AGE, GROWTH AND FOOD HABITS OF FOUR SELECTED CYPRINIDS IN NAVIGATION POOL 8 OF THE UPPER MISSISSIPPI RIVER

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ABSTRACT

The age, rate of growth and food habits of four selected cyprinids were determined for specimens collected from Pool 8 of the Upper Mississippi River during the summer of 1975. The following four species were analyzed: spotfin shiner, Notropis spilopterus (Cope); golden shiner, Notemigonus crysoleucas (Mitchill); emerald shiner, Notropis atherinoides (Rafinesque); and spottail shiner, Notropis hudsonius (Clinton).

All age and growth calculations were made using total length measurements. Age and growth data included mean length at capture, back calculated lengths at time of annulus formation, length-weight regressions, condition factors, K, and young-of-the-year growth rates. The longevity of these four species was shorter in Pool 8 than those reported by most other researchers.

Food habit analyses were based on frequency of occurrence, percent of total number and percent of total volume. Algae followed by Cladocera were the most important food items for all four species of cyprinids. A comparison of seasonal and area variations in food habits determined that they were opportunistic. Their food habits were a reflection of the general availability of food rather than active selection.

ACKNOWLEDGEMENTS

I wish to thank everyone involved in all phases of this study, especially the 1975 River Studies fishery field crew for the collection of specimens. I would like to express my gratitude to Dr. George Becker, Dr. Ronald Rada and John Massey for their taxonomic assistance. I greatly appreciate Donna Sefton's aid with the sampling area descriptions and David and Cathy Wynes' help in determining the format. Special thanks are due to my major professor, Dr. John Held, for his constructive criticisms in editing the manuscript.

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INTRODUCTION

Purpose

The goal of this study was to describe the age, growth and food habits of four selected cyprinid species from Navigation Pool 8 of the Upper Mississippi River. The following species were investigated: spotfin shiner, Notropis spilopterus (Cope); golden shiner, Notemigonus crysoleucas (Mitchill); emerald shiner, Notropis atherinoides (Rafinesque); and spottail shiner, Notropis hudsonius (Clinton). The Family Cyprinidae contains more members than any other freshwater group and is represented in Wisconsin by more individuals and species (45) than any other family of fish (Eddy and Underhill 1974; Johnson and Becker 1970). Many authors have noted the importance of these minnows as forage fish (Dobie et al. 1956; Gale and Gale 1976; Reiger 1963; Eddy and Underhill 1974). Due to their prominent role in food webs, an understanding of cyprinid life history is basic to determing the effects of ecosystem manipulations and habitat alterations on the Pool 8 fishery. Studies of the cyprinid communities in the Upper Mississippi River are sparse. This investigation will fill this void, in part.

Life Histories

Spotfin shiner. Spotfin shiners occur from the eastern part of the Dakotas to New England, except in Lake Superior and its tributaries, and south in the central Mississippi basin to the Tennessee River drainage of Alabama and to central Missouri (Dobie et al. 1956). Becker (1966) found that the spotfin shiner is encountered in moderate-sized streams with numbers of spotfin shiners being positively correlated with stream size. This species can tolerate a wide variety of habitats. They prefer a moderate current, although they are commonly found in large lakes. According to Trautman (1957), the spotfin shiner occurred in the greatest abundance in streams of low gradients with sandy silt bottoms. In relation to its abundance in Wisconsin, Greene (1935) found that its most favorable habitat was on the sandy and silty bottoms of the main tributaries of the Mississippi River in the Driftless area.

Spotfin shiners are intermittent spawners and depending upon geographical location spawn from late May to late August (Stone 1940; Gale and Gale 1976; Pflieger 1960). They spawn on gravel riffles or over sandy shoals. The adhesive eggs are often laid in clusters on logs, on dock pilings or in crevices of submerged tree trunks (Dobie et al. 1956). Gale and Gale (1976) observed 99% of the eggs within crevices.

The spotfin shiner feeds on algae, aquatic insects and microcrustaceans (Eddy and Underhill 1974; White and Wallace

1973; Stone 1940). The spotfin shiner is a hardy bait and forage species for smallmouth bass (Micropterus dolomieui), crappie (Pomoxis sp.), and northern pike, (Esox lucius) (Dobie et al. 1956; Gale and Gale 1976).

Golden shiner. The golden shiner is widely distributed throughout the United States from Canada to Florida and westward to the Dakotas and Texas (Dobie et al. 1956). It is common to abundant in lakes, slow-flowing streams and rivers throughout Wisconsin and is generally associated with aquatic vegetation (Johnson and Becker 1970; Becker 1966; Greene 1935). Golden shiners are rarely found in water with fast current.

The golden shiner has a long spawning season, extending from June into August in Michigan (Cooper 1935), early May to August in Minnesota and New York (Forney 1957), May to July in Illinois (Forbes and Richardson 1908), and March through July in California (McKechnie 1966). In New York and Alabama, spawning usually occurs at water temperatures between 20-21 C (Forney 1968; Prather et al. 1953). The eggs, which are adhesive, are scattered over filamentous algae and less frequently over rooted aquatic plants (Cooper 1936b). No parental care is given the eggs or fry and the adults may become cannabalistic (Altman and Irvin 1950).

The primary foods reported for golden shiners are zooplankton, algae, insect larvae, adult insects and molluscs (Pearse 1916; McKechnie 1966; Reiger 1963; Flemer and Woolcott 1966).

Golden shiners are desirable forage fish for crappie, bass, sunfish, (Lepomis sp.) and northern pike (Reiger 1963; Greene 1935; Cooper 1936b; Rice 1942). Due to its importance as a forage fish, it has emerged as an important bait fish in the United States despite its tendency to scale easily in warm weather and develop infections (Flickinger 1971; Hedges and Ball 1953).

Emerald Shiner. Emerald shiners range from northwestern Canada to Lake Champlain and Hudson Bay, the Great Lake drainages, the larger tributaries of the Mississippi River and southward to Texas and Virginia (Dobie et al. 1956; Eddy and Underhill 1974). In Wisconsin, this species occurs commonly in Lakes Michigan, Superior and Winnebago as well as in large streams and rivers such as the Wisconsin and Mississippi (Becker 1966; Johnson and Becker 1970). Forbes and Richardson (1908) reported that emerald shiners are a pelagic species and form large schools.

Dobie et al. (1956) noted emerald shiners spawning over gravel shoals from mid-May to early June. Emerald shiners were considered to be early spawners in the Des Moines River by Starrett (1951), since females collected during mid-July were spent. Females ready to spawn were taken in Illinois from mid-May to early June (Forbes and Richardson 1908). Spawning occurred from June until August in both Lake Erie and Lewis and Clark Lake, South Dakota (Fish 1932; Fuchs 1967). Spawning commenced when the water reached 24 C in Lake Simcoe, Canada and continued until the end of August (Campbell and MacCrimmon 1970).

Emerald shiners have been reported to feed primarily on aquatic and terrestrial insects, algae, zooplankton and oligochaetes (Forbes 1883, Coker 1929; Fuchs 1967; Campbell and MacCrimmon 1970). This species is also an important forage fish and is used by anglers as bait for yellow perch (*Perca flavescens*), walleyes (*Stizistedion vitreum*) and bass (Eddy and Underhill 1974).

Spottail shiners. The spottail shiner ranges from the Northwest Territories of Canada to North Dakota and Kansas, east to the Hudson River, southeast through Iowa, Illinois and the northern Ohio River drainage, and southward in the coastal region to Georgia (Eddy and Underhill 1974). In Wisconsin, this species is common in very large inland lakes, in Lake Michigan and Lake Superior and in large slow-moving rivers, such as the lower Wisconsin, the Mississippi and the St. Croix (Johnson and Becker 1970; Greene 1935). Becker (1966) reported spottail shiners to be less abundant in the Wisconsin River than in the Mississippi River. He found it commonly in sloughs and abundant in moderate currents. Similarly, Forbes and Richardson (1908) observed spottails in Illinois to be more prevalent in large lakes and rivers than in small rivers and creeks.

According to Griswold (1963), spottail shiners are most often found in areas of moderate to abundant submergent vegetation. Surber (1939) found an abundance of spottail shiners in beds of *Salix* sp. in the Shenandoah River. In Lake Michigan, Basch (1968) observed this species frequenting areas with moderate amounts of emergent vegetation, mainly *Typha* sp. and *Scirpus* sp. He noted fewer spottail shiners in areas where there were dense beds of submergent vegetation, such as *Potamogeton* sp.

Spottail shiners spawn on sandy shoals and creek mouths, where the eggs develop and hatch in less than two weeks (Hubbs and Cooper 1936; Wells and House 1974). After the water reaches 20 C, spawning commences from late May through mid-July in Iowa, Minnesota and Lake Michigan (Griswold 1963; McCann 1959; Smith and Kramer 1964; Basch 1968).

The primary foods of spottail shiners are Cladocera, phytoplankton, aquatic insects and Amphipoda (Smith and Kramer 1964; Griswold 1963; McCann 1959). Wells and House (1974) reported this species to be an important forage fish for walleyes, smallmouth bass, yellow perch, white bass (*Morone chrysops*) and lake trout (*Salvelinus namaycush*).

Study Area

Navigation Pool 8 of the Upper Mississippi River (Lat. 43° 52'N, Long. 91° 17' W) extends from U.S. Army Corps of Engineers Lock and Dam No. 7 at Dresbach, Minnesota (mile point 702.5) to Lock and Dam No. 8 near Genoa, Wisconsin (mile point 679.2). The pool is 38 km long and 4.7 km wide at its widest point. The longitudinal gradient of the Mississippi River in Wisconsin is less than 10.2 cm per 1.61 km (Martin 1974).

The floodplain contains not only the main channel of the

Mississippi River but also numerous sloughs and backwater areas representing great ecological diversity and productivity (Figs. 1 and 2). These areas serve as reproduction and feeding habitats for many species of fish, reptiles, amphibians, waterfowl and mammals. Some of these sloughs are the outlet of tributary streams into which water flows rapidly; others leave the main channel and later rejoin it; and still others are abandoned channels of the Mississippi that contain large amounts of water without perceptible current (Martin 1974).

Cyprinids were collected from June through August of 1975 while gathering data for a simulation model study of Navigation Pool 8 of the Upper Mississippi River conducted by the University of Wisconsin-La Crosse River Studies Center. The intent of the simulation study was to identify significant correlations between certain physical-chemical parameters (depth, current velocity, dissolved oxygen, turbidity, sediment size and sediment composition including organic nitrogen, nitrate-N, nitrite-N and orthophosphate-P) and biological parameters (fish, benthos, periphyton, aquatic macrophytes and bacteria). The fisheries portion of this investigation included species composition, relative abundance, biomass, and habitat preferences of fishes in Navigation Pool 8. If successful, the model, which based on empirical data and is still in developmental stages, will have predictive capabilities for the biological communities operating in the river system. A prediction of natural and man-made effects on the navigation

Figure 1. Aerial photograph, 1974, of the upstream half of Navigation Pool 8 of the Upper Mississippi River, showing inset designations (Appendix I).


Lock &
Dam 7
La Crosse
A
B
C
F
N
miles
0 ½ 1 1½
0 1 2
kilometers

Figure 2. Aerial photograph, 1974, of the downstream half of Navigation Pool 8 of the Upper Mississippi River, showing inset designations (Appendix I).


C
G
H
I
J
D
K
E
N
miles
0 ½ 1 1½
0 1 2
kilometers
Lock & Dam

pool may then be possible.

Forty-one areas in Navigation Pool 8 were designated for sampling in the simulation model study. These areas were chosen and numbered on the basis of increasing current velocity. Two of these areas were not sampled for fish due to inaccessability (Appendix II).

METHODS AND MATERIALS

Collection

Cyprinids were collected from Pool 8 of the Upper Mississippi River during the summer of 1975 by three methods; frame nets, bag seines and A.C. boom-shocking. However, only minnows captured in seines and by shocking were used in this study due to the digestion and decomposition of food items that occurred in fish caught in frame nets. Nylon bag seines (9.2 x 1.8 m with 0.3 cm square mesh netting) were used along all appropriate shorelines. Thirty-five meter shore seine hauls were made in an attempt to standardize seine effort in calculation of catch (number and biomass) per haul. Specimens were also collected during daylight hours by a boom-shocking unit that generated 230 volts A.C. at 180 cps. Fish netted during 30-min shocking runs were held in a tank and later transferred to another boat for processing. The catch was measured as catch per 30 min of boom-shocking. All of the fish caught were placed in 10% aqueous formalin to prevent further digestion of the stomach contents.

Processing

All of the cyprinid specimens were keyed according to Becker and Johnson (1970) and Eddy (1974). When the sample size for an area was large and the variability of fish length was small, random subsamples were taken. The total length (to the nearest mm) and weight (to the nearest 0.01 g) were recorded for each fish. The entire alimentary canal was excised and preserved.

Approximately ten scales were removed from the left side of each fish immediately above the lateral line and caudad to the insertion of the dorsal fin (Fuchs 1967; Smith and Kramer 1964; Parker 1958). The thin, translucent emerald shiner scales were stained with Safranin O to facilitate reading. All scales were placed on a glass slide (25 X 75 x 1 mm) and covered with cellophane tape. The scales were examined using an Eberbach Model 2700 Microprojector. Golden shiner scales were read at a magnification of 42X and all other scales were read at 90X. The two best scales from each slide were read atleast twice. Regenerated scales were discarded. Each reading was taken from the focus to the anterior margin along the center ray. The distance from the focus to the margin was marked on strips of paper and an average length to the nearest mm was taken. Age was determined by counting the number of annuli. An annulus was recognized on the basis of crowding of the circuli and the anastomosis, or crossing over, of circuli in the lateral fields.

Analysis

Body-scale relationships were determined for 5-mm intervals for all species. Total length-scale length regression analysis (Whitney and Carlander 1956) were computed on the University of Wisconsin LACE computer system. This relationship is described by the equation:

$$TL = a + b\ (SL)$$

where TL = total length (mm)

a = y intercept

b = slope of the line

SL = scale length (mm)

Using this information, a nomograph was constructed to determine the length of each fish after each year of growth according to the methods described by Carlander ans Smith (1944) and by Hile (1950).

For the determination of the length-weight relationships, mean weights were calculated at intervals corresponding to the increments already calculated for the mean total length. Logrithmic length-weight regressions were run on the LACE computer system and were calculated from the formula as described by Lagler (1964):

$$W = a(TL)^b$$

where W = weight (g)

a = adopted variable

TL = total length (mm)

b = adopted variable

The condition factor, K, for each 5-mm interval was determined from the equation:

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

where W = weight (g)

L = total length (mm)

In the analysis of food habits, the entire digestive tract posterior to the esophagus was utilized. The alimentary canal was split lengthwise and the contents were flushed with water into a circular counting chamber. The large food items were then examined at 10-30X under a binocular dissecting microscope. The food items contained in the digestive tract were identified and enumerated.

Plankton identification and enumeration were done with a compound microscope using a calibrated Whipple disk and a Sedgewick-Rafter cell. All counts were made using a 20X ocular and 21X objective. Depending on the number of organisms, three strips or ten fields were counted at random and the total number was multiplied by a derived factor which then estimated the total number of organisms per fish. Food organisms were identified to genus when possible (Appendix VIII) with the aid of several keys (Pennak 1953; Hilsenhoff 1975; Needham and Needham 1962; Smith 1950; Weber 1971).

A combination of the numerical method, frequency of occurrence and volumetric methods were used in the analysis of food habits of four cyprinid species (Windell 1966; Hynes 1950). The numerical count was determined by the number of individuals of each food type in each stomach. The percentage of the total number of organisms these composed was then calculated. Frequency of occurrence was the percentage of stomachs in which each food item occurred. Volumes of food items were determined by the water displacement of a known number of organisms in a graduated centrifuge tube. Phytoplankton volumetric values were obtained from the literature (Marcus 1972; Knight 1975; Wright and Soltero 1973) and also calculated according to Findenegg (1969).

RESULTS

Age and Growth

Spotfin shiner. Spotfin shiners were collected from the following 27 of the 39 study areas sampled: 1-3,9,10,12-16,19-23,25,27,28,31,33-38,40 and 41. Three hundred sixty-eight specimens from age groups 0-II were collected, ranging from 29-94 mm and 0.16-10.1 g. The mean total lengths at capture of age groups 0-II were 47.3, 57.4 and 76.3 mm and the mean weights were 1.2, 3.3 and 5.6 g, respectively (Table 1).

The mean length at annulus formation was 30 mm for age group I. In two-year-old spotfin shiners, the first annulus was laid down at 27 mm and the second at 57 mm (Table 1).

The total length-weight relationship of spotfin shiners was calculated from fourteen 5-mm length increments (Table 2). The relationship was expressed by the equation $\text{Log } W = -5.4022 + 3.2568 \text{ Log } TL$ (Fig. 3). The correlation coefficient, r, was 0.9984.

Table 1. Mean total lengths and weights at the time of capture and mean total length at each annulus for age groups 0-II of 368 spotfin shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

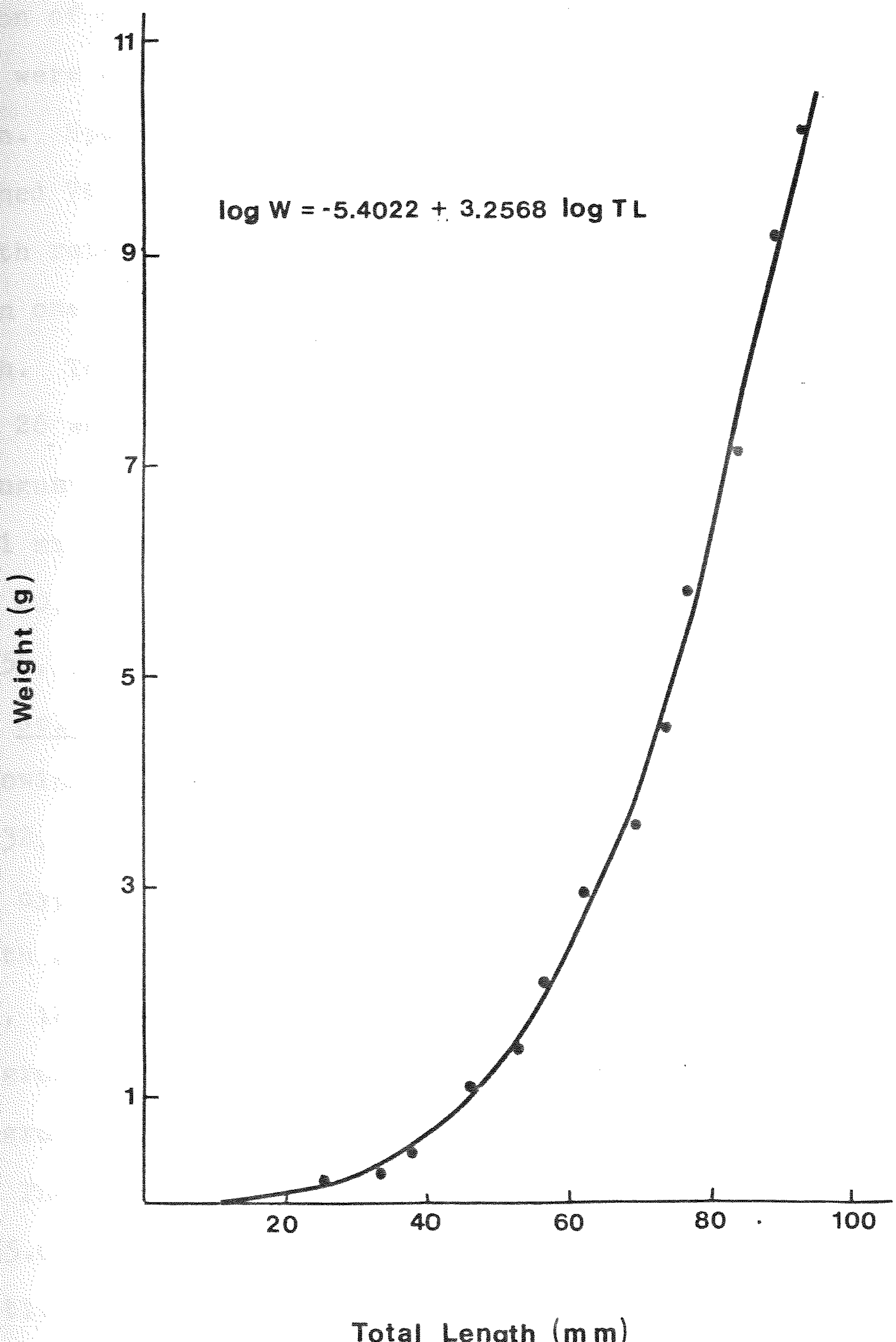
Age group	Number examined	Mean length (mm)	Length range (mm)	Mean weight (g)	Weight range (g)	Length at time of annulus formation (mm) 1	2
0	210	47.3	29-74	1.2	0.2-5.0		
I	142	57.4	45-90	3.3	0.7-8.2	30	
II	16	76.3	68-94	5.6	4.4-10.1	27	57

Table 2. Mean total lengths, mean weights and condition factors, K, for 5-mm increments of 374 spotfin shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

Length increment (mm)	Number examined	Mean length (mm)	Mean weight (g)	Weight range (g)	K
26-30	3	26.3	0.19	0.16-.21	1.04
31-35	20	33.2	0.32	0.18-.44	0.90
36-40	28	38.0	0.52	0.35-.68	0.95
41-45	54	43.4	0.81	0.62-1.13	0.99
46-50	57	47.8	1.18	0.88-2.74	1.08
51-55	58	53.2	1.66	1.14-2.70	1.10
56-60	40	57.8	2.11	1.57-2.59	1.10
61-65	29	62.9	2.89	2.33-4.32	1.16
66-70	27	68.2	3.67	2.47-4.85	1.16
71-75	30	72.9	4.64	2.84-5.82	1.20
76-80	14	77.3	5.84	4.91-7.06	1.26
81-85	10	82.4	7.22	6.12-8.9	1.29
86-90	1	90.0	9.22	9.22	1.26
91-95	3	94.0	10.28	9.23-11.54	1.24

Figure 3. Total length-weight regression of 374 spotfin shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River.

Spotfin Shiner



The condition factor, K, ranged from 0.90 for the 31-35 mm increment to 1.29 for the 81-85 mm increment (Table 2). The mean K value was 1.12.

Because intermittent spawning prevented exact determination of hatching time, maximum lengths of young-of-the-year fish were considered to represent those fish of the first hatch. Spotfin shiners from the first hatch in Pool 8 reached 70 mm by August 26. According to back calculated growth rates, spotfin shiners had the potential to reach 71 mm in one growing season if they were members of the first hatch. The mean total length of spotfins from age 0 to August 26 was 55.27 mm. The mean daily increment from June 20 to August 26 was 0.267 mm and from July 28 to August 26 was 0.211 mm. The mean total lengths for young-of-the-year on June 20, 27, July 7, 28, 31, August 5 and 26 were 37, 40, 47, 49, 50, 52, and 55 mm, respectively.

Golden shiner. Golden shiners were collected from the following 36 of 39 study areas sampled: 1-4, 6, 8-16, 18-29, 31, 32, and 34-41. They had the widest distribution of the four cyprinid species studied in Pool 8. The average total length at time of capture for age groups I-III and V were 87.5, 122.6, 151.0 and 188.0 mm, respectively (Table 3). Age group I contained the largest number of specimens while age groups III-V were poorly represented.

The mean total length at each annulus was calculated to be 55.0, 95.7, 127.5, 139.0 and 167.0 mm for annuli 1-5, respectively (Table 4). Mean annual growth increments of 55.0,

Table 3. Mean total lengths and weights at the time of capture for age groups 0-V of 180 golden shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

Age group	Number examined	Mean length (mm)	Length range (mm)	Mean weight (g)	Weight range (g)
I	151	87.5	52-115	7.60	1.32-18.83
II	25	122.6	102-142	22.00	12.16-39.61
III	3	151.0	145-157	43.90	36.30-47.70
IV	0	----	----	----	----
V	1	188.0	188	83.10	83.10

Table 4. Mean total lengths at each annulus and mean annual increments calculated from scales of 180 golden shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

Age group	Number examined	Length at capture (mm)	Length at time of annulus formation (mm)				
			1	2	3	4	5
I	151	87.5	57				
II	25	122.6	58	100			
III	3	151.0	61	105	135		
IV	0	-----	--	---	---	---	
V	1	188.0	44	82	120	139	167
Mean length at annulus			55.0	95.7	127.5	139.0	167.0
Mean annual increment			55.0	41.3	34.0	19.0	28.0

41.3, 34.0, 19.0 and 28.0 mm (Table 4) for years 1-5 showed a decrease in growth as the fish increased in age (Fig. 4).

The total length-weight relationship of golden shiners, calculated from 21 5-mm increments (Table 5), was expressed by the equation Log W = -5.25916 + 3.15398 Log TL (Fig. 5). The correlation coefficient, r, was 0.9989. K values ranged from 1.01 for the 61-65 mm increment to 1.26 for the 131-135 mm increment (Table 5). The mean K value was 1.12.

According to back calculated growth rates, golden shiners had the potential to reach 69.27 mm in one growing season if they were members of the first hatch. A young-of-the-year specimen collected on August 26 was 75 mm in length.

Emerald shiner. Emerals shiners were collected from the following 24 of 39 study areas sampled: 1, 8, 10, 12, 14-16, 18, 22, 23, 25-29, 31, 37, 40 and 41. The scales of 81 young-of-the-year and 36 age I emerald shiners were analysed for age and growth data (Table 6). The mean total length at capture for young-of-the-year fish was 48.9 mm and 64.4 mm for age I specimens. At the time of capture, young-of-the-year emerald shiners had a mean average weight of 1.0 g while age group I fish averaged 2.6 g.

The mean total length at annulus I formation was calculated to be 47.9 mm. No fish older than age group I were captured during the study.

The total length-weight relationship for 119 emerald shiners was calculated from 10 5-mm increments (Table 7). The relationship was expressed by the equation Log W =

Figure 4. Mean annual growth increments of 180 golden shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River.

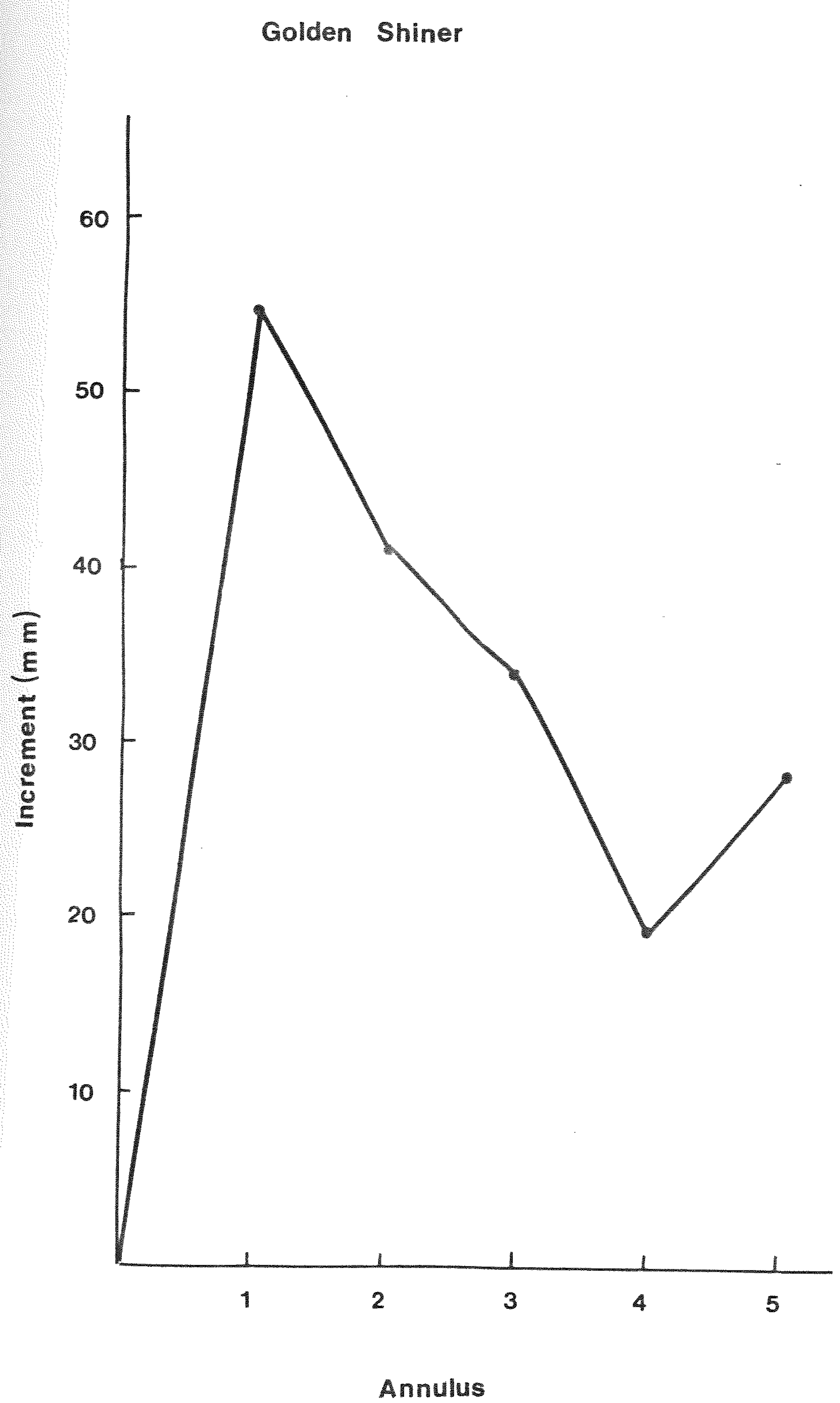

Golden Shiner
Increment (mm)
60
50
40
30
20
10
1
2
3
4
5
Annulus

Figure 5. Total length-weight regression of 186 golden shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River.

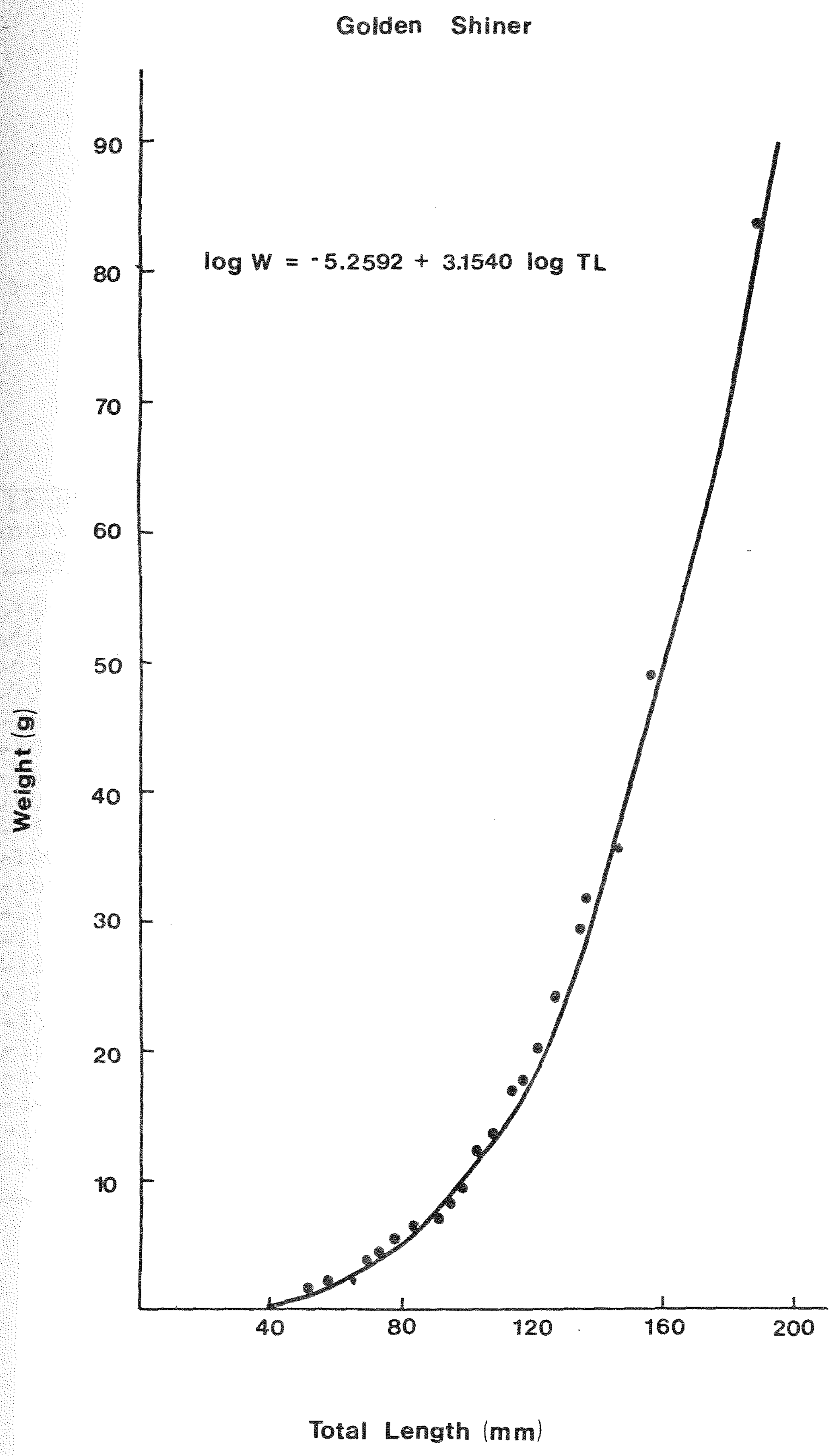

Golden Shiner
log W = -5.2592 + 3.1540 log TL
Weight (g)
90
80
70
60
50
40
30
20
10
40
80
120
160
200
Total Length (mm)

Table 5. Mean total lengths, mean weights and condition factors, K, for 5-mm increments of 186 golden shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

Length increment (mm)	Number examined	Mean length (mm)	Mean weight (g)	K
50-55	6	51.8	1.5	1.06
56-60	3	57.3	1.9	1.03
61-65	4	62.3	2.4	1.01
66-70	6	69.2	3.7	1.12
71-75	11	73.7	4.2	1.05
76-80	12	78.2	5.3	1.10
81-85	23	82.7	6.3	1.11
86-90	29	87.9	7.4	1.09
91-95	33	92.6	8.5	1.07
96-100	15	97.7	9.7	1.03
101-105	11	103.7	12.2	1.09
106-110	9	107.6	14.1	1.14
111-115	4	114.3	17.0	1.14
116-120	4	118.3	17.6	1.06
121-125	4	122.3	20.4	1.12
126-130	3	127.7	24.1	1.16
131-135	1	135.0	30.9	1.26
136-140	4	137.3	31.6	1.22
141-145	2	143.5	35.9	1.22
156-160	1	157.0	47.7	1.23
186-190	1	188.0	83.1	1.25

Table 6. Mean total lengths and weights at the time of capture for age groups 0-I of 117 emerald shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

Age group	Number examined	Mean length (mm)	Length range (mm)	Mean weight (g)	Weight range (g)
0	81	48.9	36-65	1.00	0.38-2.00
I	36	66.4	52-84	2.56	0.69-4.84

Table 7. Mean total lengths, mean weights and condition factors, K, for 5-mm increments of 119 emerald shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

Length increment (mm)	Number examined	Mean Length (mm)	Mean weight (g)	Weight range (g)	K
36-40	7	38.0	0.47	0.38-.53	0.86
41-45	20	43.0	0.63	0.46-.86	0.80
46-50	20	47.5	0.82	0.58-1.10	0.77
51-55	24	52.9	1.16	0.69-1.49	0.78
56-60	17	57.9	1.49	1.29-1.74	0.77
61-65	12	63.1	2.08	1.64-2.51	0.83
66-70	8	67.3	2.61	1.88-3.28	0.71
71-75	2	72.0	2.77	2.66-2.87	0.74
76-80	4	77.5	4.39	4.13-4.87	0.94
81-85	5	83.6	4.72	4.34-5.05	0.81

-5.1115 + 3.0074 Log TL (Fig. 6). The correlation coefficient, r, was 0.9898.

K values ranged from 0.71 for the 66-70 mm increment to 0.94 for the 76-80 mm increment (Table 7). The mean K value was 0.80.

According to back calculated growth rates, emerald shiners had the potential to reach 61.33 mm in the first growing season if they were members of the first hatch. The average daily growth of young-of-the-year from July 28 to August 26 was 0.55 mm. Age group 0 fish collected on August 26 ranged in length from 43-65 mm. The average young-of-the-year length in July was 41 mm and 50 mm in August. On August 8, the mean length for young-of-the-year emerald shiners was 45 mm.

Spottail shiner. Spottail shiners were collected from the following 25 of the 39 study areas sampled: 3, 8-14, 16, 18, 19, 22-24, 27, 31, and 33-41. All of the spottail shiners collected during the summer of 1975 were young-of-the-year with the exception of one specimen from age group I. This individual was 87 mm in total length and weighed 6.57 g. According to back calculation, the annulus for this fish was formed at 77 mm. For the 126 age group 0 spottail shiners, the mean total length was 57.0 mm and ranged from 41-79 mm while the mean weight was 2.12 g, ranging from 0.65-4.15 g.

The total length-weight relationship of 127 spottail shiners was calculated from nine 5-mm increments (Table 8). The relationship was expressed by the equation Log W =

Figure 6. Total length-weight regression of 119 emerald shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River.

Emerald Shiner

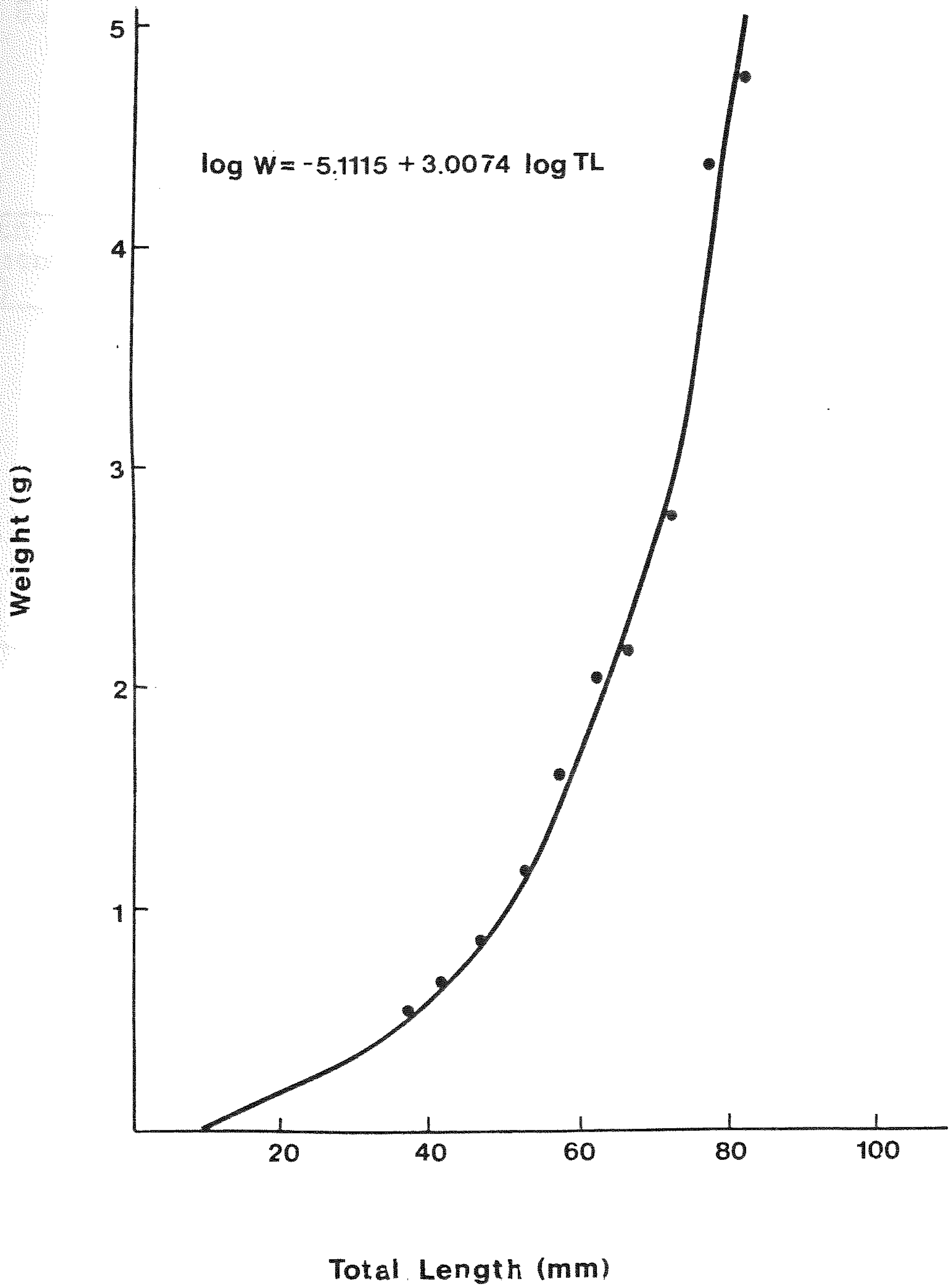
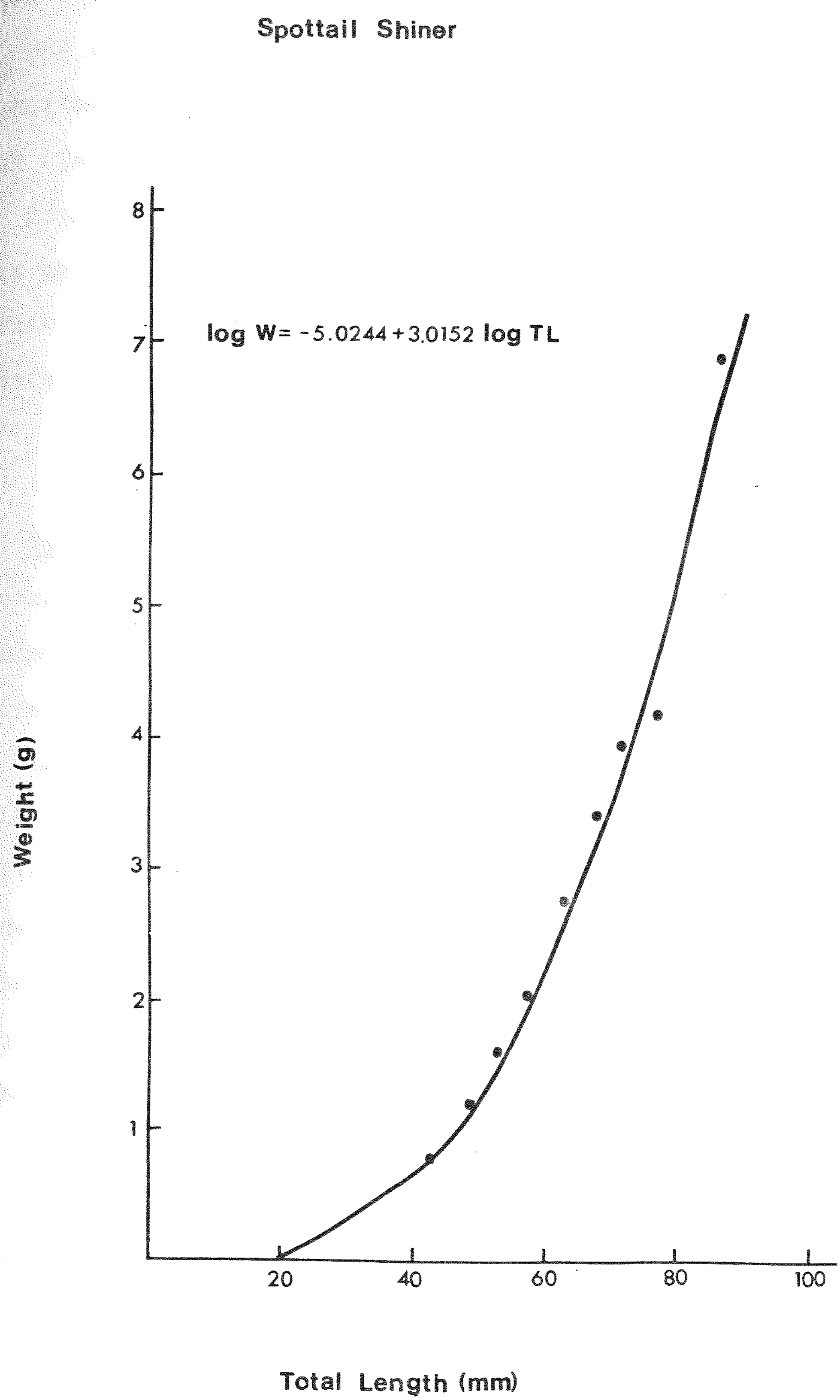


Table 8. Mean total lengths, mean weights and condition factors, K, for 5-mm increments of 127 spottail shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River.

Length increment (mm)	Number examined	Mean length (mm)	Mean weight (g)	Weight range (g)	K
41-45	27	43.7	0.80	0.65-0.92	0.96
46-50	20	50.2	1.18	0.86-1.40	0.94
51-55	12	53.3	1.60	1.38-1.70	1.06
56-60	17	57.7	2.01	1.31-3.30	1.05
61-65	10	63.5	2.73	2.30-3.00	1.07
66-70	24	68.2	3.39	2.96-3.80	1.07
71-75	13	71.8	3.82	3.14-4.15	1.03
76-80	3	77.0	4.13	4.10-4.16	0.90
86-90	1	87.0	6.57	6.57	1.00

Figure 7. Total length-weight regression of 127 spottail shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River.



Spottail Shiner
log W= -5.0244+3.0152 log TL
Weight (g)
8
7
6
5
4
3
2
1
20
40
60
80
100
Total Length (mm)

-5.0244 + 3.0152 Log TL (Fig. 7). The correlation coefficient, r, was 0.9915.

The condition factor, K, ranged from 0.90 for the 76-80 mm increment to 1.07 for both the 61-65 and 66-70 mm increments (Table 8). The mean K value was 1.01.

Young-of-the-year spottail shiners exhibited a potential daily growth of 0.8611 mm and a mean daily increment of 0.7615 mm from July 28 to August 26. The mean length of spottail shiners from age 0 on August 28 was 66.9 mm.

Food Habits

Spotfin shiner. The alimentary canals from 199 spotfin shiners were examined to determine food habits. The fish were divided into three length groups; 0-45 mm, 46-70 mm and 71-95 mm (Table 9). All of the specimens contained food organisms.

Bacillariophyceae were the most important food items of small spotfin shiners, comprising 65% of the total number of food organisms, 63% of the total volume and having a 40% frequency of occurrence (Table 9). Cyanophyta accounted for 15% of the volume and 29% of the number of food items, with a 32% frequency of occurrence. Chlorophyta were found in 20% of the stomachs, but represented less than 1% of the total volume and 5% of the total number of food items. Cladocera accounted for 2% of the total number of food organisms and 21% of the total food item volume. A 90% frequency of occurrence was found for Cladocera. Ostracoda exhibited an 18% frequency of occurrence and unidentifiable insects were present in 17% of the specimens, but neither represented more than 1% of the total number or volume of food organisms. Sand and vascular plant material were found in 23% of the fish in this group.

Algae were also a substantial part of the spotfin's diet for the size group 46-70 mm. Bacillariophyceae accounted for 83% of the food by volume, 21% of the food by number and was represented in 72% of the specimens. Cyanophyta comprised 78% of the total number of food items and 6% of the food volume with a 37% frequency of occurrence. Chlorophyta was represented in 16% of the specimens and made up 2% of the total food volume but less than 1% of the total number of food items. Cladocera had an 88% frequency of occurrence and represented 9% of the total food volume but less than 1% of the total number of food items. Immature Tendipedidae were in 27% of the fish and unidentifiable insects were found in 43% of the stomachs, but neither group was responsible for more than 1% of the total volume or number of food organisms. Sand was present in 7% of the specimens and vascular plant material appeared in 12% of the fish.

Bacillariophyceae comprised the primary food source of the largest spotfin shiners (71-95 mm). Bacillariophyceae accounted for 89% of the total volume of food items and were represented in 54% of the digestive tracts. Cladocera were present in 83% of the fish and comprised 10% of the total food volume. While unidentifiable insects were represented in 44% of the digestive tracts and Tendipedidae larvae were observed in 20% of the fish, neither comprised more than 1%

of the total volume or number of food organisms. Vascular plant matter was found in 20% of the fish but sand was present in only 2% of the specimens (Table 9).

Small spotfin shiners 0-45 mm collected on June 20 from study area 34 fed heavily on Bacillariophyceae (83% total food volume) and secondarily on Cladocera (11% total food volume). Shiners captured on the same date from study area 38 fed primarily on Cladocera (66% total food volume) with Bacillariophyceae (22% total food volume) of secondary importance.

Bacillariophyceae followed by Cladocera were the major food organisms of medium-sized spotfin shiners (46-70 mm) collected on June 12 in study area 28. The reverse was true for shiners captured on the same date in area 22. In medium-sized spotfins collected in area 34 on July 28, Cladocera were the dominant organism followed by diatoms. In area 35 on July 28, the importance of diatoms and Cladocera was reversed. On August 5, diatoms were the most important food item by volume (59%) for the medium-sized shiners from area 28 with Cladocera occupying 22% of the total food volume. For shiners collected from area 19 on August 5, Cladocera accounted for 41% of the total food volume and diatoms represented 36% of the food volume. Cladocera were the primary food item, followed in importance by diatoms, for large spotfin shiners (71-95 mm) collected on June 20 in areas 34 and 35.

All three length groups of spotfin shiners were used to determine seasonal variation in food habits. Small spotfins

Table 9. Relative importance of major food items for three size groups of spotfin shiners collected during the summer of 1975 from Pool of the Upper Mississippi River (*=values less than 0.5%). For the algae, the total number indicates the total number of individual cells (Appendix III).

Size class and number of fish examined	Food item	Fish with food item No.	Fish with food item %	Total number food item No.	Total number food item %	Total volume food item ml	Total volume food item %
0-45 mm (60)	Bacillariophyceae	40	67	1,086,162	65	28.8168	63
	Cyanophyta	19	32	477,941	29	6.7828	15
	Chlorophyta	12	20	81,665	5	0.3098	*
	Cladocera	54	90	27,351	2	9.4314	21
	Ostracoda	11	18	1,189	*	0.1510	*
	Other	17	28	703	*	0.3816	1
Total				1,675,011	101	45.8734	100
46-70 mm (98)	Bacillariophyceae	71	72	5,001,584	21	309.2944	83
	Cyanophyta	36	37	18,311,412	78	22.6955	6
	Chlorophyta	16	16	153,150	*	6.4696	2
	Cladocera	86	88	94,641	*	32.6350	9
	Ostracoda	14	14	3,624	*	0.4602	*
	Tendipedidae	26	27	89	*	0.9392	*
	Trichoptera	18	18	52	*	0.2364	*
	Unident. insect	42	43	122	*	1.2444	*
	Other	14	14	6,176	*	0.4535	*
Total				23,570,847	99	374.3772	100

(cont.)

Table 9 (cont.).

71-95 mm (41)	Bacillariophyceae	22	54	3,177,499	73	195.5537	89
	Cyanophyta	2	5	15,000	*	0.0178	*
	Chlorophyta	3	7	103,517	25	1.5875	*
	Cladocera	34	83	62,668	1	21.6100	10
	Amphipoda	1	2	203	*	0.1827	1
	Tendipedidae	8	20	30	*	0.0316	*
	Unident. insects	18	44	58	*	0.5916	*
	Other	14	14	415	*	0.4746	*
Total				3,359,399	99	220.4950	100

preferred Bacillariophyceae during both June and July, comprising 68% and 82% of the total food volume, respectively. Cladocera were the next important food group accounting for 28% of the total food volume during June and 9% of the total food volume in August.

For medium-sized spotfin shiners collected in June, Cladocera were the most important food organism, making up 64% of the total food volume and having a frequency of occurrence of 97%. Bacillariophyceae were the second most important food item, comprising 32% of the total food volume and present in 63% of the specimens. For medium-sized fish captured in both July and August, diatoms were the dominant food item by volume (50% and 72%, respectively). In July, Cyanophyta were the second most important food item by volume (30%) followed by Cladocera (15%). Cladocera were of secondary importance in August samples, representing 20% of the total food volume and present in 90% of the specimens. Cyanophyta were found in 55% of the shiners but comprised only 5% of the total food volume.

Cladocera were present in 100% of the large spotfin shiners collected in June and represented 90% of the total food volume. Following in importance were the diatoms with a 44% frequency of occurrence and comprising 8% of the total food volume. However, in the July specimens from the same length group, Bacillariophyceae were the most important food item with a 71% frequency of occurrence and making up 82% of the total food volume. Cladocera were of secondary importance in July, representing only 9% of the total food volume.

Golden shiner. Food habit analyses were conducted on 123 golden shiners. The fish were divided into three length ranges; 0-80 mm, 81-95 mm, and 96-188 mm (Table 10). All of the alimentary canals contained food organisms.

Bacillariophyceae were the most important in percent total number (50%), percent total volume (58%) and in frequency of occurrence (94%) for 31 small golden shiners.(Table 10). Chlorophyta comprised 20% of the total food volume, 3% of the total number of food organisms and exhibited a 26% frequency of occurrence. Cyanophyta made up 47% of the total number of food organisms, had a 29% frequency of occurrence and represented 14% of the total food volume. Cladocera exhibited a 71% frequency of occurrence and comprised 9% of the total volume of food. Vascular plant material was present in 22% of the specimens but sand was not observed in any stomachs.

In 53 medium-sized golden shiners (81-95 mm), Bacillariophyceae were the dominant food items, comprising 89% of the total number, 53% of the total volume of food items and having a 91% frequency of occurrence. Chlorophyta accounted for 14% of the food by volume, 5% of the food by number and exhibited a 38% frequency of occurrence. Cyanophyta were found in 55% of the specimens, comprising 5% of the total number of food organisms but accounted for only 7% of the total volume. Cladocera were found in 72% of the stomachs and represented 25% of the total volume of food organisms. Despite the fact that the frequency of occurrence of Copepoda (19%), Corixidae (17%), and Ostracoda (13%) were significant,

Table 10. Relative importance of major food items for three size groups of golden shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River (*-values less than 0.5%). For the algae, the total number indicates the total number of individual cells (Appendix IV).

Size class and number of fish examined	Food item	Fish with food item		Total number food item		Total volume food item	
		No.	%	No.	%	ml	%
0-80 mm (31)	Bacillariophyceae	29	94	17,087,945	50	11.0170	58
	Cyanophyta	9	29	16,055,417	47	2.6186	14
	Chlorophyta	8	26	972,617	3	3.3761	20
	Cladocera	22	71	4,703	*	1.6218	9
	Other	6	10	1,250	*	0.2628	1
Total				34,125,532	100	18.8875	102
81-95 mm (53)	Bacillariophyceae	48	91	236,564,371	89	31.3330	53
	Cyanophyta	29	55	1,432,855	5	3.8730	7
	Chlorophyta	20	38	13,323,940	5	8.1599	14
	Cladocera	38	72	41,962	*	14.4700	25
	Ostracoda	7	13	647	*	0.0882	*
	Copepoda	10	19	2,041	*	0.1021	*
	Corixidae	9	17	29	*	0.6960	*
	Other	8	15	1,055	*	0.7795	*
Total				264,262,624	99	58.8693	99

(cont.)

Table 10 (cont.).

96-188 mm (39)	Bacillariophyceae	34	87	5,605,022	2	12.7139	15
	Cyanophyta	29	74	235,486,489	96	35.1860	42
	Chlorophyta	17	43	4,375,014	2	1.6949	2
	Cladocera	13	33	46,668	*	16.0930	19
	Ostracoda	13	33	109,002	*	13.8430	16
	Mollusca	10	26	10	*	0.4298	1
	Statoblast	10	26	53	*	0.0695	*
	Nematoda	15	38	32	*	1.2864	2
	Other	17	44	3,346	*	1.3703	2
Total				245,625,658	100	84.0073	100

neither their volumes nor their numbers were 1% of the total. Vascular plant material was present in 21% of the specimens but sand was found in only 4% of the fish from this group.

Cyanophyta accounted for 42% of the food by volume of golden shiners in the 96-188 mm range, 96% of the food by number and exhibited a 74% frequency of occurrence. Bacillariophyceae comprised 15% of the food items by volume, 2% of the food organisms by number and had an 87% frequency of occurrence. Chlorophyta were present in 43% of the stomachs but accounted for only 2% of the total number and volume of food organisms. Cladocera and Ostracoda were represented in 33% of the fish and comprised 19% and 16% of the total food volume, respectively. Statoblasts and Mollusca were observed in 26% of the stomachs. Nematoda was found in 38% of the fish but comprised only 2% of the total food volume. Vascular plant matter was found in 18% of the specimens and sand was present in only 3% of the fish.

For large golden shiners captured on August 20 in study areas 25 and 14, Bacillariophyceae were the dominant food items, comprising 80% and 93% of the total food volume, respectively. Ostracoda were the most important non-algal food item in area 25 with an 80% frequency of occurrence and comprising 10% of the total food volume. In study area 14, the dominant animal food items were Cladocera, comprising 3% of the total volume of food and occurring in 22% of the stomachs.

To determine seasonal variation in food habits, golden shiners 0-80 mm in total length captured in June were compared with shiners from the same length group captured in August. Bacillariophyceae were the dominant food item during both June and August. Cladocera were the second most important food organism in both June and August, representing 12% and 39% of the total food volume, respectively.

The food habits of golden shiners 81-95 mm collected in July were compared with those captured in August. Diatoms were found in 90% of the specimens in both July and August samples. Diatoms comprised the largest volume (47%) during July while Cladocera made up the largest food volume (69%) in the August specimens. Cyanophyta were found in 33% of the July samples and comprised 37% of the total food volume. In the August specimens, blue-green algae were present in 72% of the stomachs but made up a smaller percentage (19%) of the food volume than the July samples.

Emerald shiner. The digestive tracts from 104 emerald shiners were examined to determine food habits. These fish were divided into two length ranges, 0-50 mm and 51-92 mm (Table 11). All specimens contained food.

In the 44 fish from the 0-50 mm group, three taxa of algae comprised the dominant food organisms. Bacillariophyceae were found in 82% of the stomachs, comprised 13% of the food items by number and 42% of the volume (Table 11). Members of the Cyanophyta made up 2% of the total food volume, were in 45% of the specimens and comprised 85% of the total number of food items. Of the algae, Chlorophyta were the least important in percent total number (1%), percent total volume (19%) and

Table 11. Relative importance of major food items for two groups of emerald shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River (*=values less than 0.5%). For the algae, the total number indicates the total number of individual cells (Appendix V).

Size class and number of fish examined	Food item	Fish with food item		Total number food item		Total volume food item	
		No.	%	No.	%	ml	%
0-50 mm (44)	Bacillariophyceae	36	82	,762,181	13	15.9561	42
	Cyanophyta	20	45	5,035,591	85	8.2072	22
	Chlorophyta	30	68	86,908	1	0.5287	1
	Cladocera	43	98	35,194	*	12.1300	32
	Ostracoda	17	39	2,646	*	0.3360	1
	Amphipoda	4	9	686	*	0.6174	2
	Other	12	27	451	*	0.0942	*
	Total			5,923,673	99	37.8492	100
51-92 mm (60)	Bacillariophyceae	42	70	1,447,314	2	17.5378	10
	Cyanophyta	39	65	92,460,133	98	152.3704	83
	Chlorophyta	12	20	22,325	*	0.1267	*
	Cladocera	42	70	37,107	*	12.7960	7
	Unident. insects	28	47	84	*	0.8568	*
	Other	12	20	1,942	*	0.8294	*
	Total			92,968,920	100	184.4500	100

in frequency of occurrence (68%). Cladocera were the most significant animal food item (98% frequency of occurrence and 32% of the total food volume). Although Ostracoda were represented in 39% of the stomachs, they accounted for only 1% of the total volume. Similarly, amphipods had a frequency of occurrence of 9% and accounted for only 2% of the total food volume of food organisms. Vascular plant material was in 11% of the specimens and sand was found in 25% of the fish.

Cyanophyta accounted for 83% of the food items by volume, 98% by number and exhibited a 65% frequency of occurrence in large emerald shiners (Table 11). Bacillariophyceae comprised 10% of the food items by volume, 2% of the total number of food organisms and exhibited a 70% frequency of occurrence. Chlorophyta played a less important role in the diet of the larger emerald shiners than in the smaller ones, being found in only 20% of the larger emerald shiners. Cladocera exhibited a 70% frequency of occurrence but comprised only 7% of the total volume. Unidentifiable insects were found in 47% of the stomachs but represented less than 1% of the total volume. Compared with the smaller emerald shiners, fish in the 51-90 mm range ate more organisms and a greater variety. Vascular plant matter had a frequency of occurrence of 22% and sand was represented in 18% of the specimens.

A comparison of large emerald shiners captured on June 12 in study areas 22 and 28 found that Bacillariophyceae (87% and 54% of the total food volume, respectively) followed by Cladocera (11% and 27% of the food volume, respectively) were the important food item for emerald shiners in both areas. Unidentifiable insects were responsible for 14% of the total food volume in shiners from area 28 but were represented by only one organism in area 22. The food habits of large emerald shiners collected on August 28 in the three areas (14, 18 and 41) were compared. Cyanophyta were the dominant food item found in shiners from area 14 and 41 with Cladocera being of secondary importance. Bacillariophyceae were the predominant food organism followed by Cyanophyta in area 18.

To determine seasonal variation in food habits, emerald shiners from the 51-92 mm group captured in June were compared with those from the same length group caught in August. Algae were the dominant food organism during both months with Cladocera being the second most important food items. In the June specimens, Bacillariophyceae were the dominant algae, comprising 61% of the total food volume. Cyanophyta were the dominant algae in the August specimens, comprising 65% of the total food volume. Cladocera were the important animal constituent in their diet during both June and August (34% and 15% of the total food volume, respectively).

Spottail shiner. Seventy-five spottail shiners were examined for ingested material. They were divided into two length ranges for study, 0-60 mm and 61-87 mm (Table 12). All of the fish contained food organisms.

Algae were important food sources for the 43 spottail shiners in the 0-60 mm range. Bacillariophyceae were found in 84% of the stomachs and comprised 73% of the volume. Cyanophyta made up 62% of the food items by number, 13% of

Table 12. Relative importance of major food items for two size groups of spottail shiners collected during the summer of 1975 from Pool 8 of the Upper Mississippi River (*=values less than 0.5%). For the algae, the total number indicates the total number of individual cells (Appendix VI).

Size class and number of fish examined	Food item	Fish with food item		Total number food items		Total volume food item	
		No.	%	No.	%	ml	%
0-60 mm (43)	Bacillariophyceae	36	84	908,537	36	31.5913	73
	Cyanophyta	21	49	1,591,270	62	1.4090	3
	Chlorophyta	7	16	19,410	*	0.0266	*
	Cladocera	35	81	24,244	*	8.3601	19
	Amphipoda	5	12	1,372	*	1.2348	3
	Ostracoda	16	37	972	*	0.1236	*
	Tendipedidae	15	35	17	*	0.0179	*
	Other	12	28	705	*	0.2960	*
	Total			2,546,527	98	43.0593	98
61-87 mm (32)	Bacillariophyceae	27	84	399,214	31	5.0840	23
	Cyanophyta	15	47	870,780	67	8.4592	38
	Chlorophyta	7	22	4,313	*	0.1169	*
	Cladocera	20	63	11,569	*	3.9893	18
	Amphipoda	22	69	3,064	*	2.7576	12
	Ostracoda	22	69	3,197	*	0.4060	2
	Tendipedidae	11	34	27	*	0.0284	*
	Unident. insects	23	72	66	*	0.6732	3
	Mollusca	5	16	11	*	0.3377	2
	Nematoda	2	6	5	*	0.2010	1
	Other	8	25	127	*	0.1175	1
	Total			1,292,373	98	22.1126	100

the volume and were present in 49% of the stomachs. Cladocera were the most important animal food item (81% frequency of occurrence and 19% of the total food volume). Tendepedid larvae were in 35% of the stomachs and Ostracoda were found in 37% of the stomachs, but both taxa comprised less than 1% of the total volume of food items. Vascular plant matter was found in 30% of the stomachs and sand in 37% of the specimens (Table 12).

In the 32 spottail shiners of the 61-87 mm range, algae were also important food items. Bacillariophyceae were in 84% of the fish, made up 31% of the total number of food organisms and were responsible for 23% of the total food volume. Cyanophyta were found in 47% of the stomachs, comprised 67% of the total number and made up 38% of the volume. Chlorophyta were the least significant taxa of algae, comprising less than 1% of the total volume and occurring in 22% of the stomachs. Cladocera (63% frequency of occurrence and 18% of the total volume) and Amphipoda (69% frequency of occurrence and 12% of the total volume) were the most important animal constituents in their diet. Even though unidentifiable insect parts were found in 72% of the stomachs, they represented only 3% of the total volume. These larger spottail shiners had a greater variety of animal food items than the smaller shiners. Sand was found in 50% of the stomachs and vascular plant material in 38% of the specimens (Table 12).

Small spottail shiners captured on July 28 from areas 3, 9 and 34 exhibited a similarity in food habits. Diatoms were the dominant food organism of fish from those areas. Cladocera and Ostracoda were of secondary importance in those areas, with Cladocera being the dominant zooplankter in area 3 and 9 while Ostracoda were the best represented zooplankter from the specimens of area 34.

Amphipoda were the most important food items in large spottail shiners captured on August 26 in area 33, making up 35% of the total food volume and occurring in all of the stomachs. Cladocera and Bacillariophyceae both accounted for 22% of the total food volume in area 33. For large spottail shiners collected in area 18 on August 26, diatoms were the dominant food organism, comprising 68% of the total food volume. Cladocera and unidentifiable insect parts were of secondary importance, accounting for 15% and 10% of the total food, respectively.

To determine seasonal variations in food habits, spottail shiners from the 0-60 mm group captured in July were compared with those from the same length group caught in August. Ninety-one percent of the specimens collected in July were captured on July 28-31, thus weighting the samples. In both months, Cyanophyta were the most abundant food items followed by Cladocera and Amphipoda.

DISCUSSION

Age and Growth

Spotfin shiner. Pflieger (1960) noted that annuli other than the first were usually well defined and easily recognized. The first annulus was usually very close to the focus and not as apparent as successive annuli. Cutting over was not obvious at the location of the first annulus, and frequently the only indacation of its location was a clear, narrow streak encircling the focus. This condition was also exhibited in the spotfin shiner scales from Pool 8.

Pflieger (1960) found represenatives of age groups 0-III but the specimens from age group III represented less than 1% of the total sample. Stone (1940) reported spottails in age groups 0-IV with age groups III and IV making up only 10% of the sample. In the present study, age groups 0-II were represented. The lack of older specimens from the present study could be due to sampling bias, higher mortality for older fish, predation or competition. Pflieger noted young and half-grown specimens in shallower more sluggish water. The deeper area that is probably inhabited by the older spotfin shiners in Pool 8 was not easily accesible for seining. This is a possible reason why older spotfins were not captured in the present study.

In both the present investigation and one done in Ohio

(Pflieger 1960), the largest collected specimens were 94 mm and were from age group II. In a New York study (Stone 1940), the largest spotfin captured was 106 mm.

No data were available for the comparison of length-weight relationships, condition factors or the mean length at annulus formation.

Stone (1940), in a New York study, noted the mean total lengths of age groups 0-II were 48.6, 68.8 and 74.8 mm, respectively. The mean total lengths of age groups 0-II in the Pool 8 study were 47.3, 57.4 and 76.3 mm, respectively. The mean lengths for age groups 0 and II were in close agreement, but the mean length for age group I was smaller in the present study. This could have indicated either a strong year class in the New York investigation or poor year class strength in Pool 8.

A mean total length for young-of-the-year fish on September 28 of 46 mm was reported by Stone (1940). In Pool 8, the mean total length for age group 0 on August 26 was 55 mm. Stone's data were based on a hatchery pond and slow growth could have been caused by competition or some other limiting factor. The high growth in Pool 8 could have been indicative of better environmental conditions.

<u>Golden shiner</u>. Average calculated length at each annulus for golden shiners in Pool 8 (Table 13) were smaller than those reported for Flora Lake, Wisconsin (Parker 1958). For the first two age groups, Michigan golden shiners (Cooper 1936a) exhibited faster growth than the Pool 8 shiners (Table 13). This slower growth rate for the early years of Pool 8

Table 13. Calculated mean total lengths at each annulus of golden shiners from various locations.

Location and author	Mean total length (mm) at each annulus						
	1	2	3	4	5	6	7
Pool 8, Mississippi River (present study)	55.0	95.7	127.5	139.0	167.0		
Flora Lake, Wisconsin (Parker 1958)	89.6	126.9	158.5				
Huron River, Michigan (Cooper 1936a)	89.5	115.4	128.4	145.7	159.4		
Various Michigan locations (Cooper 1936a)	81.0	106.0	116.0	127.0	153.0	189.0	168.0
East Lake, Iowa (Lewis 1950)	45.2	110.4	169.4	188.3	194.5		

shiners may be attributed to intense competition during early life history stages, overcrowding, predation or other denisity dependent or independent variables. Differences in mean water temperatures between various study areas may also result in growth rate discrepancies. Starting with the third year, the Pool 8 golden shiners showed faster or equivalent growth rates than the Michigan shiners. Golden shiners from East Lake, Iowa (Lewis 1950) exhibited faster growth in all years than the specimens from Pool 8 except for the first year (Table 13). Poor success in the early hatches of golden shiners from East Lake could have caused a depression in the growth rate. Only 6 specimens from East Lake were examined from this age group and could have caused these results. In all of the above studies (Table 13), age group I was dominant, indicating that most of the populations were immature and natural mortality was taking a large amount of the older age groups.

The fact that the older captured fish showed slower growth rates in their early life than fish that were captured at a young age may be explained by Lee's phenonemon (Table 13). This was probably caused by selective natural mortality favoring greater survival of the smaller fish of a given age. The older fish captured were actually the slowest growing fish of that year class.

The 3.15398 Log TL value obtained from the length-weight relationship equation indicated that Pool 8 golden shiners were growing nearly isometrically. The mean condition factor of 1.12 also indicated that the population was following the cube law.

In New York ponds, Forney (1957) found that the maximum length at the end of the first growing season was 74 mm, while Reiger (1963) reported 58 mm for the same time interval. The maximum total length attained by young-of-the-year in Pool 8 was 75 mm.

Emerald shiner. The absence of fish older than age group I from the specimens collected during the summer of 1975 in Pool 8 was probably due to selective predation, mortality or the movement of older fish into deeper water and out of the seining areas. Emerald shiners from age group II and III were probably present in Pool 8 but represented a small percentage of the population. Both Fuchs (1967) and Campbell and MacCrimmon (1970) found age groups 0-III in Lewis and Clark Lake, South Dakota and Lake Simcoe, Ontario, respectively. However, no age III emerald shiners were collected in July or August in the Lake Simcoe study.

Fuchs and Campbell and MacCrimmon determined, by back calculation, that the average length at annulus formation for age group I was 66 and 57 mm, respectively. The present study found that the first annulus was laid down at 48 mm. The spawning season in Pool 8 extended from June through August and caused a wide variation in fish length at annulus formation. Fish hatched early in the season were larger at annulus formation than those that hatched later. A smaller value for the mean total length at annulus formation could have indicated that the hatching success from the early spawns was low in Pool 8. However, emerald shiners from Pool 8 showed greater growth than those in an Illinois study (Dobie et al. 1956) where the first annulus was formed at 44 mm.

Fuchs (1967) reported a length-weight relationship of Log W = -3.9417 + 2.9218 Log TL. Campbell and MacCrimmon (1970) found a length-weight relationship described by the equation Log W = -7.2371 + 4.1418 Log TL. Swingle (1965) reported a length-weight relationship represented by the equation Log W = -4.71 + 2.73 Log TL. The present study's length-weight relationship (Log W = -5.1115 + 3.0074 Log TL) was in agreement with other researchers' equation for emerald shiners.

Swingle (1965) reported K values ranging from 0.61-0.69. The present study had an average K value of 0.80. Values less than 1.0 for emerald shiners might have been the result of their slender, elliptical body form and not their physical condition.

In Lewis and Clark Lake, the monthly average length of young-of-the-year was 29 mm for July and 30 mm for August (Fuchs 1967). The average length of age group 0 from Pool 8 in July was 41 mm and 50 mm in August. Fuchs explained that his data did not accurately represent seasonal growth of young-of-the-year due to the emerald shiner's extended spawning season and the high mortality of age group 0 fish. The mean length of age group 0 was 18 mm on August 15 in Lake Simcoe (Campbell and MacCrimmon 1970). In the Pool 8 study on August 8, the average lenght for young-of-the-year emerals shiners was 45mm. This difference was probably also due to their intermittent spawning and the resulting collection of different spawns of varying sizes at any one sampling date.

Spottail shiner. Annulus formation was at 77 mm for the one spottail shiner from age group I collected in Pool 8. The first annulus was laid down at 60 mm in fish taken from Lake Michigan (Wells and House 1974). Smith and Kramer (1964) reported that the first annulus was formed at lengths ranging from 50.2-63.3 mm, depending on the year, in Red Lake, Minnesota. In Clear Lake, Iowa, McCann (1959) found that the first annulus was laid down at lengths ranging from 72.5-81.4 mm, depending on the year. This large variation in the length at annulus formation within a specific body of water during different years could cause speculation on the validity of comparing the results from different bodies of water in different years. The datum from one Pool 8 specimen was insufficient to speculate on the comparative growth of spottail shiners in the Upper Mississippi River.

The length-weight relationship for spottail shiners from northern Lake Michigan was described by the equation Log W = -4.7134 + 2.8535 Log TL and they had a K value of 0.97 (Basch 1968). The present Pool 8 study found a slightly higher K value (1.01) and a similar length-weight relationship (Log W = -5.0244 + 3.0152 Log TL).

The oldest spottail shiners in Nemeiben and Crooked Lakes, Saskatchewan were of age group III, according to Peer

(1966). McCann (1959) and Griswold (1963) found age groups 0-III present in Clear Lake, Iowa, but only 1% were three years old. The oldest fish Smith and Kramer (1964) and Basch (1968) found were four years old. Wells and House (1974) reported spottails from age group V in southeastern Lake Michigan but the oldest fish in western Lake Erie and the Kalamazoo River were age group IV. In the present Pool 8 study, only one specimen (less than 1% of the sample) represented age group I. The other 126 spottail shiners were all young-of-the-year. Age group 0 spottail shiners made up 90% in 1961 and 80% in 1956 of all spottails collected in Clear Lake, Iowa (Griswold 1963). Wells and (1974) noted spottail shiners in deeper water had a greater average length and age while small specimens tended to inhabit shallower water. Their seine catches contained a much higher proportion of young-of-the-year shiners (96%) than did trawl catches. In the present study, more than 99% of the sample was composed of age group 0 shiners. Peer (1966) observed mature spottails leaving the sandy shallow shoals immediately after spawning and, during the remainder of the summer, could only be taken by gill nets in 4-7 m of water. Wells and House (1974) and Smith and Kramer (1964) used both seines and trawls as capture devices. Basch (1968) utilized seines, small mesh gill nets and minnow traps to collect specimens. If additional capture devices had been used in the deeper water of the Pool 8 study, the probability of collecting older spottail shiners might have increased. Wells and House noted that spottail shiners do not live as long in the Kalamazoo River as they do in Lake Michigan. This high mortality for older age groups may also be present in Pool 8 of the Upper Mississippi River. High mortality of older spottails caused by spawning stress or predation coupled with sampling selectivity were probable reasons why older shiners were not caught in the Pool 8 study.

The mean length of young-of-the-year spottail shiners in Clear Lake, Iowa on August 27, 1956, 1957, and 1958 were 66.0, 65.4 and 59.4 mm, respectively (McCann 1959). By August 27, 1975, the growth of young-of-the-year spottails in Pool 8 was just slightly larger (66.9 mm) than those reported for Clear Lake. This could be attributed to better growing conditions or a more successful spawn in Pool 8. Lux (1960) reported the mean total length of age group 0 spottails in Lake Linwood, Minnesota on July 9, 27 and August 28 to be 28, 38 and 54 mm, respectively. The mean total lengths for young-of-the-year in Pool 8 at corresponding dates were 43, 45, and 67 mm, respectively. The difference in reported growth could have been due to intermittent spawning, variation in food quality and abundance or competition.

Food Habits

The present Pool 8 study and those done by Phillips (1969) and Griffith and Voorhess (1960) found algae to be the primary food source of selected cyprinids. Other researchers have not found this to be the case even though they included data indicating that plant matter was sometimes the only food item found in the stomachs of individual fish (Stone 1940; Campbell and McCrimmon 1970; McCann 1959; Pfleiger 1960). It is generally believed that the protein requirement for young fish is high and their primary sustenance is zooplankton. This should not exclude the utilization of phytoplankton since they are proteinaceous (Davis 1955). Birge and Juday (1932) calculated the crude protein content on the basis of percentage dry weight of certain fresh water algae between 22.87-52.19%. This evidence suggests that algae may be more important than previously supposed.

Breeder and Crawford (1922) alluded to the indigestibility of silicious phytoplankters. Many recent investigators have reported that Bacillariophyceae are easily digested while most Cyanophyta and Chlorophyta pass undigested through the intestine (Hutchinson 1973; Fish 1951; Lachner 1950; Hartley 1948). One of the main differences noted by Fish between diatoms and other algae was in the nature of the cell wall. The protoplasm of the diatom was not protected by its siliceous skeleton when in contact with digestive enzymes, whereas the matrix and cellulose surrounding the cells of Cyanophyta and Chlorophyta were apparently impervious to these enzymes. Fish noted that digestive enzymes were able to pass through raphes and punctae in diatom frustrules.

To determine algal viability after passage through a digestive system, Porter (1973) cultured the gut contents of Daphnia galeata. Colonies of gelatinous Chlorophyta and filamentous Cyanophyta, but not Bacillariophyceae, reproduced after gut passage, indicating that green and blue-green algae were poorly incorporated into aquatic food chains. This phenomenon of diatoms being easily digested and green and blue-green algae being difficult to digest was probably also found in the Cyprinidae digestive systems in Pool 8.

In England, Frost (1943) reported that algae were responsible for a larger percentage (35%) of cyprinid nutrition in River Brathay than in Lake Windermere (25%). Forbes (1888) found the cyprinids to be more dependent upon plant material than any other family of fish in the Mississippi River Valley. With the exception of Forbes and Frost, all of the food habit studies mentioned in this paper dealt with fish populations in lakes or small streams. Investigations on the biology of cyprinids is seemingly lacking for large river systems such as the Mississippi River. There are inherent physical, chemical and biological variations between lentic and lotic environments. This could explain differences between the present study and others.

Studies reporting algae as a major source for cyprinids (Griffith and Voorhees 1960; Phillips 1969; Kidd 1927; Coyle 1930) used a higher magnification when looking at stomach contents than most other authors that did not find algae to be an important food source. The significance of algae was probably underestimated in the latter studies simply due to lack of magnification. In the present investigation, some samples appeared to be devoid of food material when observed under a dissecting microscope, but when viewed at 420X algae were sighted. The presence of algae in Pool 8 cyprinids was not totally due to respiration or incidental to feeding activities because it was often the only food item present in the digestive tract and because of its high frequency of occurrence.

Cyprinids use pharyngeal teeth to grind their food before swallowing it. A tangled, broken mass of insect parts, fragments of mollusk shells and other food remnants mixed with sand and mucus was often found in their digestive tracts making enumeration and identification difficult. This problem was also noted by severl other investigators (Hartley 1948; Basch 1968; Everett 1965; Kraatz 1928). Identification of stomach contents would have been facilitated if plankton and benthos sampling had been done simultaneously with fish sampling. Another problem caused by the lack of plankton and benthos samples was that food utilization could not be compared with food availability.

No Protozoa and only trace amounts of rotifers were observed in the present Pool 8 study. Rotifers and Protozoa are digested faster than algae and therefore may be more important than indicated (Seaburg and Moyle 1964; Kidd 1927; Fuchs 1967). Statoblasts, the overwintering stage of Bryozoans, were found in all four species of cyprinids in the present Pool 8 investigation. The soft body of the Bryozoa was quickly digested and its volume and importance as a food item was probably also underestimated.

Spotfin shiner. Most researchers found that aquatic insects, especially Diptera and Trichoptera, were the major source of food for spotfin shiners and terrestrial insects were of secondary importance (White and Wallace 1973; Starrett 1950; Pfleiger 1960; Mendelson 1975). These findings do not agree with Griffith and Voorhees (1960) or with the current study where algae were found to be the primary food group.

Stone (1940) frequently found portions of vascular plants in the digestive tract of spotfin shiners but they constituted only a small part of their diet. He reported only traces of algae in large spotfins, but a few specimens in the 20-39 mm length range contained unicellular and filamentous algae in considerable amounts. Similarly, Pfleiger (1960) observed plant material consisting of filamentous Chlorophyta, Bacillariophyceae, Cyanophyta and miscellaneous structures of higher plants in many spotfin stomachs, but this plant matter seldom made up more than a small portion of the total stomach contents. He frequently observed Cyanophyta (Oscillatoria sp.) in specimens he collected in August. Starrett (1950) reported that 24% of the total food volume of his summer spotfin samples were plant material, especially Microcystis aeruginosa. In Pool 8, algae followed by Cladocera were the important summer food items of spotfin shiners. Griffith and Voorhees (1960) established that algae were the primary food source of spotfins and that they were not selective feeders but ingested most of the available forms of phytoplankton. This seemed to also be the case with the Pool 8 spotfin shiners.

Stone (1940) and Pfleiger (1960) observed that spotfin shiners did a considerable amount of feeding at or near the surface of the water. In the current study, less than 7% of the spotfins 46-95 mm long contained sand, indicating infrequent contact with the benthic interface. However, sand was found in 23% of the specimens in the 0-45 mm length range.

Since no complimentary plankton data was obtained, it was difficult to ascertain the relative rate of food item utilization compared to abundance, but speculations were made. In small spotfin shiners collected on June 20 from study area 34, diatoms were the primary food source, followed in importance by Cladocera. The reverse was true for shiners collected in area 38 on the same date. This was probably a function of relative food abundance and not active selection.

Diatoms were the primary food item and Cladocera were of secondary importance to medium-sized spotfins captured on June 12, July 28 and August 5 in study areas 28 and 35. This relationship was probably caused by the predominance of diatoms in these areas and not due to selection by the shiners. Cladocera were probably more abundant or easily attainable in areas 19, 22 and 34 where Cladocera were the dominant food items. Cladocera followed by Bacillariophyceae were the dominant food organisms for large spotfin shiners captured on June 20 in study areas 34 and 35, probably indicating that these food organisms were dominant there. Pfleiger (1960) reported that strong preferences for particular food organisms were not apparent in spotfin shiners. Instead, a variety of food items were used as food, suggesting that habitat and food abundance chiefly determined food habits.

The seasonal fluctuations in food habits, when present, were prpbably due in part to actual variation in numbers of the various food items in the habitat and partly to varying relative availability. A larger variation probably would have been observed between the winter and summer food habits than in just the summer months of June, July and August. Small spotfin shiners were likely consuming the most abundant organisms, Bacillariophyceae and Cladocera, during June and July rather than actively selecting these food organisms. Perhaps, Cladocera were more important food items for medium spotfin shiners in June than the other months because the Cladocera were at a population peak during June. Cyanophyta were probably more abundant in Pool 8 during August than the other two months but were represented by a larger percentage of the total food volume in July (30%) than in August (5%). However, Cyanophyta had a greater frequency of occurrence in August (55%) than in July (46%). Cladocera were the most important food item in June while Bacillariophyceae were the dominant food organism in July for large spotfin shiners. This was probably an indication of food item abundance and not selectivity.

Golden shiner. Food habit studies on golden shiners have indicated they have a wide ranging diet. Evans (1974) and McKechnie (1966) observed young shiners feeding principally on microcrustaceans and algae while larger fish fed mainly upon insects, crustaceans, mollusks, algae and other vegetable matter. Keast and Webb (1966) noted no significant difference in the basic diet of adults and young. In the present study, algae were the dominant food item for all sizes. However, the larger golden shiners utilized non-crustacean animal taxa more than the smaller shiners.

Numerous investigators have concluded that the food habits of golden shiners vary with food availibility (Forbes and Richardson 1908; Ewers and Boesel 1935; Flemer and Woolcott 1966). In studies done by Keast and Webb (1966) and Keast (1966), they found that algae became an extremely important food group in the late summer. Algae were responsible for 32% of the total food volume in shiners 45-60 mm long and 80% of the volume in fish 95-125 mm long in July. Several other investigators reported algae being 50% of the total food volume (Forbes 1883; Sibley 1932; Rice 1942). The present study found algae to be the dominant food with Cladocera and aquatic insects of secondary importance.

Several authors (Evans 1974; Keast and Webb 1966; Keast 1966) reported that golden shiners are almost entirely middle water and surface feeders. Their dorso-terminal mouth is an adaptation for this kind of feeding. In accordance with these findings, only 3 of the 123 golden shiners examined from Pool 8 contained sand.

The golden shiner is equipped with ailimentary structures that adapt it to a wide range of plant and animal food sources. The gill rakers are long, fine and numerous and strain plankton from the water (Trautman 1957). The pharyngeal teeth are provided with both terminal hooks and grinding surfaces. The intestine is 1.0-1.8 times the length of the head and the body (Forbes and Richardson 1908). The diet of golden shiners is dependent upon what is the most abundant organism at that time. In specimens observed by Forbes (1883) and in the present Pool 8 study, the diet of individual fish was occasionally composed of one food item. Where molluscs were abundant, they often fed on nothing else or when cladocerans or algae were dominant in the food habitat, these food organisms were often the golden shiners' only food. Phytoplankton represented the only food item found in 11% of the golden shiner stomachs collected from Pool 8 of the Upper Mississippi River.

Without auxillary plankton data from each of the study areas, it was difficult to ascertain whether the golden shiners collected from different locations on the same date were actively selecting the food items in their diet or just utilizing the most abundant food organisms. For large golden shiners collected in study areas 25 and 14 on August 20, diatoms were the dominant food item in both areas. Ostracods were the most important zooplankter in area 25 while Cladocera were the dominant food animal organism in area 14. This was probably an indication that ostracods were dominant in area 25 while cladocerans were abundant in area 14 on August 20 and not that the shiners were selecting different food items in seperate areas on the same date.

Since members of the class Bacillariophyceae were the dominant food item in both June and August, perhaps the small golden shiners were actively selecting for diatoms in August when Cyanophyta were probably more prevalent. During both months, Cladocera were the second most important taxon, comprising 12% of the total food volume in June and 3% in August.

Emerald shiner. Morphological as well as behavioral adaptations play roles in determining diet. Emerald shiners have gill rakers that are short, triangular and about one-fourth the length of the filament (Forbes 1883). These aid in the removal of plankton from the water. The masticatory surface of their pharyngeal teeth is a very narrow groove. Their intestine is less than the length of the head and body (Forbes and Richardson 1908). Emerald shiners feed and move in large schools in midwater or near the surface. According to this spatial distribution, Mendelson (1975) observed that emerald shiners' diet usually consisted of drift organisms or food items that were in the water column rather than benthic forms. This trend was also followed by the emerald shiners in Pool 8 since phytoplankton and zooplankton were their dominant diet.

Fuchs (1967) noted that food habit changes were associated with a change in size. The number of organisms eaten by emerald shiners was positively correlated with size. This generalization was also followed in the present Pool 8 study.

Mendelson (1975) observed emerald shiners preying on three principal taxa of organisms: Tendipedidae larvae, Copepoda and terrestrial insects. Campbell and MacCrimmon (1970) found the dominant food of the emerald shiner to be zooplankton with insects being of secondary importance. According to Fuchs (1967), Cyanophyta were the major food items of this species until they reached 41 mm when Cladocera became the dominant food organism, followed by insects. Bacillariophyceae were the most important summer food of emerald shiners up to 50 mm in Pool 8 of the Upper Mississippi River. Specimens longer than 50 mm utilized Cyanophyta and Cladocera as their primary food sources. Cladocera were probably nutritionally the more important of the two food items since they are more easily digested. The smaller sized group of emerals shiners consumed more Cladocera than the larger group, while the larger group depended more on aquatic insects as a food source. This difference might be explained by a combination of food item selectivity and availability due to algal succession.

It was difficult to determine the amount of food organism utilization by emerald shiners collected from different locations in Pool 8 since no concurrent benthos or plankton data was obtained. Diatoms and Cladocera were the major food items of large emerald shiners collected on June 12 in study areas 22 and 28. This might be because they were the dominant or most easily attainable organism in those locations. Similarly, unidentifiable insects were important to the shiners in area 28 but not to shiners from area 22 probably because insects were more prevalent in area 28 than in area 22 and not due to selection.

Even though Cyanophyta were the most numerous food item in large emerald shiners collected on August 26 in areas 14 and 41, it was probably not the most nutritionally important food organism. Cladocera were the next most dominant organism and were, perhaps, more important nutritionally. Large emerald shiners collected on the same date from area 18 relied on diatoms for their nutrition. The difference in food habits of shiners collected in different study areas was probably due to food item abundance and not selection.

Members of the class Bacillariophyceae were the dominant food organism in the large emerald shiners collected in June. Cyanophyta accounted for the greatest frequency of occurrence (81%) and total volume of food (65%) in the August specimens. Even though Cyanophyta were present in a larger percentage of the stomachs and comprised a grater volume, Cladocera (15% of the total food volume) were probably the most nutritionally important food item, since blue-green algae are not easily digested. These large emerald shiners were likely being opportunistic and foraging on food that was the most abundant rather than actively selecting food items. Similarly, Campbell and MacCrimmon (1970) reported that strong preferences for a particular food organism were not apparent for emerald shiners. Instead, a variety of food items were utilized, suggesting that habitat and abundance chiefly determined food habits.

Spottail shiner. Morphological and behavioral adaptations of the predator as well as abundance, size, ease of capture and palatability of the prey were responsible for spottail shiners' food habits. The intestine of the spottail shiner is 0.9-1.4 times the length of the head and body. Their pharyngeal teeth are hocked and compressed with a grinding surface composed of a narrow groove (Forbes and Richardson

1908). This morphology allows them to be omnivores, utilizing the most abundant food. Like emerald shiners, spottail shiners also dwell in midwater or near the surface. However, Mendelson (1975) found that spottail shiners utilized the benthic populations more and had a larger variety of prey than the emerald shiners despite their spatial proximity. Similar results were noted in the current Pool 8 study.

Some investigators noted no correlation between the type of food taken and the size of the spottail shiner (Boesel 1938; McCann 1959; Basch 1968). Smith and Kramer (1964) reported a definite change in food selection with increase in size which became evident at 70 mm. In the Pool 8 study, algae were the dominant food organism for all spottail shiners but fish larger than 60 mm consumed a greater amount and variety of animal food items than the smaller fish.

McCann (1959) and Griswold (1963) both investigated the spottail shiner population in Clear Lake, Iowa, but during different years. They noted spottails feeding on different organisms in different environments due to food item abundance. Basch (1968) found a shift in food item importance caused by seasonal variation. The seasonal succession of algae might explain why Cyanophyta were more dominant in the larger fish caught in late summer than in younger fish captured in early summer on the Pool 8 study. Griffith and Voorhees (1960) established that algae were the primary food source of spottail shiners. In addition, they noted that this species was not very selective but ingested most of the available forms of phytoplankton.

In Lower Red Lake, Minnesota, Smith and Kramer (1964) found that spottail shiner food habits were related to food availability in both plankton and bottom fauna. They determined that Cladocera were preferred to Copepoda and Ostracoda and larger fish selectively took larger Cladocera. Similarly, Cladocera were far more important food items than either Copepoda or Ostracoda in the Pool 8 study.

Several authors have reported finding sand grains in the digestive tract of spottail shiners (Smith and Kramer 1964; McCann 1959; Basch 1968). The results obtained from the present study corroborates these findings, indicating that benthic foraging was occurring.

The lack of knowledge about food organism availability made it difficult to relate their degree of utilization of various food organisms by spottail shiners collected in different localities. For small spottails captured in areas 3, 9 and 34, diatoms constituted the principal food. Cladocera were the secondary food in areas 3 and 9 while ostracods were of secondary importance in area 34. This was probably an indacation that Cladocera were more prevalent in areas 3 and 9 and ostracods were the dominant zooplankter in area 34. It appeared that large spottail shiners were also feeding on the most readily available, suitable food. For specimens collected in area 33 on August 28, amphipods were the most important food items while diatoms were the dominant food organism in shiners collected in area 18 on the same date.

The reason Cyanophyta were the dominant food organisms for small spottail shiners collected in both July and August was that a large percentage (91%) of the July specimens were collected from July 28-31. Diatoms probably would have been the dominant algae if more of the specimens had been collected in early July. Spottail shiners were probably picking the most abundant food organism rather than actively selecting food items. Since Cyanophyta are not easily digested food items, spottails probably utilized Cladocera as their major source of nutrition during both months.

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Appendix I. Description of the 41 sampling areas established for the simulation model study of Navigation Pool 8 of the Upper Mississippi River during the summer of 1975.

Forty-one areas of Navigation Pool 8 of the Upper Mississippi River were designated for sampling in the simulation model study. The areas were numbered on the basis of increasing current velocity. Mean depth and mean current velocity of each area were obtained from Claflin (1975). Depths were corrected to a mean pool elevation. The major aquatic macrophytes occurring in each area were determined and their relative biomass calculated (total dry weight of a species in an area/total dry weight of all species in an area). The percent biomass figure given after each species name is an average of two samplings. The first sampling occurred in June and early July and the latter in late July and August. Figures I-1 through I-11 are enlargements of the delineated sections of Navigation Pool 8 shown in Figs. 1 and 2. Areas 5 and 7 were not sampled for fish due to inaccessability.

Areas 1-5. These areas were small, euthrophic marsh openings located above the Goose Island area in the midsection of the pool (Fig. I-1). All had no measureable current velocity. They varied slightly in size and were differentiated on the basis of size of the opening of water in the center. All contained large amounts of emergent vegetation. Area 1, with a mean depth of 1.7 m, contained the largest opening. *Ceratophyllum demersum* (17.4%) was the predominant species in the opening. Patches of *Nuphar variegatum* (16.9%) occurred along the edges of the emergent *Sagittaria latifolia* (43.7%) surrounding the area. Area 2 had a mean depth of 1.2 m.

Figure I-1. Aerial photograph, 1974, of middle Running Slough and adjoining backwaters of the upper Goose Island area in the midsection of Navigation Pool 8 of the Upper Mississippi River.

B

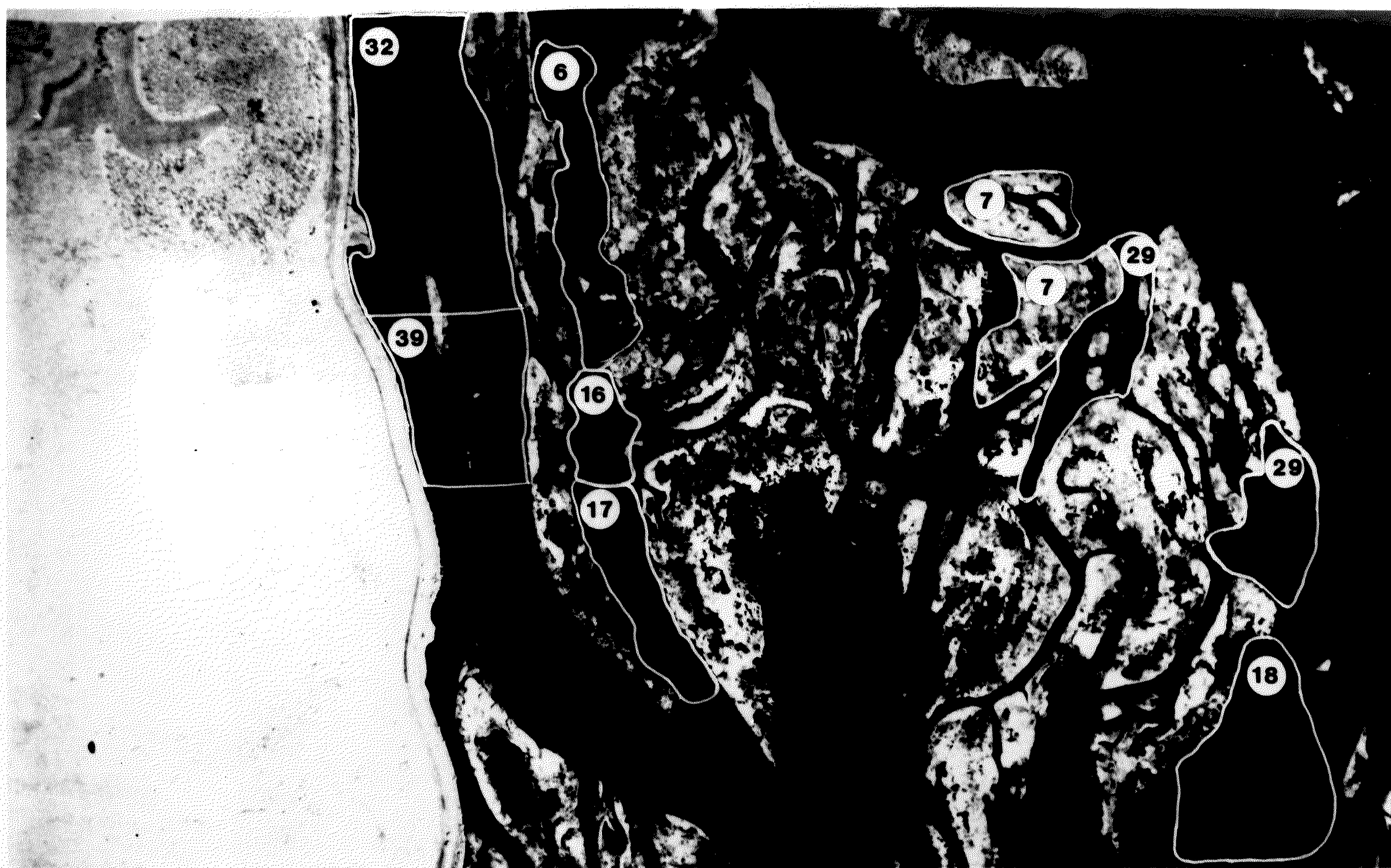
C. demersum (11.7%) and N. variegatum (11.4%) were found in the opening, which was bordered by dense stands of S. latifolia (66.9%). Area 3 had a mean depth of 1.1 m and contained emergent and floating leaved communities. S. rigida (32.0%), S. latifolia (23.6%) and Sparganium eurycarpum (18.6%) were the major emergent macrophytes. Nymphaea tuberosa (5.3%) dominated the floating leaved community. The buildup of Lemnaceae (12.3%) was marked during the summer. Both areas 4 and 5 had dense Sagittaria sp. stands consisting of 92.2% and 98.5% S. latifolia, respectively. Area 4 had a mean depth of 1.0 m and area 5 a mean depth of 0.9 m.

Area 6. Located in a side channel along the east side of upper Raft Channel (Fig. I-2), area 6 had a mean depth of 1.08 m and a current velocity of 0.015 m/sec. The center of the area was open, but the margins had stands of S. latifolia (57.2%), S. rigida (17.6%) and Nelumbo pentapetala (11.4%).

Area 7. This area was south of the main channel above the "S" curve below Brownsville, Minnesota (Fig. I-2). The mean depth was 0.61 m. The area contained a stand of S. latifolia (75.9%) with a slight current (0.016 m/sec) passing through it due to its location next to the channel. N. pentapetala (8.0%), Potamogeton nodosus (4.5%) and N. tuberosa (3.7%) occurred on the edges of the Sagittaria sp. beds.

Area 8. Located east of upper Raft Channel and separated from it by a thin land mass (Fig. I-3), area 8 had a

Figure I-2. Aerial photograph, 1974, of middle Raft Channel and associated backwatar areas downstream from Brownsville, Minnesota in Navigation Pool 8 of the Upper Mississippi River.



J

Figure I-3. Aerial photograph, 1974, of the confluence of Raft Channel and the main channel, immediately below Brownsville, Minnesota in Navigation Pool 8 of the Upper Mississippi River.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mean depth of 0.98 m and an average current velocity of 0.019 m/sec. This was predominantly a floating-leaved community containing N. pentapetala (37.7%), N. tuberosa (23.9%) and associated submergent species. S. rigida (6.2%) and S. latifolia (6.2%) were found near the shoreline.

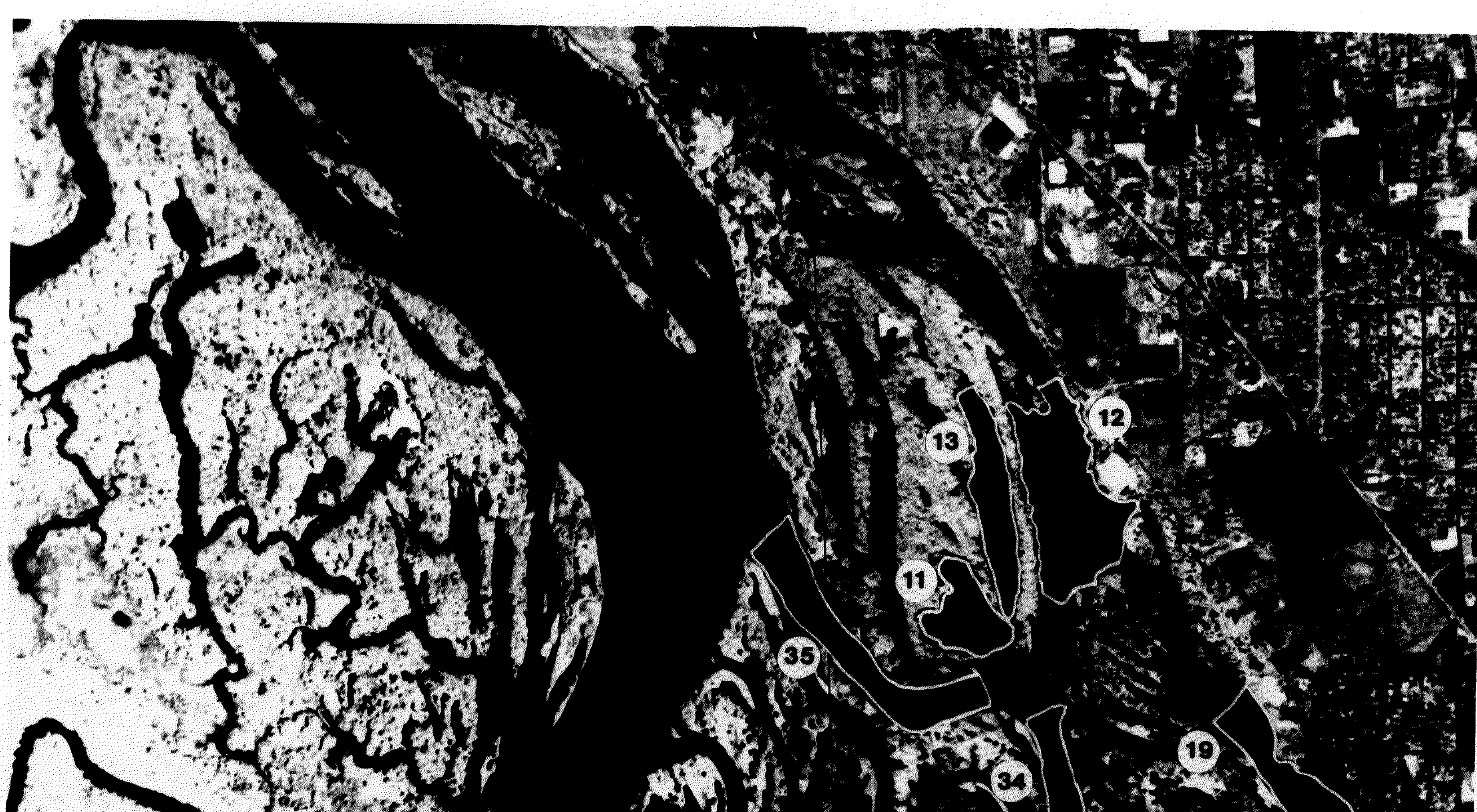
Area 9. Located approximately 1.7 km downstream from the head of Running Slough (Fig. I-1), area 9 had a mean depth of 1.6 m and a current velocity of 0.020 m/sec. The water flow in this area was a result of currents from Running Slough. The water was too deep to support an appreciable amount of vegetation. Aquatic macrophytes were not collected from this area.

Area 10. This area adjoined study area 8 on its downstream border (Fig. I-3). There were no obvious physical or chemical barriers between these two areas. The mean depth was 0.96 m and the current velocity was 0.300 m/sec. Like area 8, it supported a floating-leaved community containing N. tuberosa (5.9%) and N. pentapetala (4.1%). Emergent Scirpus validus (27.6%) and S. latifolia (21.5%) were found on the perimeter of the area.

Area 11. Study area 11 was located just off Running Slough at the downstream end of area 35 (Fig. I-4). The mean depth was 0.51 m with a current velocity of 0.034 m/sec. P. nodosus (21.3%), C. demersum (13.8%) and Lemnaceae (10.3%) were predominant in the open water. Emergent macrophytes were S. latifolia (37.1%) and S. rigida (9.7%).

Area 12. This area, referred to as Ebner's Gravel Pit,

Figure I-4. Aerial photograph, 1974, of upper Running Slough and adjoining backwater areas in the midsection of Navigation Pool 8 of the Upper Mississippi River.



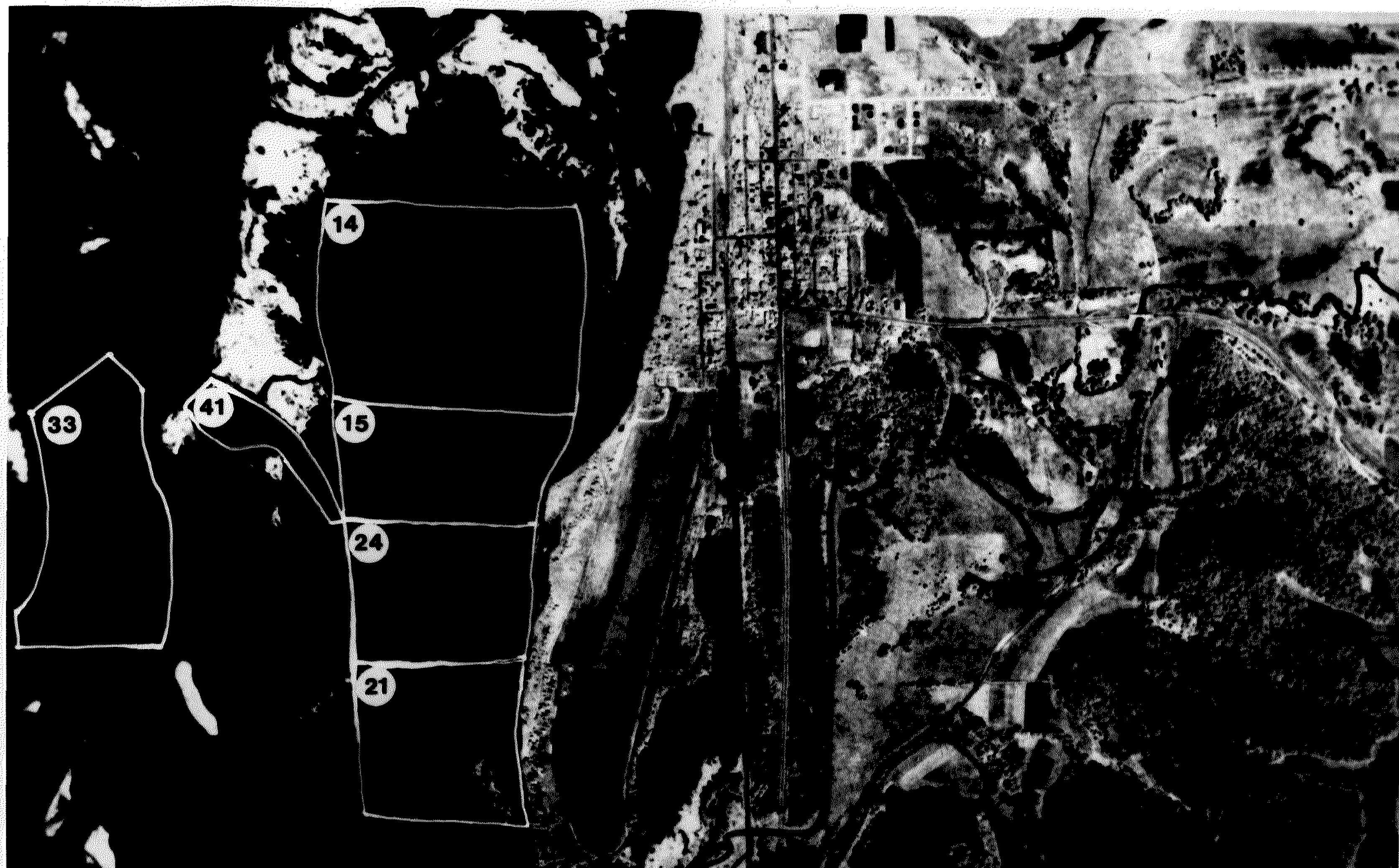
A

was located east of area 11 (Fig. I-4). The mean depth was 4.91 m with a current velocity of 0.039 m/sec. Being so deep, vegetation was restricted to the shallow perimeter, where C. demersum (43.6%) and Vallisneria sp. (43.4%) were the predominant species.

Area 13. A long, slender area that opened at its lower end into area 11 (Fig. I-4), area 13 had a mean depth of 1.5 m and a current velocity of 0.043 m/sec. The water was too deep and turbid to support an appreciable amount of aquatic vegetation. Emergent vegetation was not present. Submergent C. demersum (64.4%) and Potamogeton foliosus (21.4%) were the predominant macrophyte species encountered.

Areas 14 and 15. These areas were contiguous and situated in the upper end of the Stoddard stump field (Fig. I-5). They possessed silt and clay sediments. The water currents were best characterized as being slow sheeting movements that were uniform throughout the entire area. Area 14 had a mean depth of 1.6 m with a current velocity of 0.078 m/sec while area 15 had a mean depth of 1.73 m and a current velocity of 0.101 m/sec. Both areas contained deep water submergent communities typical of the southern portion of the pool. The primary macrophytes in area 14 were Vallisneria americana (35.9%), C. demersum (22.9%) and Elodea canadensis (20.5%). V. americana (66.3%) C. demersum (16.8%) and P. nodosus (11.6%) were the major species in area 15.

Areas 16 and 17. These areas were located below area 6 (Fig. I-2) just east of Raft Channel. The increased current



D

Figure I-5. Aerial photograph, 1974, of the Stoddard stump fields east of the main channel, adjacent to Stoddard, Wisconsin in the southern section of Navigation Pool 8 of the Upper Mississippi River.

velocity in areas 16 and 17 was due to a chute off Raft Channel located near the downstream end of area 6. The mean depth of area 16 was 1.22 m with a current velocity of 0.116 m/sec. Area 17 had a mean depth of 1.35 m and a current velocity of 0.134 m/sec. The centers of these areas were deep and open, but floating leaved and emergent vegetation was present along the edges. S. latifolia (50.5%), S. rigida (27.7%) and N. tuberosa (14.2%) were the major macrophytes bordering area 16. S. latifolia (56.7%), N. tuberosa (20.1%) and Ceratophyllum sp. (12.5%) were the most abundant macrophytes in area 17.

Area 18. Study area 18 was situated west of the main channel, downstream from the "S" curve below Brownsville, Minnesota (Fig. I-2). Its currents were created by an inflow of water from the main channel. The mean depth was 0.95 m with a current velocity of 0.136 m/sec. A deep water submergent community dominated by V. americana (90.9%) was found here.

Area 19. This study area was located downstream from area 12 (Fig. I-4) and like area 12, contained dredged portions which were quite deep. The mean depth of study area 19 was 6.1 m with a current velocity of 0.140 m/sec. Although the center was too deep to support aquatic vegetation, the shallower borders supported C. demersum (67.6%), Lemnaceae (16.7%) and Heteranthera dubia (8.9%).

Area 20. Located in the upper Goose Island backwaters (Fig. I-1), study area 20 was a pond-like area which recieved its inflow of water from a small feeder channel connected to Running Slough. The mean depth was 0.81 m with a current velocity of 0.159 m/sec. It supported emergent, floating-leaved, and shallow water submergent communities typical of the midsection of Pool 8. The major emergent macrophytes were S. latifolia (36.8%) and S. rigida (28.7%), floating-leaved N. pentapetala (8.0%) and submergent C. demersum (9.8%).

Area 21. This area was located at the lower end of the Stoddard stump field (Fig.I-5). It was similar to study areas 14 and 15, except that it had fewer landforms to protect it from the currents of the main channel. The mean depth was 2.63 m with an average current velocity of 0.206 m/sec. The dominant macrophytes in this deep water submergent community were V. americana (63.8%), P. nodosus (20.1%) and Ceratophyllum sp. (7.6%).

Area 22. Located at the upper end of Crosby Slough (Fig. I-6), area 22 possessed a fairly swift current (0.218 m/sec). The mean depth of area 22 was 2.26 m. The depth, current and sediments of the channel were unsuitable for macrophyte growth. There were, however, plant communities along the shore, the dominant species being S. latifolia (49.2%), C. demersum (16.2%), Nelumbo sp. (15.4%) and S. rigida (6.5%).

Area 23. Study area 23 was located immediately downstream from study area 22 (Fig. I-7). There was a slightly higher current velocity (0.235 m/sec) than area 22, due to

Figure I-6. Aerial photograph, 1974, of the main channel and upper Crosby Slough in the midsection of Navigation Pool 8 of the Upper Mississippi River.

G

Figure I-7. Aerial photograph, 1974, of the main channel and lower Crosby Slough in the midsection of Navigation Pool 8 of the Upper Mississippi River.

H

the smaller mean depth (1.84 m). A high influx of sediments caused the downstream end to be fairly shallow. Area 23 also supported a denser macrophyte population than area 22; the major shoreline species being S. latifolia (54.3%), S. rigida (15.0%) and E. canadensis (10.1%).

Area 24. Located immediately above area 21 in the Stoddard stump field (Fig. I-5), this area resembled study area 21 in its general ecology and vegetation. The dominant species were V. americana (66.9%), N. tuberosa (13.2%) and H. dubia (8.2%). Area 24 had a mean depth of 1.71 m and a current velocity of 0.282 m/sec.

Area 25. A large lake-type area with its downstream end at the lower end of Running Slough (Fig. I-8), area 25 was fed by numerous small, meandering channels. Although the area was shallow (mean depth, 0.61 m), the area precluded the growth of most aquatic macrophytes except for a few patches of P. nodosus (6.5%). Stands of emergent species bordered the area, with S. latifolia (67.2%) and S. rigida (20.3%) being dominant.

Area 26. Study area 26 was also a large lake-type area (Fig. I-9) located immediately below area 18. Its relatively high current velocity (0.301 m/sec) can be attributed to the main channel bordering on its eastern boundary, and numerous feeder channels off Raft Channel to the west. The area supported a deep water submergent community in which V. americana (80.2%) and H. dubia (9.8%) were the dominant species.

Figure I-8. Aerial photograph, 1974, of lower Running Slough and adjoining backwaters in the Goose Island area in the midsection of Navigation Pool 8 of the Upper Mississippi River.

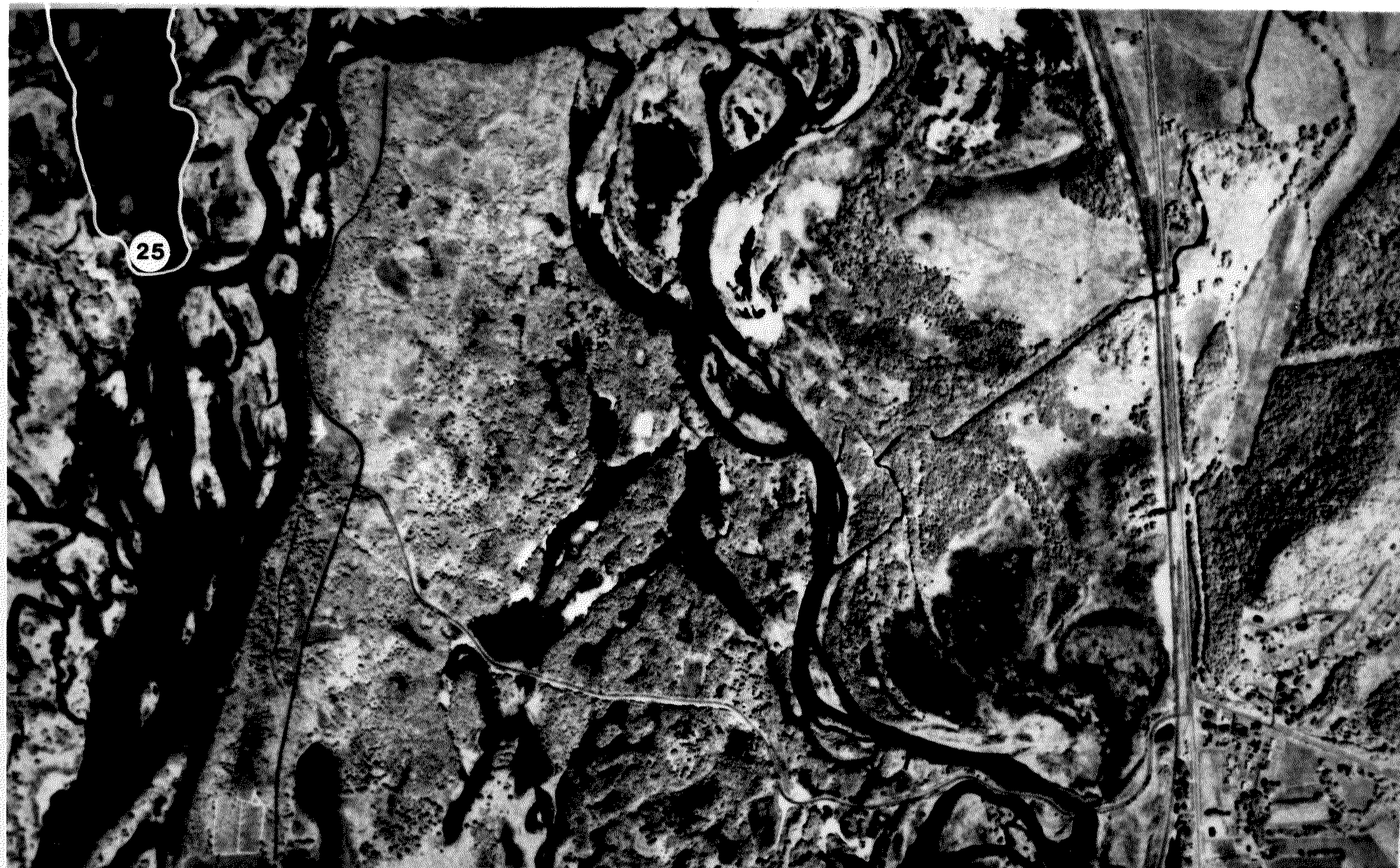


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Figure I-9. Aerial photograph, 1974, of the lower reaches of Raft Channel and associated backwater areas downstream from Brownsville, Minnesota in Navigation Pool 8 of the Upper Mississippi River.

K

Area 27. A small side channel off of lower Running Slough, area 27 (Fig. I-1) was fairly deep (2.34 m) and had a relatively high current velocity (0.344 m/sec). The area only possessed vegetation on the shallow borders, with *S. latifolia* (67.5%), *S. rigida* (15.7%) and *N. tuberosa* (6.6%) being prominent.

Area 28. This area was located in the main channel with its upstream end bordering the mouth of Crosby Slough (Figs. I-6 and I-7). The mean depth was 4.73 m with a current velocity of 0.344 m/sec. The area was virtually devoid of macrophyte populations except along the shoreline where the dominant species were *V. americana* (59.0%), *P. pectinatus* (26.0%) and *P. nodosus* (13.3%).

Area 29. Located along the west side of the main channel at the lower end of the "S" curve (Fig. I-2), area 29 was bordered by large stands of *S. latifolia*. The mean depth was 1.63 m with a current velocity of 0.352 m/sec. The predominant macrophytes were *V. americana* (54.0%), *N. tuberosa* (31.6%) and *P. nodosus* (14.4%).

Area 30. Located a short distance downstream from the entrance to Raft Channel (Fig. I-2), this area was fairly deep and open with a gradual slope on the eastern shore. The mean depth was 1.57 m with a current velocity of 0.385 m/sec. The dominant macrophytes along the shoreline were *S. latifolia* (48.8%), *S. rigida* (18.8%) and *N. pentapetala* (7.2%). *P. nodosus* (14.1%) also occurred on a sandbar near the eastern shore of the area.

Area 31. Study area 31 was a small channel system located at the downstream end of area 27 along with some flow from lower Running Slough (Fig. I-2). The channels were fairly deep (1.57 m), swift (0.393 m/sec) and open. The borders supported stands of S. latifolia (74.1%), C. demersum (6.8%), S. rigida (5.0%), N. tuberosa (4.6%) and P. nodosus (3.4%).

Area 32. The area (Fig. I-2) bordered the downstream edge of area 30. It included the widest part of Raft Channel and had a mean depth of 2.01 m. The mean current velocity was 0.407 m/sec. The western portion was fairly deep and open, supporting only a small amount of V. americana (9.6%). S. latifolia (64.6%), C. demersum (12.5%) and N. tuberosa (3.3%) were the major macrophytes on the shallower eastern shore.

Area 33. Located in the main channel at the downstream end of the "S" curve (Fig. I-5), area 33 lacked aquatic macrophytes. The mean depth was 6.71 m with a current velocity of 0.411 m/sec.

Area 34. The middle reach of Running Slough (Figs. I-1 and I-4) was relatively deep (2.41 m) and had a current velocity of 0.448 m/sec. It was similar in its general ecology to upper Running Slough (area 35) but was slightly slower-flowing due to side channels branching off at the downstream end of area 35. The only macrophyte sampled along the shoreline was N. tuberosa (100%).

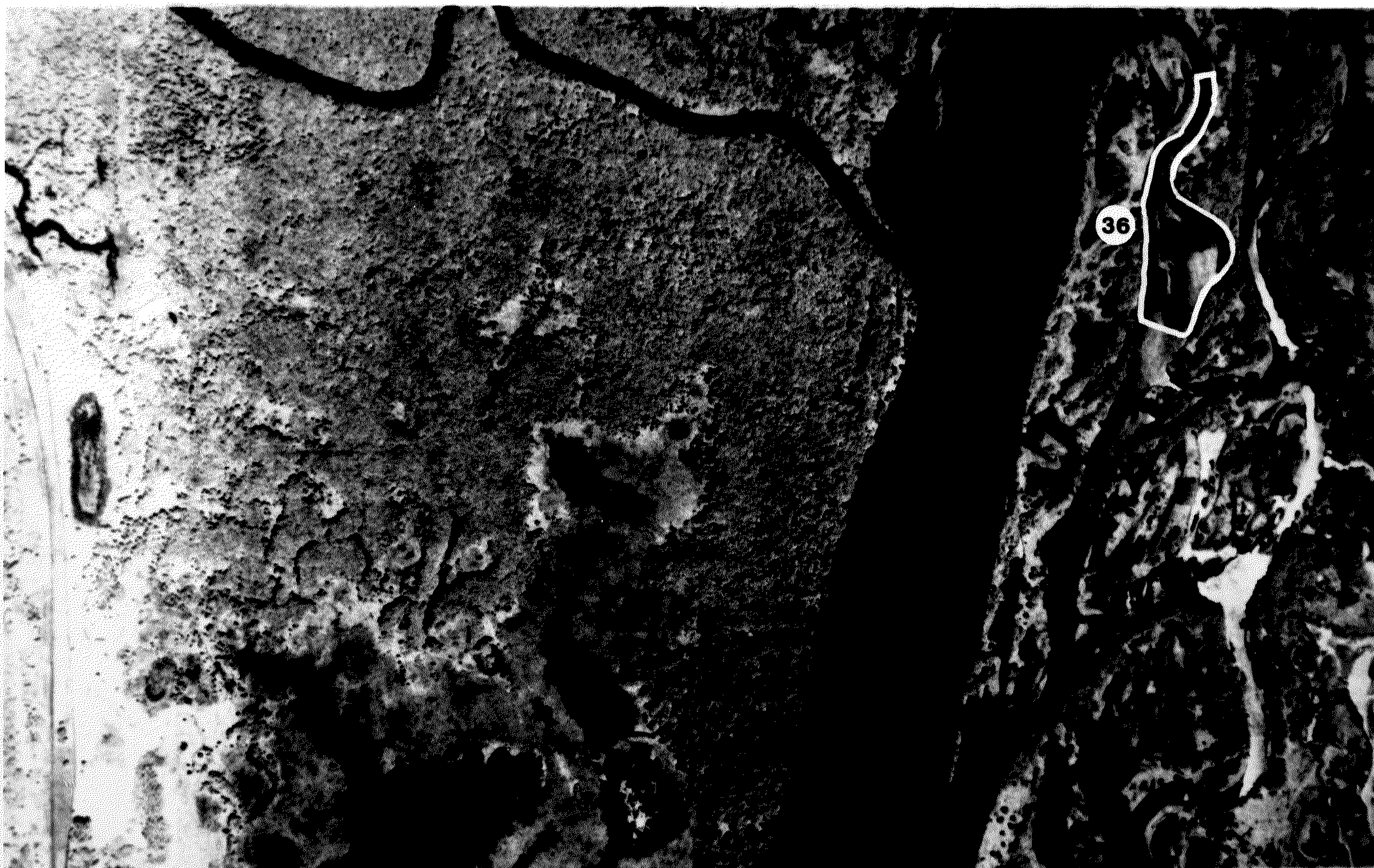
Area 35. The upper part of Running Slough (Fig. I-4) had a mean depth of 2.91 m. The current velocity was 0.463 m/sec. This area recieved its water flow directly from the main channel and was, itself, quite channled. Aquatic macrophytes were found along the shore only, with _C. demersum_ (70.4%) the dominant species.

Area 36. Study area 36 was located off the east side of the main channel, a short distance downstream from the entrance to Running Slough (Fig. I-10). The primary inflow was from the main channel. Area 36 flowed back into the main channel approximately 350 m downstream from where it began. Although the area was fairly shallow (mean depth, 1.33 m), the sand sediment and high current velocity (0.470 m/sec) precluded the growth of aquatic macrophytes in the center of the area. The dominant macrophytes along the shore were _S. latifolia_ (44.7%), _S. rigida_ (20.2%), _P. nodosus_ (14.9%) and _H. dubia_ (11.3%).

Area 37. Located downstream from the Stoddard stump field (Fig. I-11), area 37 was bordered on the western side by the main channel. It, therefore, recieved heavy flow from the main channel. The current velocity was 0.527 m/sec and the mean depth was 1.33 m. The area supported large beds of submergent vegetation, with _V. americana_ (64.4%), _P. nodosus_ (16.7%) and Lemnaceae (12.0%) being the dominant species.

Area 38. This study area was the most downstream portion of Running Slough that was sampled (Fig. I-1). It was a chaneled area with a mean depth of 1.89 m and a current

Figure I-10. Aerial photograph, 1974, of the main channel and backwaters immediately downstream from the mouth of Running Slough in the midsection of Navigation Pool 8 of the Upper Mississippi River.



F

Figure I-11. Aerial photograph, 1974, east of the main channel in the southern section of Navigation Pool 8 of the Upper Mississippi River immediately downstream from Stoddard, Wisconsin.

E

velocity of 0.534 m/sec. Vegetation was lacking in most of the area with the dominant shoreline forms being P. nodosus (28.95%), S. rigida (18.8%), N. tuberosa (13.3%) and S. latifolia (12.1%).

Area 39. Located below area 32 (Fig. I-2), area 39 was the farthest downstream portion of Raft Channel sampled. Very little vegetation was supported in most of the area due to the depth (2.33 m) and current velocity (0.578 m/sec). S. latifolia (54.1%) and P. nodosus (13.0%) were the predominant species along the shallow eastern boundary and along the island in the center of the area.

Area 40. The uppermost part of Raft Channel (Fig. I-3) possessed the second highest current velocity (0.587 m/sec) due to the direct flow from the main channel. The area had a mean depth of 1.9 m. The majority of the area was open, with vegetation restricted primarily to the shorelines. The major species were S. latifolia (84.0%) P. pectinatus (10.9%) and C. demersum (3.1%).

Area 41. A narrow chute located along an outside curve of the main channel (Fig. I-5), area 41 had the highest current velocity of any area sampled (0.720 m/sec) and was fairly deep (3.7 m). The constricted channel lacked aquatic vegetation; however; V. americana (56.6%), N. tuberosa (11.5%) Potamogeton richardsonii (8.4%) bordered the chute.

Appendix II. Study areas in which specimens of spotfin shiners (SF), golden shiners (GS), emerald shiners (ES) and spottail shiners (ST) were collected from Navigation Pool 8 of the Upper Mississippi River during the summer of 1975.

Area	SF	GS	ES	ST
1	+	+		
2	+	+	+	
3	+	+		+
4		+		
6		+		
8		+	+	+
9	+	+		+
10	+	+	+	+
11		+		+
12	+	+	+	+
13	+	+		+
14	+	+	+	+
15	+	+	+	
16	+	+	+	+
17				
18		+	+	+
19	+	+		+
20	+	+		
21	+	+		
22	+	+	+	+
23	+	+	+	+
24		+		+
25	+	+	+	
26		+	+	
27	+	+	+	+
28	+	+	+	
29		+	+	
30				
31	+	+	+	+
32		+	+	
33	+		+	+
34	+	+	+	+
35	+	+	+	+
36	+	+	+	+
37	+	+	+	+
38	+	+		+
39		+		+
40	+	+	+	+
41	+	+	+	+

Appendix III. Relative importance of all food items for three size groups of spotfin shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River (*=values less than 0.5%). For the algae, the total number indicates the total number of individual cells.

Size class and number of fish examined	Food item	Fish with food item No.	Fish with food item %	Total number food item No.	Total number food item %	Total volume food item ml	Total volume food item %
0-45 mm (60)	Bacillariophyceae	40	67	1,086,162	65	28.8168	63
	Cyanophyta	19	32	477,941	29	6.7828	15
	Chlorophyta	12	20	81,665	5	0.3098	*
	Cladocera	54	90	27,351	2	9.4314	21
	Amphipoda	2	3	294	*	0.2646	*
	Ostracoda	11	18	1,189	*	0.1510	*
	Rotifera	2	3	392	*	0.0010	*
	Unident. Insects	10	17	10	*	0.1020	*
	Other	7	12	7	*	0.0140	*
	Sand	14	23				
	Vascular Plants	14	23				
	Total			1,675,011	101	45.8734	99

(cont.)

Appendix III. (cont.)

46-70 mm (98)	Bacillariophyceae	71	72	5,001,584	21	309.2944	83
	Cyanophyta	36	37	18,311,412	78	22.6955	6
	Chlorophyta	16	16	153,150	*	6.4696	2
	Cladocera	86	88	94,641	*	32.5840	9
	Amphipoda	4	4	114	*	0.1026	*
	Ostracoda	14	14	3,624	*	0.4602	*
	Rotifera	4	4	5,991	*	0.0150	*
	Tendipedidae	26	27	89	*	0.9392	*
	Trichoptera	18	18	52	*	0.2364	*
	Corixidae	4	4	4	*	0.0096	*
	Unident. Insect	42	43	122	*	1.2444	*
	Statoblasts	6	6	26	*	0.0341	*
	Nematoda	6	6	6	*	0.2412	*
	Other	4	4	5	*	0.0510	*
	Vascular Plants	12	12				
	Sand	7	7				
	Total			23,570,847	99	374.3772	100

(cont.)

Appendix III.(cont.)

71-95 mm (41)	Bacillariophyceae	22	54	3,177,499	73	195.5557	89
	Cyanophyta	2	5	15,000	*	0.0778	*
	Chlorophyta	3	7	103,517	25	1.5875	*
	Cladocera	34	83	62,668	1	21.6100	10
	Amphipoda	1	2	203	*	0.1827	1
	Ostracoda	2	5	294	*	0.0373	*
	Copepoda	1	2	98	*	0.0049	*
	Tendipedidae	8	20	30	*	0.0316	*
	Trichoptera	4	10	5	*	0.0227	*
	Ephermidae	3	7	3	*	0.1134	*
	Unident. Insect	18	44	58	*	0.5916	*
	Statoblast	4	10	8	*	0.0149	*
	Nematoda	5	12	7	*	0.2814	*
	Vascular Plants	8	20				
	Sand	1	2				
	Total			3,359,399	99	220.4950	100

Appendix IV. Relative importance of all food items for three size groups of golden shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River (*=values less than 0.5%). For the algae, the total number indicates the total number of individual cells.

Size class and number of fish examined	Food item	Fish with food item		Total number food item		Total volume food item	
		No.	%	No.	%	ml	%
0-80 mm (31)	Bacillariophyceae	29	94	17,087,945	50	11.0170	58
	Cyanophyta	9	29	16,055,417	47	2.6186	14
	Chlorophyta	8	26	976,217	3	3.3761	20
	Cladocera	22	71	4,703	*	1.6218	9
	Copepoda	2	6	392	*	0.0196	*
	Nauplii	1	3	52	*	0.0016	*
	Ostracoda	2	6	475	*	0.0603	*
	Rotifera	4	13	313	*	0.0008	*
	Other	10	32	18	*	0.1733	*
	Vascular Plants	8	22				
	Total			34,125,532	100	18.8875	101

(cont.)

Appendix IV (cont.)

81-95 mm	Bacillariophyceae	48	91	236,564,371	89	31.3330	53
(53)	Cyanophyta	29	55	14,328,544	5	3.8730	7
	Chlorophyta	20	38	13,323,940	5	8.1599	14
	Cladocera	38	72	41,962	*	14.4700	25
	Amphipoda	1	2	235	*	0.2115	*
	Ostracoda	7	13	647	*	0.0882	*
	Rotifera	3	6	785	*	0.0020	*
	Copepoda	10	19	2,041	*	0.1021	*
	Corixidae	9	17	29	*	0.0696	*
	Trichoptera	2	4	2	*	0.0091	*
	Tendipedidae	5	9	6	*	0.0063	*
	Unident. Inscets	2	4	5	*	0.0510	*
	Mollusca	3	6	7	*	0.2149	*
	Statoblasts	4	8	8	*	0.0105	*
	Nematoda	4	8	4	*	0.1608	*
	Other	3	6	3	*	0.1134	*
	Sand	2	4				
	Vascular Plants	11	21				
	Total			264,262,624	99	58.8693	99

(cont.)

Appendix IV (cont.)

96-188 mm (39)	Bacillariophyceae	34	87	5,605,022	2	12.7139	15
	Cyanophyta	29	74	235,486,489	96	35.1860	42
	Chlorophyta	17	43	4,375,014	2	1.6949	2
	Cladocera	13	33	46,668	*	16.0930	19
	Amphipoda	4	10	316	*	0.2844	*
	Ostracoda	13	33	109,002	*	13.8430	16
	Copepoda	4	10	942	*	0.0471	*
	Nauplii	1	3	157	*	0.0048	*
	Rotifera	3	8	1,804	*	0.0045	*
	Ephemeridae	6	15	14	*	0.5292	1
	Tendipedidae	7	18	11	*	0.0116	*
	Corixidae	13	33	70	*	0.1680	*
	Unident. Insect	4	10	28	*	0.2856	*
	Mollusca	10	26	10	*	0.4298	1
	Statoblast	10	26	53	*	0.0695	*
	Nematoda	15	38	32	*	1.2864	2
	Other	3	8	4	*	0.0351	*
	Sand	1	3				
	Vascular Plants	7	18				
	Total			245,625,658	100	84,0073	98

Appendix V. Relative importance of all food items for two size groups of emerald shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River (*=values less than 0.5%). For the algae, the total number indicates the total number of individual cells.

Size class and number of fish examined	Food item	Fish with food item No.	Fish with food item %	Total number food item No.	Total number food item %	Total volume food item ml	Total volume food item %
0-50 mm (44)	Bacillariophyceae	36	82	762,181	13	15.9561	42
	Cyanophyta	20	45	5,035,591	85	8.2072	22
	Chlorophyta	30	68	86,908	1	0.5287	1
	Cladocera	43	98	35,194	*	12.1300	32
	Ostracoda	17	39	2,646	*	0.3360	1
	Amphipoda	4	9	686	*	0.6174	2
	Rotifera	2	5	441	*	0.0011	*
	Unident. Insect	7	16	7	*	0.0714	*
	Other	3	7	3	*	0.0217	*
	Sand	11	25				
	Vascular Plants	5	11				
	Total			5,923,673	99	37.8492	100

(cont.)

Appendix V (cont.)

51-92 mm (60)	Bacillariophyceae	42	70	1,447,314	2	17.5373	10
	Cyanophyta	39	65	92,460,133	98	152.3704	83
	Chlorophyta	12	20	22,325	*	0.1267	*
	Cladocera	42	70	37,107	*	12.7960	7
	Ostracoda	9	15	1,179	*	0.1497	*
	Amphipoda	3	5	539	*	0.4851	*
	Copepoda	1	2	147	*	0.0074	*
	Corixidae	4	7	5	*	0.0120	*
	Trichoptera	5	8	6	*	0.0273	*
	Unident. Insect	28	47	84	*	0.8568	*
	Statoblast	7	12	57	*	0.0748	*
	Other	7	12	9	*	0.0731	*
	Vascular Plants	13	22				
	Sand	11	18				
	Total			93,967,929	100	184.4500	100

Appendix VI. Relative importance of all food items for two size groups of spottail shiners collected during the summer of 1975 from Navigation Pool 8 of the Upper Mississippi River (*=values less than 0.5%). For the algae, the total number indicates the total number of individual cells.

Size class and number of fish examined	Food item	Fish with food item No.	Fish with food item %	Total number food item No.	Total number food item %	Total volume food item ml	Total volume food item %
0-60 mm (43)	Bacillariophyceae	36	84	908,537	36	31.5913	73
	Cyanophyta	21	49	1,591,270	62	1.4090	3
	Chlorophyta	7	16	19,410	*	0.0266	*
	Cladocera	35	12	24,244	*	8.3601	19
	Amphipoda	5	12	1,372	*	1.2348	3
	Ostracoda	1	2	972	*	0.1236	*
	Copepoda	1	2	99	*	0.0050	*
	Rotifera	3	7	588	*	0.0015	*
	Tendipedidae	15	35	17	*	0.0179	*
	Unident. Insect	4	9	7	*	0.0714	*
	Mollusca	3	7	4	*	0.1228	*
	Other	5	12	7	*	0.0953	*
	Sand	16	37				
	Vascular Plants	13	30				
	Total			2,546,528	98	43.0593	98

(cont.)

Appendix VI. (cont.)

61-87 mm (32)	Bacillariophyceae	27	84	399,214	31	5.0845	23
	Cyanophyta	15	47	870,780	67	8.4592	38
	Chlorophyta	7	22	4,313	*	0.1169	*
	Cladocera	20	63	11,569	*	3.9893	18
	Amphipoda	22	69	3,064	*	2.7576	12
	Ostracoda	22	69	3,197	*	0.4060	2
	Copepoda	1	3	98	*	0.0049	*
	Tendipedidae	11	34	27	*	0.0284	*
	Trichoptera	3	9	7	*	0.0273	*
	Corixidae	2	6	2	*	0.0048	*
	Unident. Insects	23	72	66	*	0.6732	3
	Mollusca	5	16	11	*	0.3377	2
	Statoblasts	6	19	17	*	0.0223	*
	Nematoda	2	6	5	*	0.2010	1
	Other	3	9	3	*	0.0582	*
	Sand	16	50				
	Vascular Plants	12	38				
	Total			1,292,373	98	22.1126	99

Appendix VII. Taxonomic list of food organisms used by four selected cyprinids from Navigation Pool 8 of the Upper Mississippi River during the summer of 1975.

Chlorophyta
  Chlorophyceae
    Actinastrum sp.
    Ankistrodesmus sp.
    Chlorella sp.
    Cladophora sp.
    Closterium sp.
    Cosmarium sp.
    Eudorina sp.
    Hormidium sp.
    Microspira sp.
    Oedogonium sp.
    Pediastrum sp.
    Scenedesmus sp.
    Selenastrum sp.
    Staurastrun sp.
    Ulothrix sp.

Crysophyta
  Bacillariophyceae
    Amphora sp.
    Cocconeis sp.
    Coscinodiscus sp.
    Cymatopleura sp.
    Cymbella sp.
    Diatoma sp.
    Fragillaria sp.
    Gomphonema sp.
    Gyrosigma sp.
    Melosira sp.
    Meridion sp.
    Navicula sp.
    Nitzchia sp.
    Stauroneis sp.
    Stephanodiscus sp.
    Surirella sp.
    Synedra sp.

Cyanophyta
  Myxophyceae
    Anabaena sp.
    Aphanizomenon sp.
    Merismopedia sp.
    Microcystis sp.
    Oscillatoria sp.

Platyhelminthes
  Turbellaria
    Rhabdocoelida

Rotatoria
  Monogonota
    Ploima

Nematoda

Bryozoa
  Phylactolaemata
    Plumatellina
      Pectinella sp.

Arthropoda
  Crustacea
    Branchiopoda
      Cladocera
        Bosmina longirostris
        Daphnia galeata
        Daphnia sp.
        Diaphamosoma sp.
        Eurycercus lamellatus
        Leptodora sp.
        Pleuroxus sp.
    Copepoda
      Encopepoda
        Cyclops sp.
        Diaptomus sp.
    Ostracoda
    Malacostraca
      Amphipoda
        Hyallella azteca
  Arachnoidea
    Hydracrina
  Insecta
    Ephemeroptera
      Ephemeridae
        Hexagenia sp.
    Odonata
      Zygoptera
        Coenargrionidae
    Hemiptera
      Corixidae

Appendix VII. (cont.)

Trichoptera
  Hydropsychidae
    Cheumatopsyche sp.
Coeleoptera
Diptera
  Ceratopogonidae
    Palpomya sp.
  Simuliidae
  Tendipedidae

Mollusca
  Gastropoda
    Planorbidae
      Helisoma sp.
  Pelecypoda
    Sphaeriidae
      Disidium sp.
      Musculium sp.