m below the surface. Velocities are higher on the downstream side of the canal toward the bar racks. A low velocity eddy is formed on the upstream side of the canal just inside the log boom.

The approach velocity that a fish might be exposed to depends on where the fish passes through the bar racks. Currents in the intake canal are turbulent and velocities at any point can change from moment to moment. The highest velocities recorded by Grotbeck and Bechthold (1975) in front of the bar racks were approximately 60 cm/sec (2 ft/sec). This was similar to the current regime found on July 31, 1976, when the plant was pumping 16 m^3/sec (565 cfs) (near maximum normal rate) and the river was quite low. These observations are probably close to worst-case conditions (highest approach velocities).

Table 5.2-9 summarizes the literature on swim speeds of some small fish found in the Mississippi River. Maximum swimming

TABLE 5.2-9

SWIM SPEEDS (cm/s) OF SMALL FISHES FOUND NEAR MNGP

Species	Size (mm)	Speed (cm/s)	Duration	Temperature	Reference
Bluegill	34-45 TL	15.5	Maximum sustained	25.6-26.1°C	King 1969
	41-49	14.3	Maximum sustained	28.9-30.0°C	
White crappie	60-88 TL	16.5	Maximum sustained	21.1-28.9°C	
	66-95	18.6	Maximum sustained	26.1-26.6°C	
Smallmouth bass	21-24 TL	4.5	Maximum	5°C	Larimore & Duever 1968
		10.7		10°C	
		15.2		15°C	
		21.3		20°C	
		25.6		25°C	
		30.48		30°C	
		24.7		35°C	
Carp	~36-66 mm (5-6g)	21.9-57.9			Bainbridge 1960
	135	170.6	Darting		
Fathead minnow	59 mm	35.0 (5 ppm D.O.)		18°C	MacLeod & Smith 1966
		38.4 (8 ppm D.O.)			
Trout-perch	72 FL	54.8	10 min	7-20°C	Jones, Kiceniuk & Bamford 1974
Burbot	33 FL	17.1	10 min	7-20°C	Jones, Kiceniuk & Bamford 1974
	67	18.9	10 min	7-20°C	
	100	20.1	10 min	7-20°C	
Northern pike	80 FL	17.1	10 min	7-20°C	Jones, Kiceniuk & Bamford 1974
	133	21.9	10 min	7-20°C	
	200	27.1	10 min	7-20°C	
	200	21.9	10 min	7-20°C	
White sucker	33 FL	21.9	10 min	7-20°C	Jones, Kiceniuk & Bamford 1974
	67	32.0	10 min	7-20°C	
	100	36.9	10 min	7-20°C	
Walleye	33 FL	27.1	10 min	7-20°C	Jones, Kiceniuk & Bamford 1974
	67	36.0	10 min	7-20°C	
	100	43.9	10 min	7-20°C	

speed for small fish is generally ten times the body length per second (Gray 1957). This "burst" speed can be maintained for several seconds. Speeds that can be maintained for longer periods of time are slower. Small fish entering a rapidly moving mass of water in the intake canal cannot escape impingement after they pass a point where velocities are so high that a sustained effort to escape against the current only leads to exhaustion and impingement. Escape is possible along the bottom or sides of the canal where velocities are lower because of frictional drag. Escape is also possible into masses of slower water, i.e., the eddy on the upstream side of the canal just inside the log boom.

Swimming speeds are influenced by temperature, dissolved oxygen, turbulence, physiological condition and size of the fish. Maximum current velocities in the MNGP intake may be too fast for many small fish to swim against. Swim speeds are proportional to size of most fish and this could explain the predominance of young-of-year fish in the screenwash collections.

The schooling tendencies of the suckers, black crappies and bullheads could account for large numbers of fish being impinged at once. Other behavioral characteristics of fish that could influence impingement include feeding activities, spawning movements, habitat preferences and rheotactic responses. Foraging activities, spawning movements and habitat preferences could result in fish moving into the intake canal or even residing there. The slower back-eddy behind the log boom could serve not only as an escape route for fish from the area behind the bar racks, but could also be an attractive habitat where food organisms are concentrated or where fish could find shelter from the faster currents in the river.

Of the above mentioned behavioral characteristics of fish, the rheotactic response may be the most important, as this response is necessary if the fish is to swim against the current to escape impingement. The rheotactic response to water current involves orientational and kinetic responses to water current over the body or to visual, tactile or inertial stimuli resulting from displacement of the fish in space (Harden-Jones 1968). Light is necessary for visual orientation and insufficient light could cause disorientation and drift. Approximately 52% of the total number of fish impinged in the 1976-1977 study year were collected during the 8:00 PM to midnight and the midnight to 4:00 AM screen-wash periods.

Dodson and Young (1977) report that water temperature is often a common factor in controlling upstream movements in several species of fish. Northcote (1958) demonstrated that the interaction of photoperiod and temperature regulates the frequency of movement of common shiners. Temperature also influences specific activity patterns and swimming ability in fish. Grotbeck and Bechthold (1975) found that the summer impingement ratio of black bullheads to black crappies at MNGP was influenced by a certain range of temperature, but that water temperatures were not correlated with variations in number impinged from month to month. High impingement rates during July 1976 coincided with high (>25°C or 77.5°F) water temperatures. The highest impingement rates occurred during December, January and March 1976-1977, when water temperatures were lowest. Grimes (1975) found cold water temperature during darkness to be a major factor in impingement.

One possible effect of temperature on impingement rates may have resulted from the winter use of de-icing water just ahead of the bar rack. Warm recirculation water is introduced about 3.4 m (11 ft) in front of the bar rack. Water is introduced in sufficient quantity to keep intake temperatures no more than about 4°C (7°F) above ambient. The north side of the canal just in front of the bar rack may provide a zone of warm water with fairly slow current (Figure 3.4-2) in which fish may congregate. However, the high number of silver and shorthead redhorse impinged during the winter of 1976-77 may be a result of the high 1976 abundance figures for these species as compared to previous years. Additionally, elevated impingement rates are associated with slower swim speeds which are characteristic of winter temperatures. The de-icing line may have contributed to winter impingement of these taxa in the winter study period but this influence of de-icing facilities has not been apparent for any species at MNGP in previous years.

River discharge apparently had little direct effect on the number of fish impinged during the 1976-1977 study year. The highest daily impingement occurred on March 25-26, 1977, shortly after the initial spring pulse in river flow. However, 1977 spring flows were low (less than 141.5 m^3/sec or 5,000 cfs). In 1976, spring flows were much higher (453.1 m^3/sec or 16,000 cfs), but impingement rates remained low (fewer than 80 fish/24 hours). Nevertheless, black bullheads and black crappies were impinged at maximum rates in April and May. Grotbeck and Bechthold (1975) theorized that river flow could affect impingement by displacing small fish during high water and concentrating larger fish in the intake area during low flows.

Plant intake pumping rates, along with river flow, determine the proportion of the river flow that is diverted through the plant. Pumping rates can also influence approach velocities in an intake canal (Anonymous 1973). No large increase in impingement was noted in conjunction with increased pumping rates. A distinct decrease in impingement was observed when the plant was off-line on August 6 and 7 and the pumping rate was reduced to 0.51 to 0.54 m^3/sec (18-19 cfs) (Figure 5.2-5); however, some fish were still impinged. Grotbeck and Bechthold (1975) found that pumping rates affected the frequency of black crappie impingement but did not seem to affect black bullheads or the numerical occurrence of all species.

Dissolved oxygen levels in the Mississippi River near MNGP remained relatively high throughout the study year and at no time appeared to impose stressful conditions that could influence rates of fish impingement.

A screen rinse return sluiceway was installed in 1973 in an effort to decrease mortality of impinged fish. The sluiceway proved to be very effective, producing up to 95% immediate survival in conjunction with a continuous screen rinse mode (Heberling and Weinhold 1976).

6 IMPACT ASSESSMENT

6.1 PRIMARY PRODUCERS

Phytoplankton is the only primary producer in the MNGP area that potentially could be significantly impacted by intake operation. The MNGP withdrew approximately 19% of the Mississippi River flow during the April 1976 to April 1977 study year. Since phytoplankton is expected to be randomly distributed in the water column of a rapidly moving river like the Mississippi, a maximum reduction of 19% of annual phytoplankton production could have occurred during the study year, if 100% mortality is assumed upon passage through the plant. During periods of open and helper cycle operation high percentages of algae entrained are predicted to survive. A reduction of this magnitude does not impose a serious threat to the integrity of the Mississippi River biota, as phytoplankton can reproduce rapidly, thus minimizing downstream effects (EPA 1976a). In addition, phytoplankton is not judged to be as important to primary production as periphyton in this section of the Mississippi River. Because periphyton is more or less attached to substrates, it will not be entrained in significant quantities.

6.2 ZOOPLANKTON

Zooplankters are susceptible to entrainment because they are virtually free-floating. However, all zooplankton that is entrained is not killed. Davies and Jensen (1974) cite several studies in which mortality among entrained zooplankton was less than 20%. During once-through operation, it is likely that a large percentage of entrained zooplankters will survive. During closed cycle operations, most of the zooplankton that enter the system may be killed; however, the number of individuals which are entrained is minimized due to the small volumes of water withdrawn from the river.

On a volumetric basis, MNGP would have entrained approximately 19% of all zooplankton flowing past the plant during the study year (April 16, 1976 - April 9, 1977). The short reproductive cycles characteristic of most zooplankters and the low expected entrainment mortalities minimize the effect of entrainment on the zooplankton community.

The ecological importance of zooplankton in the upper Mississippi River is probably limited. The majority of adult fish consume benthic organisms or other fish. A few filter-feeding benthic invertebrates (e.g., clams, some caddisflies and black flies) and young fishes feed on zooplankton. The temporary nature of zooplankton in the lotic environment and its susceptibility to fluctuations in physical and chemical factors further emphasize the limited role of zooplankton in the trophic dynamics of rivers. As noted by EPA (1976a), entrainment generally does not significantly impact zooplankton because zooplankters have rapid reproductive rates and short life spans.

6.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are subject to entrainment when they become suspended in the water column through behavioral or catastrophic drift. Numbers, kinds and periodicity of benthic macroinvertebrates in the drift depend on environmental factors which influence drift density and timing and the behavioral factors of the insects.

Matter's (1975) study of drift organisms near MNGP indicates that drift is composed of 37% Ephemeroptera, 28% Trichoptera, 30% Diptera and 5% "miscellaneous". The relative numbers and species composition of macroinvertebrate entrainment samples collected by Gundersen and Lewis (1976) closely resemble those of Matter (1975). Estimates of worst case entrainment losses at MNGP are presented in Table 6.3-1. These estimates were made by applying 1976-1977 MNGP intake volumes to the densities which Matter (1975) found in drift

TABLE 6.3-1

ESTIMATED INVERTEBRATE ENTRAINMENT AT MNGP MAY 1976-MARCH 1977 --
(Adapted from Matter 1975)

	Number Drifting Past MNGP Per Month (x 10^6)[a]	Number That Would Be Entrained by MNGP Per Month (x 10^6)[a]
May	769	130.7
June	978	273.8
July	263	81.5
August	1,470	529.2
September	214	53.5
November	252	30.2
December	238	52.4
February[c]	224	53.8
March[c]	336	47.0
TOTAL	4,744	915.5

[a]July 1973-July 1974 drift invertebrate densities at MNGP (Matter 1975) times mean river discharge for the month sampled.

[b]Based on invertebrate drift densities per gallon at MNGP (Matter 1975) times percent of river flow withdrawn by MNGP during respective month

[c]Excluding Psychodidae which were imported; suitable habitat does not exist on site for this family

samples taken in the river in 1973-1974. Matter associated high drift densities with high river flows. Since there were no high flows in the 1976-1977 study period, the estimated entrainment ratio shown in Table 6.3-1 may be unrealistically high.

Considering that drift represents a small fraction of the standing crop (Bishop and Hynes 1969) and has been considered as production in excess of the carrying capacity of a stream (Waters 1972), and considering the relatively minor proportion of river flow (and drift) that MNGP entrains, these rates of entrainment should not have a detectable influence on the macroinvertebrate communities near MNGP.

6.4 FISH

6.4.1 Impact Analyses

Analysis of the impact of entrainment of fish eggs and young at MNGP is based on the population model described by Horst (1975), in which the numbers of eggs, larvae and juveniles entrained are converted to an estimate of the number of adult fish that would have been produced had entrainment mortality not occurred.

If the entrained stage is an egg, the estimate of the number of adults lost is calculated as:

$$N_a = S_g N_e = \frac{2}{\bar{F}} N_e$$

where

N_a = number of adults

S_g = survival from egg to adult

N_e = number of eggs entrained

2 = number of adults needed to be produced by a breeding pair to maintain a stable population

F = total lifetime fecundity of a female based on the generation time (g) of the population and the average fecundity ($\bar{F}$)

According to Horst (1975), fish lifetime fecundity is the number of eggs produced in the lifetime of a species. Calculations were made using average lifetime fecundities to permit a comparison of results. It should be recognized that the average lifetime of a species can be estimated only roughly and is determined by mortality rates among age classes as well as by life span. It is also necessary to make the assumption that the limited data available from various locations and times are roughly representative of the indigenous populations near MNGP.

This procedure used for calculation of lifetime fecundity (F), following Horst (personal communication), is most clearly shown by an example. Representative calculations for the walleye are shown below.

A Age	B Surviving portion	C Eggs per female	D Weighted eggs per female (B x C)
1	.50	0	0
2	.25	0	0
3	.125	77,000	9,625
4	.063	119,500	7,529
5	.031	180,500	5,596
6	.017	258,000	4,386
7	.008	303,000	2,424
8	.004	333,000	1,332
9	.002	502,000	1,004
10	.001	484,000	484
	1.001		32,380

Population fractions (B), assuming 50% mortality per year, are multiplied by eggs per female (C) to give weighted eggs per female (D). Total weighted eggs per female is divided by total of fractions, if the latter is not exactly one, to give mean fecundity of age classes. This mean fecundity is multiplied by an estimate of mean generation time in years to give mean lifetime fecundity. How to select the mean generation age has not been clearly defined. In this report it is assumed to be the age which yields the largest numbers of weighted eggs per female. This is a conservative approach in that the use of higher mean generation times results in lower impact projections.

Survival of white crappie eggs has been determined as 49 to 94% in a study by Siefert (1968); an average value of 75% has been used in this report.

Forney (1976) used fecundity-at-age and larval densities to estimate an egg to larva survival rate of 0.5% for Oneida Lake walleye. Egg studies indicated a survival rate of 2.4 to 25% in a Minnesota Lake (Johnson 1961).

The 0.3% survival rate used for white sucker and Catostomidae was based on the observation that as few as 0.3% of eggs may survive to migrant larvae (Geen et al. 1966).

A survival of 0.5% has been used for unidentified Cyprinidae. The normal range of survival for minnows is not known. The 0.5% value used was based on the observation that unguarded eggs usually exhibit high mortality. Survival of eggs of the carp (a cyprinid) was estimated as 80 to 94% by Nikolskii (1969). However, mortality was high when dissolved oxygen concentrations were reduced; this stress is usually not present in the Mississippi River near MNGP. The habit of depositing adhesive eggs in vegetation may afford protection and may account for observed high survival rates. Egg survival of 34 to 90% has been reported for another cyprinid, the carp-bream (Nikolskii 1969). A range of 0.5 to 94% was used for carp.

If the entrained stage is a larva:

$$N_a = S_l N_l = \frac{2}{S_e F} N_l$$

where

N_a, 2 and F are defined as above

S_l = survival from larva to adult

N_l = number of larvae entrained

S_e = survival from egg to larva

The following assumptions are made in this analysis:

- o There is 100% mortality of entrained eggs and larvae due to passage through the plant.
- o The populations are at equilibrium and have a stable age structure, and the total lifetime fecundity produces two adults.
- o No compensatory mechanisms are operating.
- o 0.5% of the eggs produced by a species with high fecundity, randomly broadcast eggs and/or no parental care survive to become larvae [based on data of Rothschild (1961) for smelt].
- o 75% of the eggs produced by species which exhibit nesting behavior and a high degree of parental care survive to the larval stage.

- o Larvae are entrained immediately after hatching. Since larvae are entrained at all stages of development, this assumption can lead to an underestimate of the number of potential adults lost. Survival data among the stages are, for the most part, unavailable. However, for many species in this study, the larvae entrained were yolk larvae, making the above assumptions realistic.

The analysis of the impact of fish impingement on the traveling screens at MNGP was similar to that used for entrainment, since it has been shown that most fishes impinged in 1976 were age 0, i.e., members of the 1976 year class (See Section 5.5.2.2). The numbers of adults that would have resulted from age 0 fish impinged was calculated as:

$$N_a = S\ N_I$$

where

N_a = number of adults lost

S = survival from juvenile (age 0) to mean generation time (g)

N_I = number of age 0 fish impinged

S is calculated as:

$$S = S_y \cdot S_i^{(g-1)}$$

where

S_y = average overwinter survival, i.e., survival from age 0+ to age 1

S_i = average annual survival for fish older than age 1

S_y was estimated from data supplied by Clady (1975, 1976) and Forney (1976) for yellow perch, smallmouth bass and walleye, respectively. Survival to yearlings averaged 0.8% (0.1 to 1%) for yellow perch and 0.9% (0.3 to 32%) for walleye. Clady (1975) estimated overwinter survival for young smallmouth bass at 23%. Survival data for other species during this time period are lacking; however, if 0.1% survival is chosen as the lower limit and 32% is chosen as an upper limit, it seems reasonable to assume that most species will fall within this range. Annual survivals after the yearling stage are more easily obtained. Clady (1976) reports average annual survivals for yellow perch between ages 3 and 8 of 72%. Paragamian and Coble (1975) report average annual survivals of 35 to 45% for age 2 to 8 smallmouth bass in the Red Cedar and Plover rivers in Wisconsin and 34% for age 2 to 7 smallmouth bass in Missouri streams. Forney (1972) found that annual survival for age 3 to 7 smallmouth bass in Oneida Lake, New York averaged 60% over a 13 year period. An unexploited walleye population in

Manitoba showed 20 to 30% survival over a one year period (Kelso and Ward 1972). In contrast, Nelson and Walburg (1977) found that walleye aged 2 to 9 in three Missouri River reservoirs had annual survivals ranging from 44 to 62% while survival of sauger ranged from 51 to 58%. Gerking (1962) found that the annual survival for age 2 to 5 bluegill ranged from 20 to 44% in an Indiana Lake. Carlander (1977), in a summary of annual survivals for black crappie older than age 2, reported a range of 9 to 36%. Thus, the annual survivals found in this brief literature review range from 9 to 72% for various sport species and levels of exploitation.

Little information is available on annual survival of rough fish. Jester (1972), in a study of the river carpsucker of Elephant Butte Lake, New Mexico, reported annual survivals of 41 to 85% for fish age 2 to 10. Bodola (1966) estimated a 47% annual survival for gizzard shad between age 2 and 6. Based on these studies, it appears reasonable to assume that rough fish fall within the range of survival values for gamefish.

Assumptions in this method of estimating loss due to impingement are similar to those made for entrainment estimates:

- There is 100% mortality for impinged fish.
- No compensatory mechanisms are operating.

Estimates of the number of adults lost due to entrainment of eggs and young and the impingement of young will be summed. This total estimate of potential adults lost to the Mississippi River will then be compared to sport fishing harvests to place the losses in perspective.

6.4.2 Entrainment Losses

A total of nine taxa were chosen for analysis of impact (Table 6.4-1). Each of the taxa accounted for more than 1% of the young entrained and all nine taxa represented nearly 97% of the identifiable young. No northern pike, smallmouth bass or walleye young were collected in entrainment samples in 1976. The number of young entrained, the number of potential adults lost and the values of fecundity and survival used to calculate losses are summarized in Table 6.4-1. Between 248,360 and 250,124 potential adult fish were estimated to have been lost due to the entrainment of 2,734,000 young over a year. Rock bass was the only sport species collected in entrainment samples and calculated adult losses of rock bass (106 fish) represented much less than 0.1% of the estimated total adult fish loss. Logperch, a forage species, accounted for as much as 88% of the predicted adults lost due to entrainment.

TABLE 6.4-1

CALCULATION OF EQUIVALENT ADULT FISH LOST DUE TO THE ENTRAINMENT OF EGGS AND YOUNG AT MNGP IN 1976

Taxon	Mean Fecundity($\bar{F}$)	Mean Generation Time(g)	Survival			Number Entrained($\times10^5$)	Number of Adults Lost(Na)
			Egg to Adult(Sg)	Egg to Larva(Se)	Larva to Adult(S'l)		
Carp	28,174[a,b]	5	1.42×10^{-5}	0.005-0.94	1.51×10^{-5}-2.84×10^{-3}	0.30	1-85
Minnows	901[c]	1	2.22×10^{-3}	0.005	4.4×10^{-1}	3.08	13,600
White sucker	13,003[d]	4	3.84×10^{-5}	0.003	1.28×10^{-2}	1.50	1,920
Silver redhorse	5,970[d]	5	6.7×10^{-5}	0.003	2.23×10^{-2}	0.40	893
Shorthead redhorse	11,432[d]	4	4.37×10^{-5}	0.003	1.46×10^{-2}	6.33	9,230
Redhorses	5,970-11,432[d]	4-5	4.37×10^{-5}-6.7×10^{-5}	0.003	1.46×10^{-2}-2.23×10^{-2}	2.19	3,200-4,880
Rock bass	1,094[e]	2	9.14×10^{-4}	0.75	1.22×10^{-3}	0.87	106
Darters	733[e]	1	2.73×10^{-3}	0.75	2.64×10^{-3}	3.88	1,410
Logperch	1,615[e]	1	1.24×10^{-3}	0.005	2.48×10^{-1}	8.79	218,000
						27.34	248,360-250,124

[a]Carlander 1969
[b]Swee and McCrimmon 1966
[c]Scott and Crossman 1973
[d]Eberley 1975
[e]Winn 1958a, b

6.4.3 Impingement Losses

Thirteen of the 35 taxa impinged on the vertical traveling screens at MNGP were chosen for impact analysis (Table 6.4-2). Each of the taxa, except northern pike, rock bass, johnny darter and walleye, represented more than 1% of the total number of fish impinged during the 1976-1977 intake monitoring program (Section 5.2.2). The 13 taxa represented more than 97% of the total impinged. The minnows included at least ten species, of which only spotfin shiner and longnose dace individually made up more than 1% of the fish impinged. Sport species represented less than 10% of the total number of fish impinged.

The total number of fish estimated to have been impinged between April 1976 and April 1977 was higher than for any one year period previously examined (Section 5.2.2) and, consequently, adult losses for 1976-1977 probably represent a maximum for the operational period of MNGP.

Between 7,642 and 10,838 adults were projected to have been lost due to impingement of 38,654 fish during the 1976-1977 study period (Table 6.4-2). Logperch accounted for the largest portion (31.2 to 44.2%) of the projected loss; minnows were the next most numerous group (21.8 to 31.0%). Since it appeared that most individuals of these taxa were

TABLE 6.4-2

CALCULATION OF ADULT FISH LOST DUE TO IMPINGEMENT AT MNGP DURING 1976 AND 1977

Taxon	Number Impinged	g[a]	Survival to g[b]	Number of Adults Lost
Northern pike	7	3	8.1×10^{-6}–1.65×10^{-1}	1
Carp	2,506	5	6.56×10^{-8}–8.6×10^{-2}	1-215
Minnows[c]	2,366	-	-----[d]	2,366
White sucker	2,121	4	7.0×10^{-7}–1.19×10^{-1}	1-252
Silver redhorse	7,385	5	6.56×10^{-8}–8.6×10^{-2}	1-635
Shorthead redhorse	15,295	4	7.0×10^{-7}–1.19×10^{-1}	1-1,820
Black bullhead	1,799	-	---	1,799
Rock bass	175	2	9.0×10^{-5}–2.3×10^{-1}	1-40
Smallmouth bass	1,295	3	2.82×10^{-2}–4.66×10^{-2}	36-60
Black crappie[e]	2,254	3	8.1×10^{-3}–1.02×10^{-1}	18-230
Johnny darter	35	-	-----	35
Logperch	3,381	-	-----	3,381
Walleye	35	3	1.2×10^{-4}–1.23×10^{-1}	1-4
Total	38,654			7,642-10,838

[a] g = Mean Generation Time as defined in Section 6.4.1

[b] See Section 6.4.1. Species-specific survivals were used when available

[c] Includes hornyhead chub, golden shiner, common shiner, bigmouth shiner, spottail shiner, sand shiner, unidentified shiners, fathead minnow, bluntnose minnow and longnose dace

[d] Assumed to be adults when impinged

[e] Based on size appeared to be 1 year old at impingement

already adults when impinged, the actual number impinged was considered the most conservative estimate of loss. Most black bullhead impinged appeared to be age 1 or older, so the actual number impinged was again used as a conservative estimate of loss.

6.4.4 Combined Impact of Entrainment and Impingement

The total impact of MNGP on the fish populations of the Mississippi River is best evaluated by considering entrainment and impingement losses together. The total estimated loss of potential adults due to the operation of MNGP during the one year study period is summarized in Table 6.4-3. The significance of these losses to the populations involved may be examined in several ways. The number of sport species lost may be compared to estimated sport harvest (Section 4.3.5.4). Since sport fishing pressure is light in this portion of the Mississippi River, sport harvest is probably not a satisfactory indicator of sport fish abundance or potential yield. Losses of both sport and rough fish can also be examined in light of the estimated abundance of various populations as measured in 1969 and 1972 to 1977 (Section 4.3.5.2).

Little usable catch information for forage species is available; consequently, impact must be evaluated in a

TABLE 6.4-3

TOTAL NUMBER OF POTENTIAL ADULTS ESTIMATED TO HAVE BEEN LOST DUE TO ENTRAINMENT AND IMPINGEMENT OF FISH AT MNGP, APRIL 1976 TO APRIL 1977

	Number of Adults Lost Due to Entrainment	Number of Adults Lost Due to Impingement	Total Number of Adults Lost
Northern pike	0	1	1
Carp	1-85	1-215	2-300
Minnows	13,600	2,366	15,966
White sucker	1,920	1-252	1,921-2,172
Silver redhorse	893	1-635	894-1,528
Shorthead redhorse	9,230	1-1,820	9,231-11,050
Unidentified redhorse	3,200-4,880	-	3,200-4,880
Black bullhead	1-500	1,799	1,800-2,299
Rock bass	106	1-40	107-146
Smallmouth bass	0	36-60	36-60
Black crappie	0	18-230	18-230
Darters[a]	1,410	35	1,445
Logperch	218,000	3,381	221,381
Walleye	0	1-4	1-4
TOTAL			256,003-261,462

[a]Includes johnny darter

different manner. From data on the abundance of young in the drift, an estimate of the number of spawning adults can be calculated in the manner used to arrive at adult losses from entrained larvae. Where available, estimates of rough standing crop calculated from 1976 seine data will also be used as a standard of comparison.

Sport fish (northern pike, rock bass, smallmouth bass, black crappie and walleye) represented less than 0.1% of the estimated adult loss while forage fish (mainly logperch) represented nearly 94% of the estimated loss (Table 6.4-3). Rough fish, such as white sucker, silver redhorse and shorthead redhorse, made up the largest proportion of the remaining estimated adult loss.

Logperch (221,381 fish) and darters (1,445 fish) accounted for 93% of the forage fish lost due to entrainment and impingement. The estimated loss of over 221,000 logperch is difficult to evaluate because little information on the abundance of this species in the MNGP area is available. Logperch were not abundant in any of the seine or electrofishing studies in the vicinity of MNGP (Section 4.3.5.2). However, the number of young in the drift in 1976 would seem to indicate that they are much more abundant than seine studies revealed. A total of 2,042,000 young were estimated to have drifted past the MNGP intake in 1976. This represents the progeny of 253,000 spawning pairs (based on the fecundity and survival values in Table 6.4-1). If all individuals were randomly distributed over the area upstream of the intake (approximately 10 ha or 25 ac) in the channel between the south bank of the river and the south shore of Beaver Island (Figure 4.3-4), their density would be approximately 50,600/ha. The average catch of logperch in this area in 1976 was one per seine haul (Table 4.3-6) or approximately 285/ha. This large discrepancy in abundance estimates could be the result of non-random distribution of logperch, an inadequate number of sampling locations, the concentration of logperch in the riffle area upstream of MNGP in the spring of 1976 for spawning when no seining was conducted, and/or the inadequacy of the seine in capturing logperch.

The number of adult logperch lost due to entrainment and impingement represents about 45% of the estimated spawning population upstream of the MNGP intake. It is not anticipated that losses of even this magnitude will have a serious detrimental effect on the population upstream of MNGP. This statement is based on information gathered by several authors on the harvesting of minnows for bait. The reproductive strategy and life history of many minnows and logperch are similar, in that they are short-lived and have low fecundities, apparently high survival rates and, probably, very high population growth rates. Larimore (1954) found that annual harvests of up to 50% of the populations of three species of minnow in a 1.4 km (0.87 mi) stretch of Jordan Creek, Illinois for four years produced no discernible effect on the populations. Brandt and Schreck (1975) found that in Rich Creek, West Virginia there was no detectable effect on forage populations in harvested areas as compared to non-harvested areas. Brynildson (1959) reported that removals of 23,000 and 28,000 minnows and suckers from a Wisconsin trout stream did not appreciably lower population densities. Summerfelt (1967) found that, after trying to remove all fish from a 273 m (896 ft) stretch of the Smoky Hill River, Kansas in 1965, collections in 1966 yielded greater numbers of minnows than 1965.

An estimated 15,966 minnows of at least nine species were lost to impingement and entrainment at MNGP during the 1976-1977 study period. It is not anticipated that a loss of this magnitude will have a detrimental effect on any of the minnow populations in the vicinity of MNGP, as nearly twice as many minnows were captured in 1976-1977 seine collections at MNGP (Section 4.3.5.2).

Between 36 and 60 adult smallmouth bass and between 18 and 230 adult black crappie were estimated to have been lost due to impingement of young or yearlings on the screens at MNGP. These losses represent about 21% of the average annual sport harvest of smallmouth bass and about 50% of the mean sport harvest of black crappie from the MNGP area (approximately 6-12 km or 3.7-7.5 mi of river near the plant, Section 4.3.5.4) between 1972 and 1976. Although these percentages appear to be high, it is likely that this reach of the Mississippi River could withstand a greater harvest as, at present, fishing pressure is very light (2,418 to 5,772 m-hr/yr). For example, a 10 km (6.3 mi) stretch of Curtois Creek in Missouri, which is much smaller than the Mississippi at MNGP, supported an average annual harvest of 732 smallmouth bass at fishing pressures much higher (5,755 to 10,224 m-hr/yr) than those in the vicinity of MNGP (Fleener 1975).

Estimated losses of northern pike and walleye of the magnitude experienced in the 1976-1977 study period do not pose a threat to either of the populations in the vicinity of MNGP. These losses represent less than 5% of the apparently low sport harvests for these species near MNGP.

The suckers (white sucker, silver redhorse and shorthead redhorse) accounted for 6 to 8% of the estimated total adult fish loss. Between 13,325 and 17,458 adult redhorse (silver and shorthead combined) were estimated to have been lost due to the entrainment and impingement of young. The combined losses of silver redhorse for 1976-1977 were estimated to be between 1,179 and 1,962 while that for shorthead redhorse was 12,146 to 15,496 (assuming that the unidentified redhorses were made up of silver and shorthead redhorse in the same proportion as those that could be identified). In order to place these losses into perspective, they may be compared with population estimates made by Hopwood and Scherer (1970). The shorthead redhorse population age 3 and older in the 7 km (4.4 mi) of the river depicted in Figure 4.3-4 was estimated to be 34,500 in 1968 and 33,400 in 1969. Hopwood and Scherer felt that these estimates were conservative. Estimated losses of shorthead redhorse in 1976 represent between 35.2 and 46.4% of the estimated 1968 and 1969 populations. If it is assumed that catch-per-unit-effort (CPUE) for electrofishing is directly proportional to abundance of a species, the shorthead redhorse population estimate for 1968, along with the 1976 CPUE data, can be used to roughly estimate the population in 1976 in a manner similar to that used by Hopwood and Scherer (1970):

$$\frac{\text{1976 population}}{\text{CPUE for 1976}} = \frac{\text{1968 population}}{\text{CPUE for 1968}}$$

For shorthead redhorse:

$$\text{1976 population} = \frac{34{,}500}{43.1} \times 77.5 = 62{,}036 \text{ fish}$$

This type of estimate was not possible for silver redhorse because no population estimate was made in 1968. When estimated 1976 losses are compared to the above estimate of shorthead redhorse population, they represent between 19.5 and 25%. However, this extrapolation must be considered with caution since two significant changes in sampling technique were made between 1975 and 1976. In 1975, a pulsed DC electrofishing unit was substituted for the AC unit that had been used since 1968. No quantitative estimate of the change in catchability of the new gear was made, but Novotny and Priegel (1974) felt that pulsed DC units were more effective in riverine situations. In 1976, the manner of calculating CPUE was also changed so that the amount of time the electrodes were energized was used as a measure of effort instead of the total amount of time necessary to make a run. This change would tend to increase CPUE relative to earlier years. These two changes and the concentrating effect of low water levels in 1976 on fish probably combined to increase CPUE in 1976 relative to other years.

The losses of shorthead redhorse and silver redhorse observed in 1976 are, however, considered abnormal and are believed to be the result of a very successful year class in 1976. Redhorse young composed less than 1% of the seine catches in 1970 and 1972, but accounted for about 17% of the catch in 1976 (Section 4.3.5.2). Abundance estimates available for young redhorse in 1976 were approximately ten times those for 1973 (Section 4.3.5.3, Table 4.3-11). Another possible indication of year class strength is the number of young impinged on the traveling screens. Between 1973 and 1975, no silver redhorse were impinged and shorthead redhorse accounted for less than 3% of the annual number of fish impinged (Heberling and Weinhold 1977a). In 1976, young shorthead redhorse composed 29.8% and silver redhorse 17.5% of the total number of fish impinged between January and December (Heberling and Weinhold 1977a). Between January and early April 1977, silver and shorthead redhorse of the 1976 year-class represented 19.1 and 45.8%, respectively, of the fish impinged.

It appears that losses due to impingement and entrainment of silver and shorthead redhorse during previous operational years produced no discernable effects on adult populations as evidenced by CPUE for electrofishing (Figure 4.3-4). Any effect of impingement losses in 1976 will probably not be detectable for several years, since silver and shorthead redhorse do not appear to become fully susceptible to electrofishing gear until age 4 or 5 (Hopwood and Scherer 1970, Neudahl 1976).

Between 1,800 and 2,299 potential adult black bullhead were estimated to have been lost due to entraiment and impingement in 1976-1977 study period (Table 6.4-3). This was intermediate among the estimates for 1973 (541), 1974 (5,467) and 1975 (747) reported by Heberling and Weinhold (1977a).

In summary, the operation of MNGP is not judged to have a serious impact on sport fish populations of the Mississippi River near MNGP. The losses of some forage and rough fish, on the other hand, appeared to be rather high. Logperch was the primary forage species lost; however, losses were not considered serious in comparison to the estimated spawning population and in light of information presented on the harvest of other forage species (mainly minnows) with similar life history strategies. Redhorse losses during the 1976-1977 study year were considered extremely high relative to other years because of an apparently very successful year class in 1976. It was estimated that it would be several years, if at all, before the loss could possibly be detected in the population with the gear used currently.

The operation of the MNGP intake does not appear to have damaged the fish community of the Mississippi River near MNGP since it began operation in 1971. With the possible exception of the redhorses (see above), losses during the 1976-1977 study are not expected to have a measurable impact on the fish populations in the vicinity of MNGP. Continued operation of the MNGP intake should not affect the propagation of the balanced indigenous aquatic communities of the Mississippi River.

7. REFERENCES CITED

Andersen, N.H. 1966. Depressant effect of moonlight on activity of aquatic insects. Nature, Lond. 209:319-320.

Anonymous. 1973. Impingement of fishes and other organisms on The Prairie Island Plant travelling screens. p. C-5.87 to 5.132 In: Northern States Power Company. 1973. Prairie Island environmental monitoring and ecological studies program. 1973 annual report, Vol. II.

Bainbridge, R. 1960. Speed and stamina in three fish. J. Exp. Biol. 37(1):129-153.

Becker, G.C. and T.R. Johnson. 1970. Illustrated key to the minnows of Wisconsin. Wisconsin State Univ. Stevens Point, WI.

Bishop, J.E. and Hynes, H.B.N. 1969. Downstream drift of the invertebrate fauna in a stream ecosystem. Arch. Hydrobiol. 66:56-90.

Black and Veatch, Consulting Engineers. 1976. Sherburne County Generating Plant units 3 and 4 environmental report.

Bodola, A. 1966. Life history of the gizzard shad, Dorosoma cepedianum (LeSueur), in western Lake Erie. U.S. Fish Wildl. Serv. Fish. Bull. 65(2):391-425.

Brandt, T.M. and C.B. Schreck. 1975. Effects of harvesting aquatic bait species from a small West Virginia stream. Trans. Am. Fish. Soc. 104:446-453.

Brynildson, C.L. 1956. Minnow-sucker removal in Milner branch and Big Green River, Grant County in 1955 and 1956. Southern Area Investigation Memo. No. 199. Wisc. Dept. Cons.

Carlander, K.D. 1969. Handbood of freshwater fishery biology. Vol. I. Life history data on freshwater fishes of the United States and Canada, exclusive of the Perciformes. Iowa State Univ. Press, Ames, IA.

Carlander, K.D. 1977. Biomass, production and yields of walleye (Stizostedion vitreum vitreum) and yellow perch (Perca flavescens) in North American lakes. J. Fish. Res. Board Can. 34:1602-1612.

Clady, M.D. 1975. Early survival and recruitment of smallmouth bass in Northern Lake Michigan. J. Wild. Manag. 39:194-200.

Clady, M.D. 1976. Influence of temperature and wind on the survival of early life stages of yellow perch, Perca flavescens. J. Fish. Res. Bd. Can. 33:1887-1893.

Colingsworth, R.F. 1969. Attached algae studies of the Mississippi River at Monticello, Minnesota. In: Northern States Power Company. 1969. Environmental Monitoring Program for the Monticello Nuclear Generating Plant, 1968 Annual Report.

Davies, R.M. and L.D. Jensen. 1974. Entrainment of zooplankton at three mid-Atlantic power plants. Proceedings of the second workshop on entrainment and intake screening, Rept. No. 15:131-155.

Department of the Army. 1974. Final environmental impact statement, Sherburne County Generating Plant. St. Paul, MN.

Dodson, J.J. and C.J. Young. 1977. Temperature and photoperiod regulation of rheotrophic behavior in prespawning common shiners, Notropis cornutus. J. Fish. Res. Board Com. 34:341-346.

Eberley, L.W. 1975. Spawning activities of major fish species in the Monticello area of the Mississippi River. M.A. Thesis. St. Cloud State College, St. Cloud, MN.

Eddy, S., B.J. Moyle and J.C. Underhill. 1963. The fish fauna of the Mississippi River above St. Anthony Falls as related to the effectiveness of this falls as a barrier. Proc. Minn. Acad. of Sci. 30:111-115.

Eddy, S. 1969. How to know the freshwater fishes. Wm. C. Brown Company, Dubuque, IA.

Eddy, S. and J.C. Underhill. 1974. Northern fishes. 3rd ed. Univ. Minnesota Press, Minneapolis, MN.

Edsall, T.A. and T.G. Yocom. 1972. Review of recent technical information concerning the adverse effects of once-through cooling on Lake Michigan. Great Lakes Fish. Lab., Ann Arbor, MI.

Elliot, J.M. 1965. Daily fluctuations of drift invertebrates in a Dartmoor stream. Nature, Lond. 205:1127-1129.

EPA. 1976a. Development document for best technology available for the location, design, construction and capacity of cooling water structures for minimizing adverse environmental impact. U.S. Environmental Protection Agency, Washington, D.C. (Draft).

EPA. 1976b. Guidance for determining best technology available for the location, design, construction, and capacity of cooling water intake structures for minimizing adverse environmental impact, Section 316(b), P.L. 92-500. U.S. Environmental Protection Agency, Washington, D.C. Draft 2.

Fish, P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U.S. Bur. Fish., 47(1931-33): 293-398, 44 figs.

Fleener, G.G. 1975. The harvest of smallmouth bass and associated species in Courtois Creek. 1959-1963. pp. 250-256. <u>In</u>: R.H. Stroud and H. Clepper, ed. Black Bass Biology and Management. Sport Fishing Inst., Washington, D.C.

Forney, J.L. 1972. Biology and management of smallmouth bass in Oneida Lake, New York. New York Fish Game J. 19:132-154.

Forney, J.L. 1976. Year-class formation in the walleye (<u>Stizostedion vitreum vitreum</u>) population of Oneida Lake, New York, 1966-1973. J. Fish. Res. Board Can. 33:783-792.

Galtsoff, P.S. 1924. Limnological observations in the Upper Missouri. Bull. Bur. Fish., Wash. 39:347-438.

Geen, G.H. T.G. Northcote, G.F. Hartman and C.C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet stream spawning. J. Fish Res. Board Can. 23):1761-1788.

Gerking, S.D. 1962. Production and food utilization in a population of a bluegill sunfish. Ecol. Monog. 32: 31-78.

Gray, J. 1957. How fishes swim. Sci. Amer. 197:48-54.

Grimes, C.B. 1975. Entrapment of fishes on intake water screens at a steam electric generating station. Ches. Sci. 16:172-177.

Grotbeck, L.M. and J.L. Bechthold. 1975. Fish impingement at Monticello Nuclear Plant. J. Power Div. ASCE 101(PO1):69-83.

Gundersen, R.W. and S.E. Lewis. 1976. Natural entrainment of macroinvertebrates from the Mississippi River at the Monticello Nuclear Generating Plant during 1973-74. pp. 2.4-1 through 2.4-14 In: Northern States Power Company. 1976. Environmental monitoring and ecological studies program for the Monticello Nuclear Generating Plant 1975 annual report.

Harden-Jones, F.R. 1968. Fish migration. St. Martin's Press, Inc. New York, NY.

Herberling, G.D. 1975. Summary of abundance and growth data for selected juvenile fishes in the Mississippi River near Monticello. In: Northern States Power Company. 1975. Monticello Nuclear Generating Station 1974 Annual Report.

Heberling, G.D. and J.W. Weinhold. 1975a. Fish impingement. In: Northern States Power Company. 1975. Monticello Nuclear Generating Station 1974 Annual Report.

Heberling, G.D. and J.W. Weinhold, 1975b. The 1974 Monticello creel survey. In: Northern States Power Company. 1975. Monticello Nuclear Generating Station 1974 Annual Report.

Heberling, G.D. 1976. 1975 Monticello creel survey report. In: Northern States Power Company. 1976. Monticello Nuclear Generating Station 1974 Annual Report.

Heberling, G.D. and J.W. Weinhold. 1976a. 1975 Monticello fish impingement study. In: Northern States Power Company. 1976. Monticello Nuclear Generating Station 1975 Annual Report.

Heberling, G.D. and J.W. Weinhold. 1976b. Monticello electrofishing surveys. In: Northern States Power Company. 1976. Monticello Nuclear Generating Station 1975 Annual Report.

Heberling, G.D. and D.W. Weinhold. 1977a. A summary of the 1976 Monticello fish impingement study. In: Northern States Power Company. 1977. Monticello Nuclear Generating Station 1976 Annual Report.

Heberling, G.D. and J.W. Weinhold. 1977b. A summary of the 1976 Monticello electrofishing survey. In: Northern States Power Company. 1977. Monticello Nuclear Generating Station 1976 Annual Report.

Heberling, G.D. 1977a. A summary of the 1976 Monticello - SHERCO creel survey. In: Northern States Power Company. 1977. Monticello Nuclear Generating Station 1976 Annual Report.

Heberling, G.D. 1977b. Water monitoring summary. In: Northern States Power Company. 1977. Monticello Nuclear Generating Station 1976 Annual Report.

Hogue, J.J.,Jr. R. Wallus and L.K. Kay. 1976. Technical note B19. Guideto the identification of larval fishes in the Tennessee River. Tennessee Valley Authority, Norris, Tenn.

Hopwood, A.J. 1969. Monticello ecological studies program, fish. In: Northern States Power Company. 1969. Monticello Nuclear Generating Station 1969 Annual Report.

Hopwood, A.J. and H.P. Sherer. 1970. Fish studies In: Northern States Power Company. 1970. Monticello Nuclear Generating Station 1969 Annual Report.

Hopwood, A.J. 1971. Monticello ecological studies program. In: Northern States Power Company. 1971. Monticello Nuclear Generating Station 1970 Annual Report.

Hopwood, A.J. 1972. Monticello ecological studies program. In: Northern States Power Company. 1972. Monticello Nuclear Generating Station 1971 Annual Report.

Hopwood, A.J. 1973. Monticello ecological studies program, fish. In: Northern States Power Company. 1973. Monticello Nuclear Generating Station 1972 Annual Report.

Hopwood, A.J. 1974a. Monticello ecological studies program. In: Northern States Power Company. 1974. Monticello Nuclear Generating Station 1973 Annual Report.

Hopwood, A.J. 1974b. Unpublished electrofishing data collected near the Monticello Nuclear Generating Station in 1974.

Hopwood, A.J. 1974c. Thermal effects of a nuclear power plant on the Mississippi River at Monticello, MN. Water Resources. Res. Center. Univ. of Minn. Bull. 69.

Horst, T.J. 1975. The Assessment of Impact Due to Entrainment of Ichthyoplankton, pp. 107-118 In: S.B. Saila (ed), Fisheries and Energy Production, A Symposium. Lexington Books, D.C. Heath & Co., Lexington, MA.

Horst, T.J. Consultant, Stone and webster, personal communicatio. with M.D. Dahlberg, Staff Ecologist, NUS Corporation, Pittsburgh, Pennsylvania. 1977.

Hubbs, C.L. and K.F. Lagler. 1958. Fishes of the Great Lakes Region. Univ. of Mich. Press.

Hynes, H.B.N. 1970. The Ecology of Running Waters. Univ. of Toronto Press.

Jester, D.B. 1972. Life history, ecology, and management of the river carpsucker, Carpiodes carpio (Rafinesque), with reference to Elephant Butte Lake. Ag. Exp. Sta. Resch. Rept. 243, New Mexico State Univ., Las Cruces.

Johnson, F.H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota, and connecting waters. Trans. Amer. Fish. Soc. 90:312-322.

Jones, D.R., J.W. Kiceniuk and O.S. Bamford. 1974. Evaluation of the swimming performance of several fish species from the Mackenzie River. J. Fish. Res. Bd. Canada 31:1641-1647.

King, L.R. 1969. Swimming speed of the channel catfish, white crappie and other warm-water fishes from Conowingo Reservoir, Susquehanna River, Pa. M.S. Thesis Cornell Univ.

Kelso, J.R.M. and F.J. Ward. 1972. Vital statistics, biomass, and seasonal production of an unexploited walleye (Stizostedion vitreum vitreum) population in West Blue Lake, Manitoba. J. Fish. Res. Bd. Can. 29:1043-1052.

Knutson, K.M. 1974. Natural entrainment of small fish from the Mississippi River at Monticello during 1973-1974. In: Northern States Power Company. 1974. Monticello Nuclear Generating Station 1973 Annual Report.

Knutson, K.M. 1975. Pumped entrainment of small fish at the Monticello Nuclear Generating Plant on the Mississippi River, 1973-1974. In: Northern States Power Company. 1975. Monticello Nuclear Generating Station 1974 Annual Report.

Krosch, H.F. 1970. Progress report on the Lake St. Croix creel census for the period April 1, 1968 to March 30, 1969. In: Northern States Power Company. 1970. Allen S. King Plant 1969 Annual Report.

Larimore, R.W. 1954. Minnow production in a small Illinois stream. Trans. Am. Fish. Soc. 84:110-116.

Larimore, R.W. and M.J. Dueyer. 1968. Effects of temperature acclimation on the swimming ability of smallmouth bass fry. Trans. Amer. Fish. Soc. 97:174-184.

Lippson, A.J. and R.L. Moran. 1974. Manual for the identification of early developmental stages of fishes of the Potomac River estuary. Power plant siting program of of the Maryland Department of Natural Resources (PPSP-MP-13).

Lutterbie, G.W. 1975. Illustrated key to the Percidae of Wisconsin (walleye, sauger, perch, and darters). pp. 17-43 In: Reports on the fauna and flora of Wisconsin, The Museum of Natural History, University of Wisconsin-Stevens Point Report No. 10.

MacLeod, J.C. and L.L. Smith, Jr. 1966. Effect of pulpwood fiber on oxygen consumptions and swimming endurance of the fathead minnow, Pimephales promelas. Trans. Am. Fish. Soc. 95: 71-84.

Mansueti, A.J. and J.D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay Region. Part I, Nat. Res. Inst., Univ. Maryland, Baltimore, MD.

Matter, J. 1975. Analysis of flying insects collected in light-trap samples. M.S. Thesis. St. Cloud College, St. Cloud, MN.

Matter, W. 1975. Invertebrate drift in the Mississippi River near Monticello, Minnesota. M.S. Thesis. St. Cloud State Univ., St. Cloud, MN.

May, E.B. and C.R. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography. Okla. Dept. Wildl. Conserv., Bul. 5.

McConville, D.R. 1969. Macroinvertebrates of the Mississippi River in the Monticello Region. M.A. Thesis. St. Cloud State College, MN.

McConville, D.R. 1972. Population dynamics of the macro-invertebrates in the Mississippi River near Monticello, Minnesota. Ph.D. Disser., Univ. of Minn.

Minnesota Department of Natural Resources (MDNR). 1974. Minnesota animals and plants in need of special consideration with suggestions for management. Spec. Publ. No. 104. St. Paul, MN.

Mischuk, M. 1976. Primary production on the upper Mississippi River near Monticello, Minnesota. M.A. Thesis. St. Cloud State College, St. Cloud, MN.

Morgenweck, R.O. 1971. A survey and distribution study of the cyprinid minnows (family Cyprinidae) in the Monticello region of the Mississippi River. M.A. Thesis. St. Cloud State College, St. Cloud, MN.

Moyle, J.B. 1940. A biological survey of the Upper Mississippi River System. Fish. Res. Invest. Report No. 10. Minn. Dept. Cons.

Minnesota Pollution Control Agency (MPCA). 1975. Minnesota's guide for biological demonstrations for administration of 316(a) and (b) of the Federal Water Pollution Control Act Amendments of 1972 and Minnesota Regulation WPC 36(u)(3). Minnesota Pollution Control Agency, Minneapolis, Minn.

Nelson, W.R., and C.H. Walburg. 1977. Population dynamics of yellow perch (Perca flavescens), sauger (Stizostedion canadense), and walleye (S. vitreum vitreum) in four main stem Missouri River reservoirs. J. Fish. Res. Board. Can. 34:1748-1763.

Nemanick, J.M. 1973. Recolonization of macroinvertebrates on artificial substrate samplers in the Mississippi River near Monticello, Minnesota. M.S. Thesis. St. Cloud State College, St. Cloud, MN.

Neudahl, L. 1976. Age and growth of the major fish species in the Mississippi River near Becker, Minnesota. M.S. Thesis. St. Cloud State Univ., St. Cloud, MN.

Neuhold, J.M. and K.H. Lu. 1957. Creel Census Methods. Utah State Dept. of Game and Fish, Publ. No. 8.

Nikolskii, G.V. 1969. Theory of fish population dynamics. Oliver and Boyd, Edinburgh.

Northcote, T.G. 1958. Effect of photoperiodism on response of juvenile trout to water currents. Nature 181:1283-1284.

Novotny, D.W. and G.R. Priegel. 1974. Electrofishing boats: Improved designs and operation guidelines to increase the effectiveness of boom shockers. Wisc. Dept. Nat. Res. Tech. Bul. 73.

NSP. 1973. A summary of creel survey data collected on the Mississippi River near Monticello during 1972. In: Northern States Power Company. 1973. Monticello Nuclear Generating Station 1972 Annual Report.

NSP. 1974. The 1973 Monticello creel survey. In: Northern States Power Company. 1974. Monticello Nuclear Generating Station 1973 Annual Report.

NSP. 1976. Sherburne County Generating Plant, Units 3 and 4, Environmental Report. Northern States Power Company, Minneapolis, MN. 2 vols.

NUS. 1975. Effects of a heated discharge on the ecology of the Mississippi River: 316(a) Type 1 demonstration on the Monticello Nuclear Generating Plant, Minnesota.

NUS. 1976. Section 316(b) Demonstration for the Sherburne County Generating Plant Units 1 and 2.

Ott, J.D. 1973. Fluorescent dyemarking of cyprinid minnows (family Cyprinidae) and other small fish for population studies in the Mississippi River near Monticello, Minnesota. M.S. Thesis. St. Cloud State College, St. Cloud, MN.

Paragamian, V.L. and D.W. Coble. 1975. Vital statistics of smallmouth bass in two Wisconsisn Rivers, and other waters. J. Wildl. Manag. 39:201-210.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Dept. of Conserv.

Quirk, Lawler and Matusky. 1974. Nine Mile Point aquatic ecology studies, Vol. II, Fish impingement. Niagara Mohawk Power Corp.

Reinhard, E.G. 1931. The plankton ecology of the upper Mississippi, Minneapolis to Winona. Ecol. Monogr. 1:393-464.

Rothschild, B.J. 1961. Production and survival of eggs of the american smelt, Osmerus mordax (Mitchill) in Maine. Trans. Am. Fish. Soc. 90:42-48.

Schneider, J.A. 1966. An electro-fishing survey of the Mississippi River, Brainerd to Elk River, Minnesota. Minn. Div. of Game and Fish. Fed. Aid Proj. FW-1-R-10; 11. Special Publ. No. 37.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Canada. Bull. 184.

Siefert, R.E. 1968. Reproductive behavior, incubation and mortality of eggs, and postlarval food selection in the white crappie. Trans. Am. Fish. Soc. 97:252-259.

Summerfelt, R.C. 1967. Fishes of the Smoky Hill River, Kansas. Trans. Kans. Acad. Sci. 70:102-139.

Swee, U.B. and H.R. McCrimmon. 1966. Reproductive biology of the carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario. Trans. Am. Fish. Soc. 95:372-380.

Swor, T. 1974. Key to the larval fishes of the North Branch Susquehana River. Unpublished.

Taber, C.A. 1969. The distribution and identification of larval fishes in the Buncombe Creek Arm of Lake Texoma with observations on spawning habits and relative abundance. Ph. D. Thesis, Univ. of Oklahoma.

Trautman, M.B. 1957. The fishes of Ohio with illustrated keys. Ohio State Univ. Press, Columbus.

U.S. Atomic Energy Commission. 1972. Draft environmental impact statement for Indian Point Nuclear Generating Plant Unit No. 3, Consolidated Edison Company of New York, Inc. Docket No. 50-286.

U.S. Fish and Wildlife Service (USFWS). 1974. United States list of endangered fauna. May 1974. Washington, D.C.

U.S. Geological Survey (USGS). 1977. Water Resources for Minnesota, 1976. Water res. Div., U.S. Geol. Surv. St. Paul, MN.

U.S. Geological Survey (USGS). 1973. Water resources outlook for the Minneapolis-St. Paul Metropoliatan Area, Minnesota. U.S. Geol. Surv., Metropolitan Council of the Twin Cities Area, St. Paul, Minn.

Waters, T.F. 1962. A method to measure the production rate of a stream bottom invertebrate. Trans. Am. Fish. Soc. 91:243-250.

Waters, T.F. 1965. Interpretation of invertebrate drift in streams. Ecol. 46:327-334.

Waters, T.F. 1972. The drift of stream insects. Ann. Rev. Ent. 17:253-272.

Wiebe, A.H. 1928. Biological survey of the Upper Mississippi River with special reference to Pollution. Bull. Bur. Fish. Wash. 43:137-167.

Winn, H.E. 1958a. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae) Ecol. Monogr. 28:155-191.

Winn, H.E. 1958b. Observations on the reproductive habits of darters (Pisces-Percidae), Amer. Midl. Nat. 59: 190-212.