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Fishery Resource of the Upper Mississippi River and Relationship to Stream Discharge

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ABSTRACT—Fish population data collected through the Northern States Power Company monitoring program near its plants at Monticello and Becker, Minnesota were analyzed to describe species diversity, changes in recreational fishing, fishing success, and the influence of stream discharge on smallmouth bass year-class success and abundance. The work is part of a more extensive effort to develop a model applicable in managing the upper Mississippi River to meet the growing needs of recreation, agriculture, communities, and industry. Analysis of these data shows 48 species to be present and that smallmouth bass, *Micropterus dolomieui*, is the most important game species in the growing recreational fishery. Comparison of smallmouth bass year-class strength estimates with stream discharge for the period 1973-1987, indicates strong year-classes develop during years characterized by low spring and summer discharge.

Introduction

The character of the Mississippi River above the Twin Cities is uniquely different from the downstream reaches, which are managed primarily for navigation. The upper Mississippi, between St. Cloud and Coon Rapids, Minnesota, is characterized by a series of pools, runs, and riffles passing through a mixture of agricultural, forested, and urban areas. This relatively free-flowing portion of the river has become a significant recreational resource, as well as an important water source for drinking, irrigation, and industry.

Spring river discharges, measured at Monticello, for this section of the river range from over 40,000 cubic feet per second (cfs; 1975) to 2,300 cfs (1976). Summer period discharges below 650 cfs have been observed for short periods during dry years. Because periods of low stream discharge typically coincide with periods of maximum demand, regulatory agencies recognize the potential negative impacts that demands for water required to meet human needs could have on the stream community. The drought of 1988 heightened awareness of the need for information on the relationship between discharge and environmental quality. Knowledge of the relation between stream discharge and fish population responses is needed to manage the fishery while allowing for offstream uses.

In this paper, we provide general information on fish populations of the upper Mississippi River, the fishery that depends upon them, and the relationships between stream discharge and abundance of smallmouth bass *(Micropterus dolomieui)*, the primary game species. The work is based upon data collected by Northern States Power Company (NSP). NSP is required to monitor waters of the upper Mississippi River near the Monticello Nuclear Plant and the Sherburne County Plant (Sherco) at Becker as part of the State of Minnesota's permitting process, which provides for both appropriation and cooling water discharge for these plants. The NSP monitoring program provides the most extensive fishery data set available on this section of the river.

Methods

The NSP monitoring program includes periodic analysis of 25 water quality parameters and daily measurements of stream discharge and temperature in the areas near the two power plants. Fish population data were collected in an area from approximately 3 km upstream of Sherco to 5 km below the Monticello plant. Electrofishing surveys began in 1968 at the Monticello plant site. A standardized electrofishing program was initiated near both plants during 1976. Electrofishing was discontinued at Sherco in 1984 but is ongoing at Monticello. A 240 volt, pulsed direct current electrofishing boat was used. Electrofishing effort, measured as the number of hours during which electric current is passed into the water, averaged 9 hr per year during 1975-1984, when upstream and downstream stations near both plant sites were sampled, and 4.5 hr per year during 1985-1987, when sampling was generally limited to Monticello sampling stations. Paired shocking runs along opposite shorelines were made eight days per year from April through November in reaches one kilometer long, upstream and downsteam from each power plant. Captured fish were identified, measured and weighed prior to release. Scale samples were collected for a number of fish species from 1976 through 1984 and in 1988.

Standardized seining surveys were initiated during 1977 in the electrofishing survey areas. Seining was conducted on a biweekly basis using a 20-foot, one-eighth inch mesh bag seine. The length of each seine haul was estimated and the number of fish captured was recorded by species prior to their release. Lengths of subsamples of Age 0 smallmouth bass were measured regularly.

To determine both the importance of each species to the fishery and fishing intensity, NSP conducted creel surveys within the study area during 1972 through 1979 and in 1982. Angling pressure was estimated using a stratified random

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creel survey design (1). Creel clerks made hourly instantaneous counts of all anglers. Interviews with individual anglers provided information on trip length, species composition of the catch, catch rates, fish length data, and scale samples.

Analysis of the relationship between stream discharge and smallmouth bass year-class strength and abundance was initiated during 1980 as part of a process designed to develop a predictive model applicable in describing fish abundance from physical habitat data. Year-class strength was estimated from age analysis of samples collected by electrofishing. Age assignments were based on scale impressions read independently by two trained observers. The method of Ketchen (2) was used to estimate age from fish lengths in cases where scales were not collected. The contribution of each year's hatch to the population was estimated by calculating catch per hour of electrofishing effort (CPE) for various individual or groups of age classes. Relationships between current velocity, and smallmouth bass nesting activity, fry survival, and fingerling growth were also investigated as part of the model building process. Results from these studies are reported by Swenson *et al.* (3).

The size which smallmouth attained by the end of their first year of life was estimated by back-calculation from scales. Frequency distributions of back-calculated lengths for specific year-classes were used to estimate modal length at the end of the first year of life. Comparison of modal lengths with temperature, discharge, and year-class strength ranks served to identify the influence of the physical habitat conditions on growth during the first year of life and the importance of first year growth to survival, success of year-classes, and smallmouth abundance.

Results

Fish Species Diversity and Changes in Abundance

The field survey shows a diverse assemblage of fish species exists in the upper Mississippi River. Forty-eight species representing twelve families were captured during the surveys. Catches of 16 species indicated they were rare (Table 1). Of the 32 remaining, 14 were rated as abundant or common on the basis of their numbers and frequency of occurrence in electrofishing runs or seine hauls. Smallmouth bass represented the only game species in these high abundance categories (Table 1).

Abundance indices for stream areas near both power plants indicated a wide range of annual and seasonal variability. Monticello electrofishing annual average catch per hour of electrofishing effort (CPE) ranged from 201 to 710 fish per hour. At Sherco the average catch varied between 230 and 604 fish per hour. Although site-specific variables resulted in slightly different indices of abundance, annual trends appeared to be similar between the two plant sites for all major species during years stations at both sites were sampled (1976-1984). Variation in CPE suggests abundance of smallmouth bass was higher during two 2-year periods (1977-1978 and 1981-1982) and again during 1988 (Figure 1). CPE of shorthead redhorse and silver redhorse appears to follow a similar trend but high abundance peaks lagged one to two years behind (Figure 1).

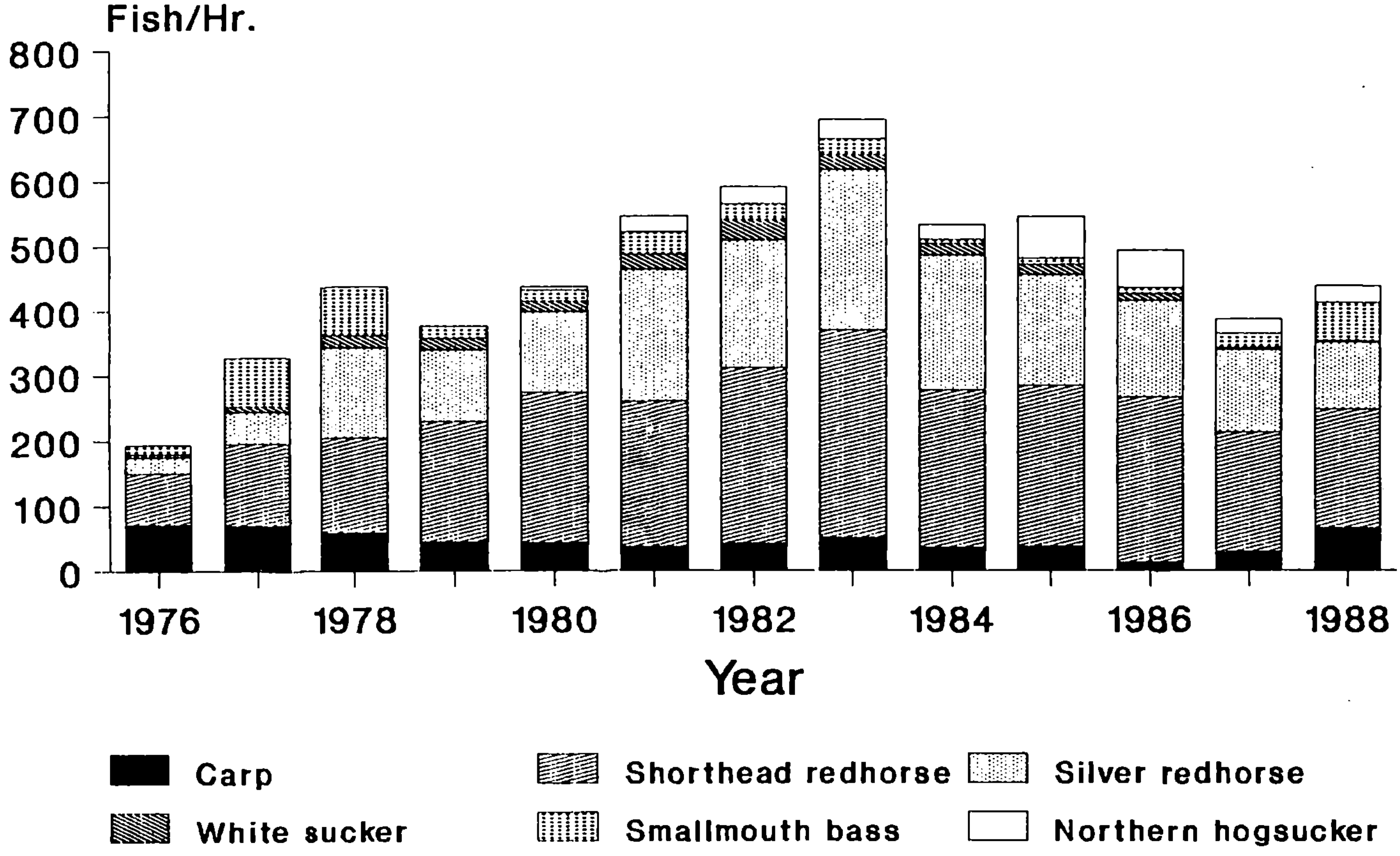

Figure 1. Upper Mississippi River electrofishing catch per unit of effort for six more abundant species.

Table 1. Species list with an index of abundance based on seining and electrofishing data.

		Index of Abundance[a]
AMIIDAE		
Bowfin	Amia calva	Ra
SALMONIDAE		
Cisco	Coregonus artedii	Ra
ESOCIDAE		
Northern pike	Esox lucius	Re
Muskellunge	Esox masquinongy	Ra
CYPRINIDAE		
Hornyhead chub	Nocomis biguttatus	C
Creek chub	Semotilus atromaculatus	Ra
Fathead minnow	Pimephales promelas	C
Bluntnose minnow	Pimephales notatus	A
Brassy minnow	Hybognathus hankinsoni	Ra
Spotfin shiner	Notropis spilopterus	A
Bigmouth shiner	Notropis dorsalis	C
Sand shiner	Notropis stramineus	A
River shiner	Notropis blennius	Ra
Spottail shiner	Notropis hudsonius	C
Common shiner	Notropis cornutus	C
Golden shiner	Notemigonus crysoleucas	Ra
Mimic shiner	Notropis volucellus	U
Carp	Cyprinus carpio	A-C
Longnose dace	Rhinichthys cataracte	C
Blacknose dace	Rhinichthys atratulus	Re
No. redbelly dace	Chrosomus eos	Ra
CATOSTOMIDAE		
Silver redhorse	Moxostoma anisurum	A
Shorthead redhorse	Moxostoma macrolepidotum	A
Greater redhorse	Moxostoma valenciennesi	Re
White sucker	Catostomus commersoni	C
Bigmouth buffalo	Ictiobus cyprinellus	U
Northern hogsucker	Hypentelium nigricans	C-A

		Index of Abundance[a]
ICTALURIDAE		
Channel catfish	Ictalurus punctatus	Ra
Black bullhead	Ictalurus melas	Re
Yellow bullhead	Ictalurus natalis	U
Brown bullhead	Ictalurus nebulosus	Ra
PERCOPSIDAE		
Trout perch	Percopsis omiscomaycus	U
GADIDAE		
Burbot	Lota lota	U
ANTHERINIDAE		
Brook silverside	Labidesthes sicculus	U
GASTEROSTEIDAE		
Brook stickleback	Culaea inconstans	Ra
CENTRARCHIDAE		
Smallmouth bass	Micropterus dolomieui	C-A
Largemouth bass	Micropterus salmoides	Ra
Black crappie	Pomoxis nigromaculatus	Re
White crappie	Pomoxis annularis	Ra
Rockbass	Ambloplites rupestris	Re
Bluegill	Lepomis macrochirus	Re
Pumpkinseed	Lepomis gibbosus	Ra
Green sunfish	Lepomis cyanellus	Ra
PERCIDAE		
Yellow perch	Perca flavescens	Ra
Walleye	Stizostedion vitreum	Re
Johnny darter	Etheostoma nigrum	C-A
Blackside darter	Percina maculata	U
Logperch	Percina caprodes	Re

[a] Ra = Rare: less than five occurrences
U = Unusual: less than annually
Re = Regularly: more than once annually
C = Common: nearly every sampling but low CPE
A = Abundant: nearly every sampling and large CPE

Sportfishing on the Upper Mississippi

Fishing pressure increased substantially between 1972 and 1982. Fishing pressure increased sharply from 2,570 angler hours in 1972 to 11,674 in 1977, and peaked at 19,942 angler hours during 1979 (Table 2). Angler interview responses indicated 60 percent of their fishing efforts were directed at smallmouth bass. Catch rates of smallmouth bass ranged from a low of 0.05 fish per hour in 1974 to over 1.2 fish per hour in 1977. The high catch rates of 1977 matched a sharp increase in fishing pressure and the highest smallmouth bass electrofishing CPE (Table 2, Figure 1). Catch rates, fishing pressure, and electrofishing CPE remained high during 1978. During 1979, when angler harvest and fishing pressure remained high (Table 2), electrofishing CPE declined (Figure 1). Angling catch of other species was almost always lower than that of smallmouth bass (Table 2). This supports other data which suggest smallmouth bass is the most abundant game fish species and the focus of the recreational fishery.

Relationship Between Stream Flow and Smallmouth Bass Abundance

Long-term trends in electrofishing CPE (Figure 1) indicate abundance of larger fish species, particularly smallmouth bass, is related to stream discharge. Because electrofishing is most effective on Age I and Age II smallmouth bass, the higher abundances during 1977-1978, 1981-1982, and 1988 appear related to improved survival of Age 0 fish during the immediately preceding years of 1976, 1980, and 1987. These three years are characterized by low summer discharge and, except for 1987, low average spring discharge (Table 3). Electrofishing CPE of silver and shorthead redhorse appears to peak approximately 3-4 years after the years of low discharge. The redhorse captured by electrofishing average 950 g and appear to be older than Age II; however, age analysis has not been completed for these species.

Recognition that a relationship may exist between stream discharge and smallmouth bass abundance occurred in 1979 and stimulated more detailed studies. The process of defining the relationship and the relative importance of discharge and temperature began with a conceptual model based on an assumption that the influence of nesting period and post nesting period temperatures and discharges are different (Figure 2). Experimental evidence shows high discharge (3) or low temperatures (4) during the nesting-period results in poor year-class survival by delaying spawning, extending the period of development, or by promoting high fry mortality. Evidence that high summer discharges and/or low temperatures cause slow growth, winter starvation, and low overwinter survival of Age 0 smallmouth bass is also available (3,4).

Age analysis completed to date supports the assumption that low spring and summer discharge stimulates the formation of strong smallmouth bass year-classes, increased abundance, and fishing success. The relative contribution of a specific year to the population was estimated for the period 1974-1987, on the basis of CPE of Age I smallmouth captured the following year (Table 3). Relative contributions of the 1973-1986 year-classes were also estimated on the basis of the average percentage contribution derived from multiple age-class combinations. Year-class specific CPE for the 1973-1985 period were calculated from subsequent catches of Ages II-III smallmouth bass. Year-class specific CPE was estimated for 1974-1986 from subsequent catches of Ages I-II smallmouth bass. The average of the percentage contribution estimated from the Age I, Age I-II and Ages II-III comparisons was considered the most reliable estimate of year-class strength (Table 3). Both types of comparisons indicate that the 1976, 1987, and 1980 year-classes ranked 1-3 respectively in terms of their contribution to the population. These years represent three of four years of low summer discharge (Table 3). The fourth year, based upon the multiple age-class comparison, was 1977, the second lowest year of spring and summer discharge.

Table 2. Sportfishing effort (angler hours) and catch per hour for eleven more common species in the upper Mississippi River.

Effort and Species	Year 1972	1973	1974	1975	1976	1977	1978	1979	1982
Fishing Effort	2570	2435	3700	4929	5771	11674	8668	19942	18222
Smallmouth bass	0.08	0.08	0.05	0.19	0.08	1.23	0.35	0.47	0.49
Black Crappie	0.01	0.10	0.10	0.28	0.01	0.01	0.25	0.07	0.06
Walleye	0.01	0.03	0.08	0.01	0.01	0.03	0.03	0.04	0.07
Northern Pike	0.01	0.15	0.02	0.01	0.01	0.01	0.01	0.01	0.02
Carp	0.20	0.08	0.09	0.10	0.05	0.08	<.01	0.01	0.01
Black bullhead	0.06	0.05	0.20	0.03	—	—	0.03	0.04	0.07
Rock bass	0.01	—	<.01	<.01	—	—	0.02	0.05	0.01
Silver redhorse	—	—	—	0.01	—	<.01	0.10	0.02	—
Shorthead redhorse	—	—	<.01	<.01	<.01	0.01	0.03	0.02	0.06
White sucker	<.01	<01	<.01	—	—	0.02	<.01	<.01	0.06
Muskellunge	—	—	—	—	—	—	—	<.01	<.01

Table 3. Smallmouth bass spawning (May 15 - June 15) and growth period (June 15 - September 30) mean discharge and temperatures in relation to year-class strength and length attained at the end of the first year of life. Years are ordered on the basis of year-class rank.

Year and Year Class	Discharge (CFS) Spawning	Growth	Temperature (C) Spawning	Growth	Length Age I (mm)	Relative Abundance[a] I	I-III	Year Class Rank
1976	2072	1449	21.1	22.4	146	36.8	51.1	1
1987	7124	3022	20.0	22.8	142	28.8	28.8	2
1980	3265	2845	20.6	21.7	122	16.1	14.8	3
1977	2314	2507	22.2	21.7	115	2.6	5.3	4
1986	15864	10824	18.9	21.1	—	5.8	4.2	5
1982	15482	4459	17.8	21.7	—	2.4	3.7	6
1981	4757	5095	18.9	21.1	—	0.6	3.6	7
1985	13807	9519	17.8	20.0	—	2.3	3.1	8
1984	10139	5641	18.3	21.1	—	1.6	2.8	9
1975	12299	6818	18.9	21.8	105	0.8	2.5	10
1983	4951	6698	17.2	22.8	—	1.2	2.5	11
1974	15021	4150	16.7	22.8	101	0.3	1.6	12
1973	5892	3049	18.3	22.8	95	-	1.6	13
1979	11135	6530	17.2	20.6	83	0.5	0.8	14
1978	6477	7129	20.0	21.8	90	0.2	0.5	15

[a] Relative abundance is percentage of the total (all years) electrofishing CPE in a specific year for yearlings (I) and the average of percentages based upon comparisons for older age classes (I-III). Because the Age I-III comparisons are the average for comparisons of CPE for Age I, Age II, Age I and II and Ages II and III, the values do not add to 100.

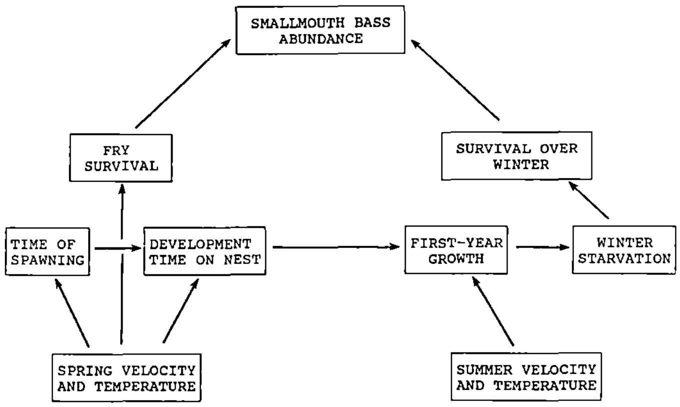

Figure 2. Flow chart indicating the mechanisms through which spring and summer stream velocities and temperatures control year-class success and abundance of smallmouth bass.

The significance of the strong year-classes, which formed during the four years characterized by low discharge is suggested by the percentage contribution estimates. They suggest these year-classes contributed over 85 percent of the fish in the population during the 14 year period.

Size attained by the end of the first summer was greatest during years which formed the strongest year-classes (1976, 1987, 1980, and 1977). Relationships between summer temperature and length at Age I were not as clear (Table 3). Modal lengths were not calculated for year-classes with sample size less than 15 (1981-1983) or for which scale samples were not collected (1984-1986) the following year (Table 3).

Discussion

Development of a model with the capacity to predict fish abundance from physical data on discharge and temperature represents the primary goal of the work reviewed in this paper. Development of such a model should improve our capacity to manage the river more effectively at a time when demands on Minnesota's water resources are increasing. The modeling effort requires a more detailed analysis of the year-class abundance data presented here. Physical stream habitat modeling work in progress is also required to describe the relationship between discharge and the stream area suitable for reproduction, fry survival, and fingerling growth.

The analysis presented here provides support for the concept that strong smallmouth bass year-classes occur in the Mississippi River during years of low spring and summer discharge. The mechanisms involved have been described by other studies that show smallmouth bass nesting success (3,5), fry survival (3,6), and year-class strength (7) are inversely related to spring discharge. Swenson *et al.* (3) also show fingerling feeding and growth decline at higher velocities. However, Paragamian and Wiley (8) found that the optimum for growth is reached at intermediate discharges in a small Iowa stream characterized by much lower discharges. This suggests a need to evaluate relationships between discharge and the distribution of velocities within individual streams or types of stream systems. It also illustrates the need for careful analysis of the response of the system to drought years. Work in progress will assess these questions.

Although this paper focuses upon smallmouth bass, limited information is presented which suggests strong year-classes of other species result during years of low discharge as well. Priegel (9) showed walleye fry drift after hatching and are unable to feed during the drifting period unless they find quiet water. Houde (10) found walleye fry (16 mm) could not maintain position at velocities exceeding 30 mm/sec. Meyer (11) found young redhorse inhabit slow water over muck bottoms.

The long-term data set developed as a result of Northern States Power Company's monitoring responsibility represents an important source of information on the river. The information presented here illustrates its importance in developing management plans for a major Minnesota water resource.

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