DEPARTMENT OF NATURAL RESOURCES

Madison, Wisconsin 53701 • 1970

Technical Bulletin 45

REPRODUCTION AND EARLY LIFE HISTORY OF THE WALLEYE IN THE LAKE WINNEBAGO REGION

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by
Gordon R. Priegel

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ABSTRACT

Because the walleye is the most sought-after game fish in Lake Winnebago and connecting waters, its early life history was studied from 1959 to 1967 to determine factors affecting spawning success, egg development and fry survival. Areas studied included spawning sites on the west shore of Lake Winnebago and numerous spawning marshes along the Fox and Wolf rivers.

Spawning success was influenced by the number, size and condition of available spawning areas.

Egg development on all spawning areas was affected by fluctuating water levels and substrate types, but not by water temperatures or predation. On Fox River marshes, embryo development was inhibited by carp activity and low dissolved oxygen concentrations.

Fry survival was influenced by water levels on the marshes and by river velocity.

Because spawning areas were large and numerous and of high quality (i.e., water flow and bottom types were favorable for spawning), factors limiting egg development or fry survival did not affect the establishment of year classes of walleyes on Lake Winnebago. Even if spawning failed on some areas, the fact that so many other large and high quality spawning sites were available meant that some successful spawning would always occur somewhere.

For these reasons management efforts to maintain necessary water levels on some spawning areas or to control carp on others were of secondary importance to the necessity of state ownership of existing spawning marshes. Through such ownership high quality spawning sites could be maintained. Specific management recommendations for state-owned marshes included: (1) the prevention of level ditching or diking which would block flow of water across the marshes, and (2) the use of controlled burning and brush cutting to curtail plant succession on marshes where desirable grasses and sedges were being replaced by undersirable woody vegetation.

ACKNOWLEDGMENTS

I wish to acknowledge the capable work of my assistant, John Keppler, who helped with the field work and tabulation of data during the entire study. Special thanks are due those who provided the same assistance during various segments of the study: Lloyd Andrews, now with Fish Management in the Northeast District; John Kubisiak, now with the Forest Game Research Group at Sandhill; Wayne Besaw, now with Game Management at Princeton; Larry Van Alstine, now teaching at Lourdes High School in Oshkosh; Harold Klix (deceased) and the various seasonal conservation aids. Special thanks are also due Lyle M. Christenson and Thomas L. Wirth who planned the study and under whose supervision the study was conducted, and numerous Fish Management personnel in the East Central District who provided assistance, equipment and suggestions.

The manuscript was critically reviewed by Lyle M. Christenson.

This research was supported in part from funds supplied by the Federal Aid to Wildlife Restoration Act, under Dingell-Johnson project F-83-1, 2, 3, 4 and 5.

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Edited by Susan Hickey

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INTRODUCTION

The walleye, *Stizostedion vitreum vitreum* (Mitchill), in Lake Winnebago and connecting waters is the most sought-after sport fish especially during the spawning migration in the rivers and during the ice fishing season on Lake Winnebago. Various studies concerning the walleye in these waters have been initiated to further contribute knowledge that will lead to improved management practices and provide for a sustained annual yield in the future. Several segments of the walleye program in the Lake Winnebago region have been completed and reported on: food of adult walleyes during the fall and winter (Priegel, 1963); early scale development (Priegel, 1964); methods of identifying young walleyes and saugers (Priegel, 1967a); movement, rate of exploitation and homing behavior as determined by tagging (Priegel, 1967-68); age and growth (Priegel, 1969a) and food and growth of young walleyes (Priegel, 1969b).

The present study deals with some of the factors affecting walleye egg and fry development plus other aspects pertaining to early life history of the walleye in these waters. The primary objectives were to determine spawning conditions and requirements, to document factors affecting egg and fry development on the spawning sites and to determine factors limiting survival of young walleyes during their first year in Lake Winnebago.

DESCRIPTION OF STUDY AREA

The water areas involved in the study include Lake Winnebago and Big Lake Butte des Morts on the 107-mile-long Fox River and Lakes Poygan and Winneconne on the 216-mile-long Wolf River (Fig. 1). The Wolf River joins the Fox River in Big Lake Butte des Morts, 10 river miles above Lake Winnebago and then enters the lake as the Fox River at Oshkosh. The Fox River also flows out of Lake Winnebago at Neenah and Menasha and flows 39 river miles north to Green Bay, Lake Michigan. The runoff water from the Fox River drainage system (6,520 square miles) enters Lake Winnebago.

Lake Winnebago has an area of 137,708 acres with a maximum depth of 21 feet and an average depth of 15.5 feet. The lake is roughly rectangular in shape: 28 miles long and 10.5 miles wide at its widest point. The smaller upriver lakes (Poygan, Winneconne and Big Lake Butte des Morts) have areas of 14,102, 4,507

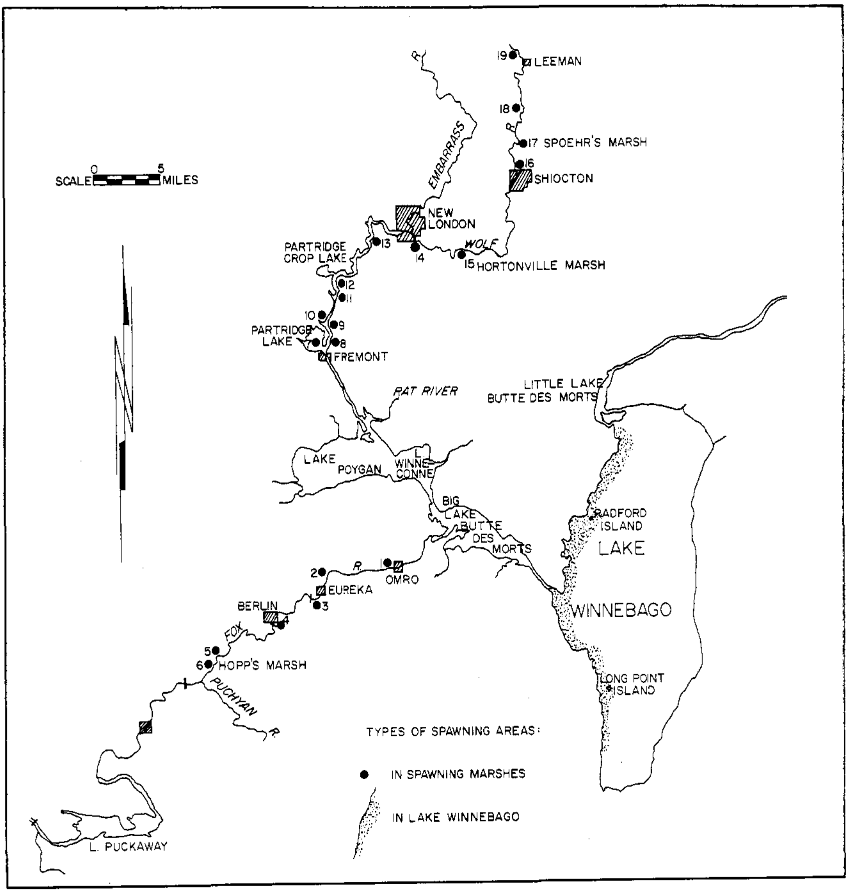


Figure 1. Water areas involved in the study and distribution of walleye spawning sites on these areas.

and 8,857 acres, respectively. Located in the river channels, these smaller lakes have similar depths, the maximum not exceeding 11 feet. All four lakes have many characteristics common to shallow eutrophic lakes.

The bottom of Lake Winnebago is an extensive plain broken only by reefs on the west shore. Except for these reefs, the rock, gravel and sand shorelines and the shoals of the lake, the bottom is finely divided soft mud mixed with peat (Wirth, 1959). Rooted aquatic plants are not abundant in the lake and occur only in localized areas.

Water samples were collected from the lake proper on August 9, 1966 and through the ice on March 21, 1967. Analyses showed

Lake Winnebago to be a fertile lake (Table 1). The water is hard with a methyl-orange alkalinity of 119-124 ppm and has an alkaline pH varying from 7.7 to 8.5. Dissolved phosphates (PO_4-D) are such that heavy algal growth could be stimulated. Massive algae blooms are common during the summer months.

TABLE 1

Water Analyses for Lake Winnebago, 1966-67

Parameter*	August 9, 1966	March 21, 1967
pH	8.5	7.7
Total alkalinity	124	119
Cl−	6.8	6.9
NH_4−-N	—	0.19
NO_3−-N	—	0.39
PO_4 (dissolved)	0.13	0.03
PO_4 (total)	0.41	0.09
Ca++	38.42	26.80
Mg++	16.71	15.20
Na+	4.55	5.10
K+	2.05	1.97

* Units of measurement are ppm with the exception of pH which is expressed in units.

—Indicate tests not performed.

Lake Winnebago is rich in fish fauna. Seventy-six species belonging to 22 families are now present or have been reported in the past (Priegel, 1967b). The more important and abundant game fish species besides walleye are sauger, *Stizostedion canadense* (Smith), yellow perch, *Perca flavescens* (Mitchill), lake sturgeon, *Acipenser fulvescens* Rafinesque, and white bass, *Roccus chrysops* (Rafinesque). The most important commercial species is the freshwater drum, *Aplodinotus grunniens* Rafinesque.

The smaller upriver lakes (Poygan, Winneconne and Big Lake Butte des Morts) have large areas of dense aquatics. Islands of *Scirpus* sp. are found near the entire shorelines of these lakes. Emergent vegetation, mainly *Typha* sp., is present over a large portion of the shoreline. The bottom of these lakes is mostly firm sand overlain with a thick layer of mud. A small amount of rubble occurs in localized areas.

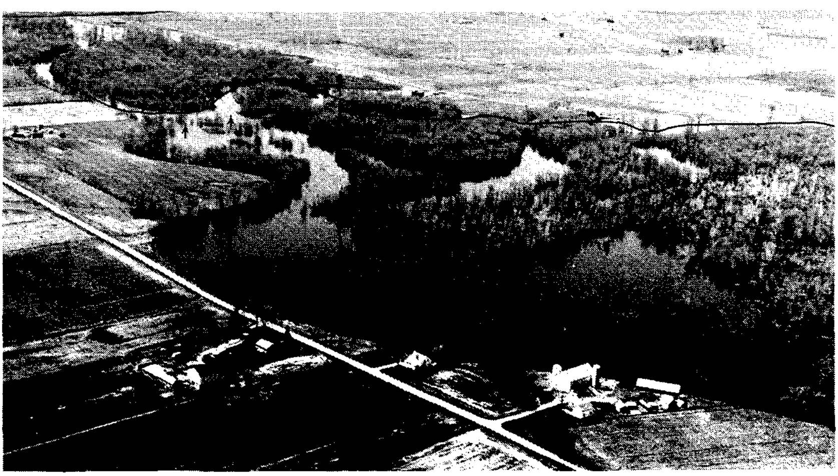
Walleyes from Lake Winnebago must migrate through one or more of the smaller upriver lakes in order to spawn in grass and sedge marshes adjacent to the Wolf and Fox rivers. Spawning walleyes from Lake Winnebago travel as far as 97 miles up the Wolf River and as many as 40 miles up the Fox River when water levels permit passage over the Eureka Dam.

The forested headwaters of the Wolf River are slow moving for about 12 miles. After this short stretch the river descends nearly 700 feet in a 90-mile stretch. The Wolf River from Shawano to Big Lake Butte des Morts drops only 56 feet in these last 114 miles. This lower stretch of the river floods over into an extensive flood plain during the spring runoff period and in so doing provides sites suitable for walleye spawning.

The sluggish Fox River drops only 37 feet in the first 82 miles to the Eureka Dam, then continues 25 miles with no drop from the Eureka Dam to Lake Winnebago. Oxbows, long meandering loops and the wide flood plain areas characterize the walleye spawning sites in this sluggish part of the river.

Although numerous walleye spawning marshes along the Wolf and Fox rivers were investigated (Fig. 1), detailed studies were conducted only on Spoehr's Marsh, Wolf River. Spoehr's Marsh is located in Sections 4, 5, 8 and 9, Town of Bovina, Outagamie County. The marsh is on the east side of the Wolf River approximately 5 river miles upstream from the city of Shiocton. Of the 224 acres the Wisconsin Department of Natural Resources has purchased in this area, approximately 100 acres are being used by spawning walleyes.

Spoehr's Marsh, outlined here in black, is the best studied of the 13 walleye spawning marshes along the Wolf River. The inlet of the marsh is off the picture to the right; its outlet and junction with the Wolf River is marked by an arrow in the upper left hand corner.



METHODS AND MATERIALS

Capture of Spawning Fish

All mature walleyes captured in the Wolf and Fox rivers and adjacent marshes were taken with an A.C. boom shocker unit during the spawning period, 1963-67. Shocking was conducted during daylight and evening hours; however, there was no significant difference in the catch during these periods. Areas that were not easily accessible or required long periods of travel on the river were always sampled during daylight hours.

On Lake Winnebago, an A.C. boom shocker unit was used to sample spawning walleyes along the shoreline during daylight and evening hours, 1964-67. Lake Erie-type trap nets set for the commercial removal of the freshwater drum also provided: (1) samples of spawning walleyes from 1964 to 1967, and (2) evidence of the presence and location of walleye spawning sites in Lake Winnebago from 1955 through 1967.

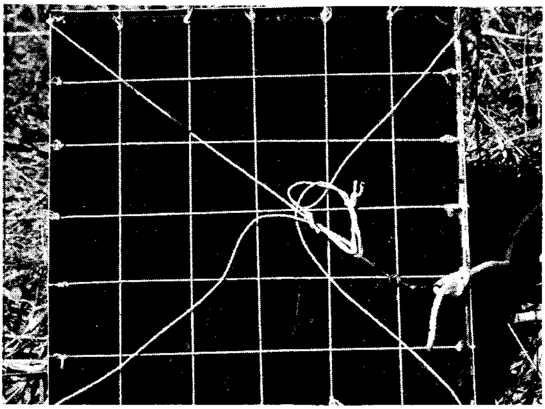
Egg Sampling

A screened basket, with 21 meshes per lineal inch, was used to search for eggs and follow egg development in the marshes, rivers and Lake Winnebago. Although the screen basket was very effective for gross sampling of walleye eggs, it was not suitable for effectively following egg development. In 1965, nylon fiber mats supported on a wooden frame (1 x 3 ft. in size) were used to follow egg development. Eggs from ripe females taken while shocking were fertilized and after becoming water hardened, were placed on these mats. The mats were then placed in various locations in Spoehr's Marsh. In 1966, these larger mats were replaced with 1-foot square nylon fiber mats supported in aluminum or galvanized steel racks. These 1-foot square mats were easier to handle and proved very effective in studying the development of known-age walleye eggs.

Fry Sampling

Use of Meter Nets

A meter net constructed of No. 20 grit gauze (19 meshes per lineal inch) was used to sample walleye fry. It was fished at the



Nylon mats, like this one, were used successfully to follow the development of known-age walleye eggs on Spoehr's Marsh.

outlet of a marsh for a definite period of time to capture fry moving out of the marsh. Usually the current was sufficient to hold the net at the surface. The number of fry captured per minute of sampling provided an index of hatching success.

Meter nets were also used in the rivers to sample fry during their downstream migration. In the rivers, the nets were usually fished by suspending them off bridges or alongside of anchored boats. In Lake Winnebago the meter nets were pulled behind a 16-foot boat or 30-foot steel launch to capture fry during May.

The total lengths of all fry handled during the course of the study were measured to the nearest millimeter.

Use of Dye

Dyed fry were used to follow the migration of known groups of fry. The dye was either neutral red or Bismarck brown Y which gives an amber color. In rivers and lakes where suspended material was abundant, fry dyed with neutral red were easier to spot; thus, of the 2 dyes, neutral red was preferred.

The dye (0.1 gram) was mixed with 3 gallons of hatchery water. At the hatchery 100,000 fry were placed in the dye solution using plastic bags as containers during transportation. The fry were in the dye solution from 6 to 9 hours depending on transportation time. The dye was normally retained by the fry for 10 to 12 days.

The only lethal effect on the dyed fry was the temperature of the dye solution when the fry were placed into it. Water temperature should be lower than 55 F. The greatest mortalities were noted when the temperature of the dye solution exceeded 55 F.

Fingerling Sampling

A 12-foot bait trawl made entirely of 1½-inch stretch mesh with a ¼-inch bobbinet liner in the cod end was used to collect young walleyes in Lake Winnebago from June through October, 1959-67.

Attempts to capture fingerlings with an A.C. boom shocker unit along the shorelines were not successful. Use of a 25-foot nylon bag seine, 4 feet deep with ½-inch bar mesh in the wings and ¼-inch bar mesh in the bag, also proved to be unsuccessful.

The total lengths of all fingerling walleyes handled during the course of the study were measured to the nearest millimeter.

Food Studies

Stomachs of 2,655 young-of-the-year walleyes collected from numerous areas of Lake Winnebago were examined. Fish were collected with meter nets during May, 1960-67 and with a 12-foot bait trawl from June through October, 1959-67. All sampling was conducted during daylight hours. Fish were measured (total length) to the nearest millimeter.

Quantitative determinations consisted of counting each individual food item (whole organisms and fragments) in each fish stomach and computing the mean number of organisms found per stomach. Miscellaneous plant remains and items that were assumed taken incidental to feeding (sand, pebbles and wood materials) were not recorded. Percentages are based on the number of stomachs containing food.

The food items in the walleye stomachs are expressed as percentage frequency of occurrence. The young walleyes were analyzed by length groups (10-50 mm, 51-75 mm, 76-100 mm and 101-175 mm).

Plankton Sampling

Zooplankton samples were collected periodically during the walleye sampling periods in Lake Winnebago, 1965-67. Horizontal tows at depths ranging from the surface to 18 feet were made with a Clarke-Bumpus plankton sampler. Plankton hauls were of 3-minute duration at a constant boat speed of approximately 3 miles per hour. In all sampling, a #2 plankton net and bucket were used. Number 2 netting does not efficiently sample phytoplankton and some of the smaller zooplankters, especially copepod nauplii. In this study, however, young walleyes were not observed to have fed upon either phytoplankton or nauplii.

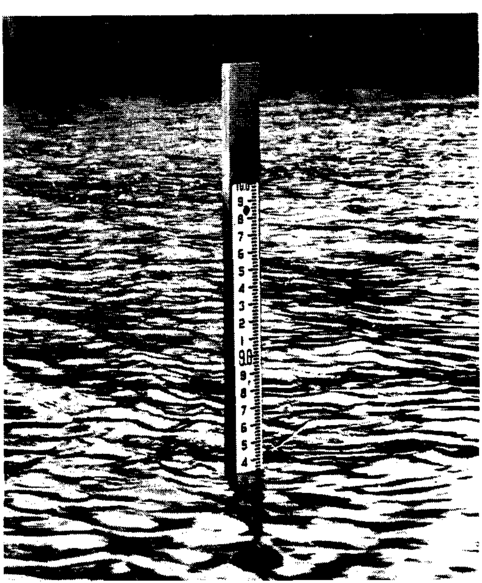
Environmental Measurements

Water temperatures before and during the spawning period were recorded on either a 30-day Ryan or a 7-day Taylor thermograph. Taylor minimum-maximum thermometers were also used on the spawning marshes. Lake Winnebago water temperatures were obtained by placing a 7-day Taylor thermograph at the intake pipe in the Oshkosh water treatment plant, 1959 and 1960. In 1961, Oshkosh began using a pretreatment basin so lake water temperature could not be obtained in this way. For the remaining years of the study, daily water temperatures were taken in 2 places: (1) at Neenah at the water treatment plant, from 1961 to 1967, and (2) in Lake Winnebago on a 30-day Ryan thermograph set from May through October, 1966-67.

Air temperatures for the Lake Winnebago area were obtained for 1959 through 1965 from the Buckstaff's Observatory, Oshkosh, Wisconsin.

Water depth on Spoehr's Marsh was measured by reading daily the measurement off a standard water level gauge, 1961-67.

Flow records from the water years, 1955 through 1967, for the Fox River at Berlin and Wolf River at New London were obtained from the United States Department of the Interior, Geological Survey, Water Resources Division, Madison, Wisconsin. Flow in the marsh and marsh outlet was determined with a Price-Patten



This gauge was used to record water depth on Spoehr's Marsh. Here it shows a reading of 8.5 feet; the actual or observed water depth would be about 3.5 feet.

current meter and is expressed as cubic feet per second.

During periods of egg development on the marshes, dissolved oxygen, pH and alkalinity values were determined for day and nighttime periods. Complete water analyses were obtained for the water areas during the course of the study.

Age Analysis and Sex Determination

Age of spawning walleyes was determined for fish taken in the marshes, rivers and Lake Winnebago. Scales were taken from the left side in an area midway between the lateral line and anterior dorsal spines. The scales were impressed on cellulose acetate slides, 0.03 inch thick, by a roller press similar to that described by Smith (1954). The examination of scales was made by means of a micro-projector at the magnification X43. Ages were determined by counting the annuli and are given in terms of completed years of life. Since all of the fish were taken in late March through early May and no new annulus had formed, the outer edge of the scale was assigned a virtual annulus. Age and growth of the walleye in Lake Winnebago has been reported by Priegel (1969a).

The length measurements of all spawning walleyes were made on fresh specimens. The total lengths were measured to the nearest tenth of an inch on a standard measuring board.

Sex and state of maturity were determined for all fish sampled. Determination of sex was not difficult as milt or eggs could usually be extracted from these spawning walleyes.

Population Estimates

Population estimates of mature male walleyes on Spoehr's Marsh were made, 1964-67. The boom shocker was used for the mark and recapture periods. A caudal or pectoral fin clip was used to mark the fish as the recapture period usually followed within 1 or 2 days after the 1-day marking period.

The population was estimated from the Peterson equation:

$$P = M\ (U + R)/R$$

where M is the number of fish marked during the first period, U is the number of unmarked fish captured during the second period, and R is the number of marked fish recaptured during the second period.

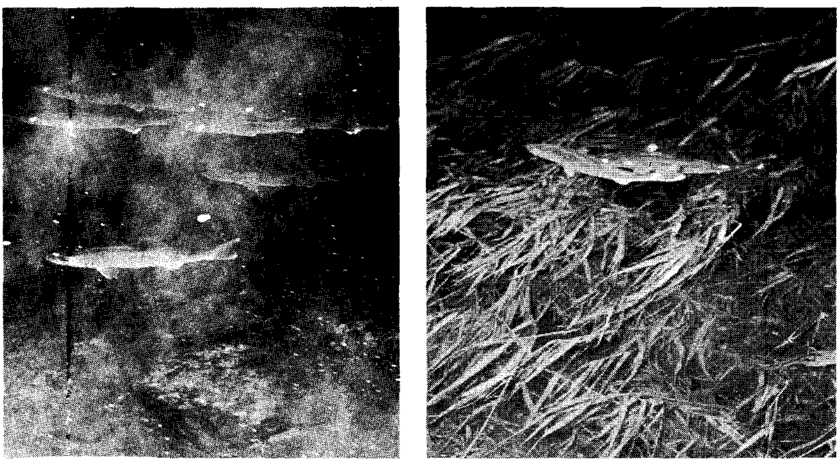
SPAWNING

Spawning Sites

Various workers have reported that walleyes spawn in either streams or lakes, apparently depending upon local conditions. The following are among the spawning sites reported by various workers: at mouths of rivers and creeks (Smith, 1892); on sandy bars in shallow water (Bean, 1903); along the entire shoreline near shore, on gravel bottom (Evermann and Latimer, 1910); on shallow bars or "flats" at the edge of deep water (Miles, 1915); on sticks and stones in running water at the foot of waterfalls (Bensley, 1915); on sand and gravel in shallow water (Henshall, 1919); in lakes over broken rocks at the point where waves break if fish are prevented by weather or other causes from entering streams (Cobb, 1923); in streams or in some cases in shallow sandy bays (Dymond, 1926); anywhere near the mouth of streams where depth and other conditions are suitable or in lakes if fish are prevented by weather or other causes from entering streams (Adams and Hankinson, 1928); in small creeks and rivers or in shallow bays near shore (Bajkov, 1930); in streams on sandy bars in shallow water (Fish, 1932); in tributary streams or in the lake (Stoudt, 1939); on hard bottoms usually in moving water (Hinks, 1943); up tributary streams in riffles or on gravel reefs in shallow waters of the lake (Eddy and Surber, 1947); in a tributary stream over a stony bottom (Derback, 1947); on gravel shoals and bars in a lake or gravel bottom in a stream with a good flow of water (Kingsbury, 1948); along the lee shore of the lake over a bottom consisting of a mixture of gravel, rubble and boulders with a substratum of sand and fine gravel (Eschmeyer, 1950); in tributary streams (Rawson, 1957); in flowing water in streams or along lake shores where wave action keeps the water in motion and the substrate is usually broken rocks or gravel, but may be sand (Niemuth, Churchill and Wirth, 1959); and on gravel bottoms when they are available (Johnson, 1961).

Eschmeyer (1950) reported that in two Michigan lakes, spawning walleyes avoided sand and utilized gravel areas only a few feet in diameter. In Lake Winnibigoshish and Big Cutfoot Sioux Lake, Minnesota, walleye eggs were found frequently on small isolated patches of firm gravel and rubble along extensive shorelines of pure sand where there was little or no spawning (Johnson, 1961).

It is quite apparent that most walleye spawning occurs in streams or along lake shores, over rocks, gravel or sand. Walleye spawn-



In Lake Winnebago, walleyes spawned on gravel bottoms (left) and in marshes along the Fox and Wolf rivers, they spawned on mats of vegetation (right).

ing has also been reported on 2 unusual sites in Wisconsin: in the flooded marsh vegetation of the Wolf River bottoms and in the tangled root masses of bog vegetation in Tumas Lake, Manitowoc County (Niemuth *et al.*, 1959).

Spawning sites considered and examined during the course of this study consisted of the flooded marsh vegetation of the Wolf and Fox river bottoms, the sand and gravel bottoms in the same rivers, and the lake shore of Lake Winnebago. Of these sites, walleyes from Lake Winnebago and connecting waters preferred the flooded marsh areas adjacent to the Wolf and Fox rivers. All of these marshes are located in the flood plain and in most cases are old oxbows that are flooded only during the spring runoff. These marshes are unique in that they are not marsh areas that are just flooded by water overflowing the river banks. These spawning marshes all have an inlet and outlet, thus providing a continuous flow of water over the marsh area during the period of high water levels in the rivers. This flowing water is considered to be the key to spawning success and escapement of the fry to the river.

The dominant vegetation of these marshes where spawning actually occurs consists of reed canary grass, *Phalaris arundinacea* L.; sweet flag, *Acorus Calamus* L.; rice cut-grass, *Leersia oryzoides* (L.) Swartz; and sedges, *Carex* sp. Minor spawning activity has occurred amongst the following vegetation: horsetail, *Equisetum fluviatile* L.; giant burweed, *Sparganium eurycarpum* Engelm;

river bulrush, *Scirpus fluviatilis* (Torr.) Gray; and common cattail, *Typha latifolia* L.

Along the Fox River there are only 6 major spawning marshes (Table 2 and Fig. 1). These marshes range in size from 97 to 748 acres; however, not all of the area is suitable for walleye spawning. Generally 25 to 35 percent of the entire marsh area here and

TABLE 2

Location and Approximate Acreage of Walleye Spawning Marshes Adjacent to the Fox and Wolf Rivers

Index	Local Name	Acreage	River Miles From Lake Winnebago
Fox River:			
1	Hoger Bayou	97	16
2	Carpenter's Marsh	227	20
3	Barbola Marsh	325	25
4	Berlin Marshes	748	33
5	Krueger Marsh	265	38
6	Hopp's Marsh	538	40
Wolf River:			
7	Partridge Lake Marshes	788	33
8	Miller Bayou	85	34
9	Templeton Bayou	600	35
10	Jenny Bayou	445	39
11	Colic Slough	91	40
12	Cincoe Lake Marshes	2,377	42
13	Shirttail Bend Bayou	58	50
14	Hortonville Lake	211	58
15	Hortonville Marsh	1,457	65
16	Strong Bayou	382	81
17	Spoehr's Marsh	348	85
18	Buckstaff Bayou	560	93
19	Topp's Bayou	91	97

along the Wolf River provides suitable spawning vegetation. During years of low water levels, (as in 1961 and 1964), the Eureka Dam is a barrier to migrating walleyes and restricts spawning to the 3 marshes found below the dam. During years of high water levels, walleyes swim over the dam to 1 of the 3 remaining spawning marshes on the Fox River. Of these 3 marshes, Hopp's Marsh, located 40 river miles from Lake Winnebago, is the farthest spawning site of any major importance.

There are 13 major spawning marshes adjacent to the Wolf River; these marshes range in size from 58 to 2,377 acres (Table 2 and Fig. 1). The first spawning area, Partridge Lake Marshes, is located 33 river miles from Lake Winnebago while the farthest marsh, Topp's Bayou, is located 97 river miles from the lake.

When water levels on the Fox River are low, (left) walleyes moving upriver to spawn are stopped at the Eureka Dam. When water levels are high (above), walleyes are able to pass over the dam.

There are no barriers prohibiting walleye movement in this section of the Wolf River. In addition to the 13 marshes listed in table 2, numerous smaller areas are used by spawning walleyes along the Wolf River but they are of minor importance and are generally used only during years of extremely high water levels. As water levels drop, these smaller areas dry up and the eggs, if spawning did occur, are lost.

Low water during the spring of 1964 in the Lake Winnebago area drastically altered the spawning habits of the walleye. The U. S. Army Corps of Engineers personnel at Appleton, Wisconsin reported that March gauge readings at New London were the lowest for that month since 1900. Spawning walleyes could not enter the marshes adjacent to the Wolf and Fox rivers. In the Wolf River, walleyes were observed spawning on sand bars in the main river channel, along the river's banks where grassy vegetation occurred and in the deeper bayous. In the Fox River, walleyes were only observed spawning below the Eureka Dam over sand, rubble and gravel areas.

During the course of this study, 1964 was also the first year that walleyes spawned in Lake Winnebago, along the shoreline over sand, gravel and rubble bottoms, with a preference for gravel and rubble areas. All spawning occurred along the entire west shore (lee shore), a shoreline distance of 28 miles (Fig. 1) and around the islands and reefs off the west shore, over gravel, rubble and boulder bottoms. Trap nets set from 1955 through 1967 provided a means of checking on walleye spawning frequency in Lake Winnebago.

Movements into Spawning Marshes

Spoehr's Marsh, Wolf River

Male walleyes arrived on Spoehr's Marsh first and their numbers increased as the water warmed. Female walleyes were only observed or captured on the marsh during the actual spawning period. The actual distribution of the walleyes on the marsh was determined by the water levels and currents on the marsh (Fig. 2). Water levels, at the time the females enter the marsh, evidently determine where spawning will occur; if water levels are high, fish spawn in shallow areas as far into the marsh as they are able to travel and if water levels are low, the walleyes spawn in the deeper channels leading into and through the marsh.

When spawning females entered Spoehr's Marsh in 1960 (Fig. 3), the water level was recorded at 5.5 feet (water levels here are reference gauge readings, not actual depth of water present on the marsh) and the fish moved as far into the marsh as possible to spawn. Spawning was successful and fry began to migrate out of the marsh until the water level had dropped to 4.0 feet at which time the fry were stranded in shallow areas of the marsh. Heavy rainfall on May 3 raised the water level in the marsh to 8.1 feet and the fry were again able to migrate out of the marsh. In 1961, as the spawning females entered the marsh, water levels were recorded at 4.5 feet and the majority of spawning occurred in the deeper channels leading into the marsh and at the lower end of the main marsh channel (Figs. 2 and 3). Few fish used the shallow areas that were used in 1960. Water levels were recorded at a low of 2.8 feet in 1961 but fry were still able to get off the marsh.

When spawning females entered the marsh in 1962, the water

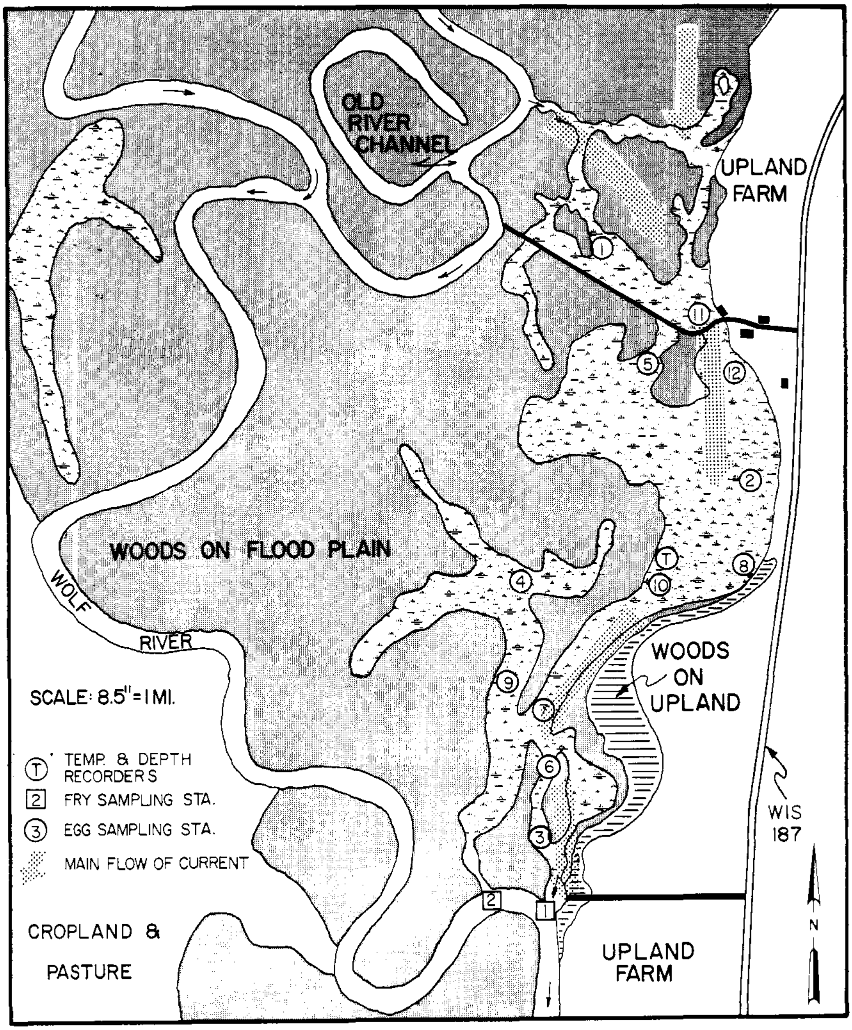


Figure 2. Distribution of current, location of sampling stations, and location of temperature and depth recorders in Spoehr's Marsh, Wolf River.

level was recorded at 5.5 feet and the fish moved as far into the marsh as possible to spawn, as they had done in 1960. Water levels began to decrease from 5.3 feet on April 14 to 4.1 feet on April 23. Although the water level never got below 4.1 feet, heavy egg mortality occurred, as decreasing water levels stranded most of the eggs.

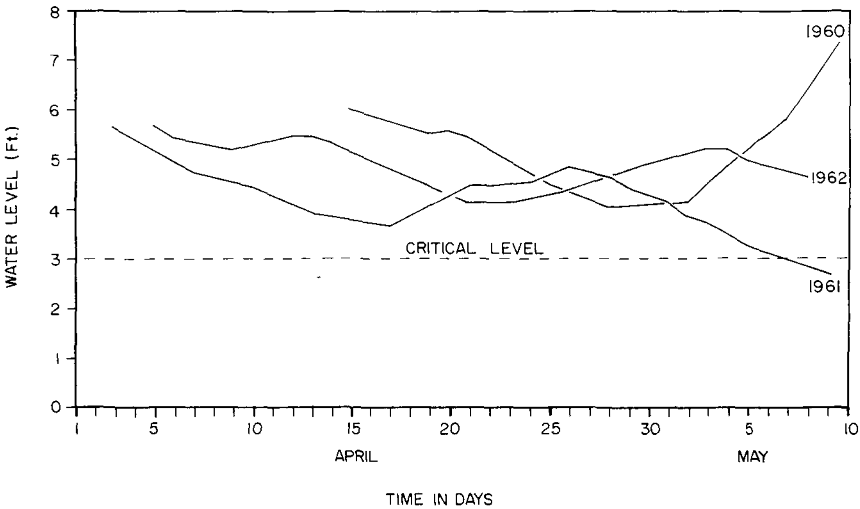


Figure 3. Daily water levels on Spoehr's Marsh, 1960-62.

On April 5, 1963, the water level was 5.0 feet when peak spawning occurred on the marsh (Fig. 4). Walleyes used the same shallow areas as used in 1960 and 1962. By April 15, 1963, the marsh was dry and complete egg mortality occurred. Low water in 1964 prevented the spawning walleyes from even entering the marsh.

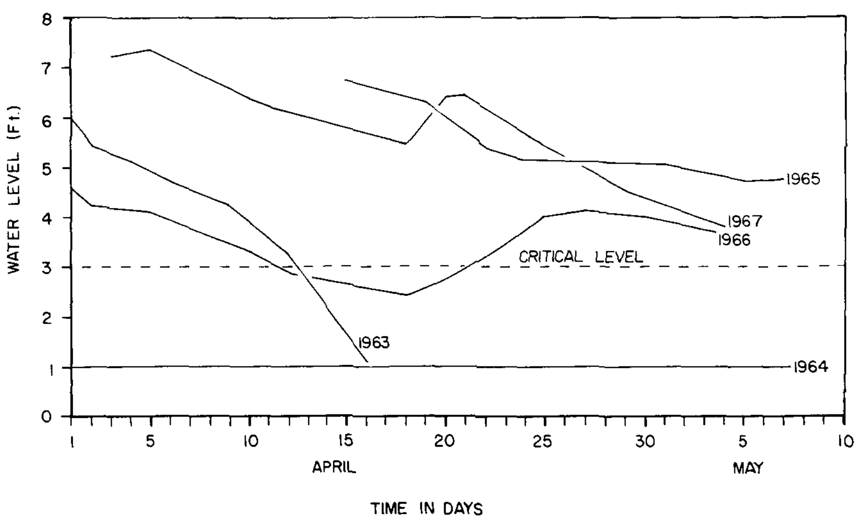


Figure 4. Daily water levels on Spoehr's Marsh, 1963-67.

Water levels on Spoehr's Marsh in 1965 were high (6.8 feet on April 15) when female walleyes entered the marsh and water levels remained high until the fry hatched and were carried out of the marsh (Fig. 4). In 1966, the water level was 4.1 feet when maximum spawning occurred, with most eggs being deposited in the deeper channel areas. By April 18, however, water levels had reached a critical low point (2.4 feet) but began to rise 2 days later so that by April 23, when the first walleye fry was taken, water levels returned to the original level recorded when spawning occurred. Water levels in 1967 were high (6.2 feet) when spawning occurred and remained high during egg development and fry movement out of the marsh.

For the years, 1960-67, when water levels were high (above 5.0 feet), successful spawning was assured only when these levels remained high throughout the spawning season. If water levels were high when walleyes first entered Spoehr's Marsh, the fish moved throughout the marsh to spawn; if water levels then dropped, eggs and fry were stranded and mortality occurred. If water levels were initially somewhat lower (between 4.0 and 5.0 feet), spawning walleyes were forced to utilize the deeper channels leading into the marsh rather than the shallow areas in the upper part of the marsh. These deeper areas allowed eggs and fry to develop successfully even if water levels dropped to 3.0 feet. Ideal

Dredging operations on Spoehr's Marsh in 1964 widened and deepened the inlet of the marsh from a narrow 4-foot channel to an opening about 75 feet wide. The widened inlet (shown above) improved the flow of water through the marsh and made more areas in the marsh accessible to spawning walleyes.

water levels for optimum spawning thus appear to be between 4.0 and 5.0 feet.

Fox River Marshes

During the course of this study, water levels permitted the passage of walleyes over the Eureka Dam during most years; walleyes traveling upriver were stopped at the dam only in 1964. As on Spoehr's Marsh, when water levels were high, spawning occurred as far into the marshes as possible, while low water restricted spawning to the deeper channels.

Spawning Season

During the course of the study, walleyes were observed spawning when water temperatures ranged between 36 and 60 F; during peak periods, however, water temperatures were usually between 42 and 46 F. Other researchers have reported various temperature ranges at which spawning occurred: 38-44, 44-49, and 45-50 F (Eddy and Surber, 1947 and Herman, 1947; Eschmeyer, 1950; and Rawson, 1957, respectively). Minimum and maximum water temperatures at which spawning took place have also been reported as 38 F (Eddy and Surber, 1947 and Herman, 1947) and 58 F (Herman, 1947).

Maximum walleye spawning occurred in April and was completed between April 25 and May 4, depending on the spawning area. Spawning seasons in various out-of-state localities extend from late March to early June, but always include a portion of April and May (Raney and Lachner, 1942; Smith, 1892; Dymond, 1926; and others).

Water temperatures and spawning season length showed the following variations between each of the 3 major spawning areas:

Spoehr's Marsh, Wolf River

The time of spawning varied in different years (1960-67), with the earliest spawning activity noted on April 2 in 1966 and the latest, on April 25 in 1965 (Table 3). The duration of the spawning period varied from 5 to 12 days with a peak occurring over a 1- to 2-day period.

Following the break-up of ice on the Wolf River, a time period of 4 to 20 days occurred before any spawning activity was noted.

TABLE 3

Summary of Information for Walleye Spawning on Spoehr's Marsh, Wolf River, 1960-67

Measurement	1960	1961	1962	1963	1964	1965	1966	1967
Date of Ice Break-up:								
On Wolf River	Apr. 2	Mar. 26	Mar. 31	Mar. 31	Mar. 27	Apr. 11	Mar. 14	Mar. 30
On Lake Winnebago	Apr. 13	Mar. 26	Apr. 15	Apr. 3	Mar. 25	Apr. 15	Mar. 20	Apr. 2
Dates of Spawning Period:**								
Duration	Apr. 17-21	Apr. 8-18	Apr. 12-19	Apr. 3-8	Apr.12-17	Apr.18-25	Apr. 2-13	Apr. 8-15
Peak	Apr. 18	Apr. 12-13	Apr. 16	Apr. 5	Apr. 14-15	Apr. 21	Apr. 5-6	Apr. 11-12
Date of Stages in Early Development:								
First Eyed Eggs	Apr. 25	Apr. 25	Apr. 25	Apr. 13	*	May 4	Apr. 18	Apr. 24
First Fry	Apr. 28	May 2	Apr. 28	*		May 5	Apr. 23	Apr. 26
Range of Water Temperature (in F):								
During Spawning Period	42-54	36-50	36-54	42-54	*	43-48	40-47	40-52
During Egg Development	45-66	36-60	36-60	36-55	*	41-58	40-52	44-56

* Marsh dry; no sampling possible.

**In 1964, spawning occurred in the river since the marsh was dry.

Male walleyes, however, would move into the marsh as soon as it was free of ice. Males were observed on the marsh when water temperatures were 36 F in 1961 and 1962. Water temperature during spawning ranged between 36 and 54 F.

Fox River Marshes

Spawning on the Fox River marshes varied in different years between March 30 and April 28; in most years it was completed by mid-April (1960-67). The duration of the spawning period varied from 6 to 16 days with a peak occurring over a 1- to 2-day period (Table 4).

A time period of 2 to 29 days occurred after the break-up of ice on the Fox River before any spawning activity was noted. Water temperature during spawning ranged between 38 and 60 F.

Lake Winnebago

The earliest spawning in Lake Winnebago was noted on April 7, 1966 and the latest was observed on May 4, 1965 (Table 5). Spawning occurred over a 9- to 23-day period with most spawning occurring in April. Peak spawning was noted over a 2-day period in all years (1964-67).

Following the break-up of ice on the lake, a time period of 6 to 19 days occurred before any spawning activity was observed. Male walleyes were noted along the shoreline before any spawning activity was observed. Water temperature during spawning ranged between 39 and 52 F.

Spawning Behavior

Walleyes arrived on Spoehr's Marsh immediately after the break-up of the ice on the Wolf River and as soon as the marsh was flooded. Even though the marsh bottom was frozen, male walleyes arrived and stayed on the marsh. Net and angler tag returns indicated a migration of walleyes out of Lake Winnebago into the rivers and upriver lakes during the late fall and winter (Priegel, 1967-68).

Male walleyes arrived on the marsh first and their numbers increased as the water warmed. Daylight and night electrofishing showed that once the males arrived on the marsh there was no mass movement off the marsh during daylight hours and then a movement back into the marsh at night. Eschmeyer (1950) noted

TABLE 4

Summary of Information for Walleye Spawning on Fox River, Marshes, 1960-67

Measurement	1960	1961	1962	1963	1964	1965	1966	1967
Date of Ice Break-up:								
On Fox River	Apr. 5	Mar. 10	Mar. 25	Mar. 27	Mar. 11	Apr. 6	Mar. 12	Mar. 30
On Lake Winnebago	Apr. 13	Mar. 26	Apr. 15	Apr. 3	Mar. 25	Apr. 15	Mar. 20	Apr. 2
Dates of Spawning Period:								
Duration	Apr. 12-17	Mar. 31-Apr. 8	Apr. 9-15	Apr. 2-7	Apr. 8-14	Apr. 13-28	Mar. 30-Apr. 10	Mar. 31-Apr. 9
Peak	Apr. 14-15	Apr. 3	Apr. 11	Apr. 3	Apr. 10-11	Apr. 17-18	Apr. 3-4	Apr. 3-4
Date of Stages in Early Development:								
First Eyed Eggs	*	*	May 1	Apr. 13	*	May 6	*	Apr. 17
First Fry	*	*	*	*	*	*	*	*
Range of Water Temperature (in F):								
During Spawning Period	40-54	38-50	42-50	40-52	42-50	41-58	40-56	43-60
During Egg Development	42-59	44-62	41-60	44-58	40-60	42-60	44-59	43-64

* No eyed eggs or fry found.

TABLE 5

Summary of Information for Walleye Spawning in Lake Winnebago, 1964-67

Measurement	1964	1965	1966	1967
Date of Ice Break-up on Lake Winnebago:	Mar. 25	Apr. 15	Mar. 20	Apr. 2
Dates of Spawning Period:				
Duration	Apr. 11-24	Apr. 20-May 4	Apr. 7-29	Apr. 8-16
Peak	Apr. 16-18	Apr. 21-22	Apr. 13-14	Apr. 12-13
Date to First Eyed Eggs:*	May 1	May 2	Apr. 28	Apr. 28
Range of Water Temperatures (in F):				
During Spawning Period	42-52	42-46	44-51	39-46
During Egg Development	41-55	42-50	43-51	40-51

* Date to first fry could not be determined as had been done on the Fox and Wolf rivers, since fry from the Wolf River had already entered the lake before fry from Lake Winnebago spawning sites were observed.

in Lake Gogebic that although most walleyes retreated to deep water during the day, small numbers of fish were occasionally seen on the spawning sites during daylight hours, depending on the visual acuity of the observer. Male walleyes were on the marsh continuously from the time the marsh was first flooded until after all spawning activity had terminated. In most years males will be found on the marsh over a 3- to 4-week period. During years of extremely high water as in 1962, male walleyes will remain on the marsh over a 6- to 8-week period; however, their numbers will diminish rapidly after major spawning activity ceases.

Female walleyes were only taken with electrofishing gear during the actual spawning period on the marsh. Most females when taken on the marsh were in the "ripe" condition. Hard females were usually found only near the outlet of the marsh, either in the adjacent river channel or in deeper areas of the marsh. On numerous occasions when the marsh was electrofished, a hard female was taken, finclipped or tagged, released and recaptured the same day in the "ripe" condition or in the actual act of spawning. There is a strong indication that female walleyes move into the marsh only when spawning is imminent, spawn and then leave the marsh immediately, all within a 1-day period.

Walleyes are essentially nocturnal spawners (Eschmeyer, 1950), usually vacating their shallow water spawning grounds during the day. This behavior pattern implies 1 of 2 possibilities: if spawning takes only 1 night to complete, then the fish leave and are replaced later by other fish or if spawning takes more than 1 night to complete, then the same fish leave the spawning grounds during the day and return again at night. Females can spawn out completely in 1 night whereas males have the potential for spawning over a longer period (Ellis and Giles, 1965).

The literature on walleyes suggests that it is not a territorial fish at spawning time (Eschmeyer, 1950), but that some slight form of courtship behavior occurs among grouped fish at night over shallow spawning grounds. In addition, the rather drab coloration and lack of specific color patterns which might serve as social releasers (Baerends, 1957) support the implication in the literature that a complex courtship ritual does not take place. Ellis and Giles (1965), having clearly seen the simultaneous release of eggs and milt, described walleye spawning as a series of synchronized acts by promiscuous groups of fish. Each act was preceded by simple short courtship consisting of approaches and bodily contacts between individuals. There was no indication of territorial defense, even though some fish would maintain position for hours on end. Ellis and Giles (1965) also recognized a dial behavioral cycle shown by walleyes on natural spawning grounds in experimental tanks and in a stream compound. The cycle consisted of low activity in daytime, expressed mainly by position-holding, and increased activity in the evening, expressed by courtship behavior. Under experimental conditions, courtship either led to spawning or diminished gradually under consummation.

On Spoehr's Marsh, walleyes were essentially nocturnal spawners; however, some spawning behavior was noted each year during daylight hours. Numerous spawning acts were observed which were similar to those described by Ellis and Giles (1965) and Eschmeyer (1950). Each act was preceded by a short courtship consisting of approaches and body contact between individuals followed by an upward rush of grouped spawners, with their dorsal fins and backs frequently breaking the water surface. On most occasions observed, two males, one on each side of the female, would participate in the spawning act as they rose above the surface, thrashed vigorously forward for a few seconds, then settled below the surface to repeat the performance. The two males and female would be extremely close to each other and their vents, adjacent. It was difficult to count the actual number of males associated with the courtship because of the vigorous action occurring; however, once the upward rush began, only two males accompanied each female with the rest of the males following in close pursuit.

During daylight hours, male walleyes could be seen lying motionless in the marsh and could be approached easily if no startling motion or noise was made.

Eschmeyer (1950) noted that walleyes were very sensitive to light and quickly attempted to escape. However, on Spoehr's Marsh, when using a hand flashlight, one could approach walleyes to the point that the fish could be captured by hand if no sudden movements or noises were made. On other occasions, the fish would move slowly a short distance when exposed to the light.

In Lake Winnebago, when the shallow water areas along the shoreline were electrofished during daylight hours, male walleyes could be readily captured along with a few hard females. If the same area was reshocked during the night, approximately the same number of male walleyes would be captured but there would be an increase in the catch of hard, ripe and spent female walleyes. There was no indication that male walleyes left the spawning areas during the day to retreat to deeper water. The majority of spawning in Lake Winnebago occurred during the night; however, some spawning was observed during daylight hours each year.

Sex Ratio on the Spawning Sites

During sampling of walleyes on the spawning grounds, we found that males comprised a large proportion of the spawning population. On Spoehr's Marsh, 94.2, 86.4, 95.4, 92.1 and 97.7 percent were males for the years 1963-67, respectively. On Hopp's Marsh, 90.5, 86.2, 81.5 and 79.3 percent were males for 1963 and 1965-67, respectively. On Lake Winnebago, 85.4, 82.4, 92.1 and 70.5 percent were males for 1964-67, respectively.

These percentages found do not, however, represent accurate sex ratios of walleyes on the spawning run. Such sex ratios are difficult, if not impossible, to obtain for 3 reasons: (1) On the one hand, males arrive on spawning marshes or sites before the females do and they remain there throughout most of the spawning season. On the other hand, females move on to the spawning areas, spawn, then leave immediately. So, on the basis of different spawning behavior for the 2 sexes, there will always be more males than females on natural spawning areas. (2) Males also begin to reach sexual maturity at the end of their third year of life, and are completely mature by the end of their sixth year. Females, however, begin to reach maturity at the end of their fourth year of life and all are mature at the end of their eighth year (Priegel, 1969a). Because they mature earlier than females, more male walleyes will be found on the spawning run. (3) Most spawning areas, such as the marshes and lake sites in this study, are too large to permit a statistically large enough sample of spawning walleyes to be captured. Other researchers have reported sex ratios of males to females varying from 3:1 to 13:1 (Eschmeyer, 1950; and Schneberger, 1938, respectively), but these ratios may not be entirely accurate because the size of the area trapped is not known. Only on spawning areas which are confined artificially by means of nets, or naturally, by the presence of a dam, can a thoroughly random and accurate proportion of the spawning walleyes be sampled.

Age Structure of Spawning Population

Age Frequency

The dominant age groups in the spawning population for males and females were VI through VII on all waters sampled except for a few years when the strong 1959 year class appeared in the spawning population as age group V. Rawson (1957) reported that the dominant age group for spawning walleyes in Lac LaRange, Saskatchewan were age groups VIII to X and that few walleyes of age group V were present on the spawning run. Priegel (1966) found age group VII to be the dominant one for males and females on Lake Puckaway.

Spoehr's Marsh, Wolf River. During the spawning period, 1963-67 on Spoehr's Marsh, a sample was taken to determine the age frequency of the spawning population. Although sampling took fewer females than males, age groups VI through VIII comprised 46.8 to 88.9 percent of the females taken (Appendix A). In 1964, age group V accounted for 53.1 percent of the females and this represented a strong 1959 year class initially entering the spawning population in any numbers. Only 1 female in age group IV was taken and this fish was taken in 1963, representing the 1959 year class.

Age group VI through VIII accounted for 36.3 to 100.00 percent of the male walleyes in the marsh (Appendix A). In 1964, age group V comprised 59.5 percent of the male population, representing a large 1959 year class. Three-year-old males were taken in 1964 and 1967. It is quite evident that the 1957, 1958 and 1959 year classes were large and comprised the bulk of the males on the spawning marsh in all years sampled, 1963-67.

Hopp's Marsh, Fox River. Age frequency of walleyes using Hopp's Marsh was obtained in 1963 and 1965-67. The marsh was completely dry in 1964. Most of the female walleyes were represented by age groups VI through VIII, comprising 66.6 to 91.9 percent of the population (Appendix A). No females from age group IV were taken on Hopp's Marsh.

In most years, male walleyes were made up of age groups VI through VIII accounting for 52.8 to 93.5 percent of the males taken (Appendix A). A strong 1959 year class (age group IV) accounted for 35.6 percent of the males in 1963.

The 1957, 1958 and 1959 year classes were large and represented most of the male and female walleyes taken in the samples.

Lake Winnebago. The first recorded walleye spawning in Lake Winnebago occurred in 1964 and the entire population as determined from our sample consisted of age group V for males and females, representing a strong 1959 year class (Appendix A). The 1959 year class continued to dominate in the Lake Winnebago spawning population for the remainder of the years studied. Although the 1957 and 1958 year classes appeared as strong year classes in the spawning population on Spoehr's and Hopp's marshes, very few fish from these year classes were taken in Lake Winnebago.

Migration of Age Groups

To determine the nature of walleye migration out of Lake Winnebago into the Fox and Wolf rivers, scale samples were taken from spawning walleyes in various marshes along the rivers in 1965-67 (Appendix A). Two general tendencies were noted: (1) Younger fish, particularly those in age groups III and IV, migrated into the Fox River, while older age groups migrated into the Wolf River. (2) Younger age groups also stayed in the lower stretches of both rivers, while older fish migrated further upstream.

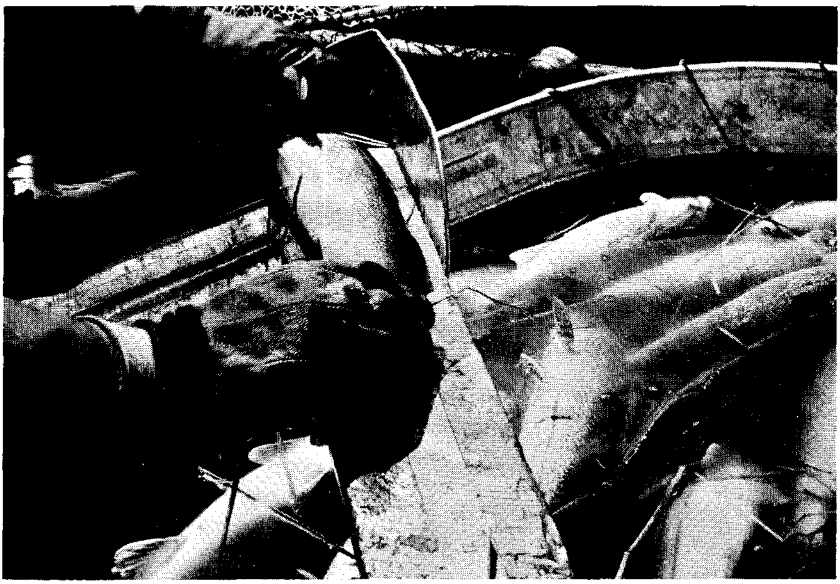
Specific differences in age group migration were observed between walleyes in the Fox River and those in the Wolf, as follows:

On the Wolf River, Hortonville Marsh is located 61 river miles from Lake Winnebago while Spoehr's Marsh is 85 miles from the lake. In 1966, on Hortonville Marsh, 9.3 percent of the males were in age group III while no age group III males were taken on Spoehr's Marsh. Age group IV comprised 23.1 percent of males on Hortonville Marsh in 1966 as compared to 3.9 percent on Spoehr's Marsh. In most years, more fish from age groups III through VI were found on Hortonville Marsh than were found on Spoehr's Marsh.

On the Fox River, samples were taken on marshes just below the Berlin Dam (33 river miles from Lake Winnebago), on marshes just above the Berlin Dam and on Hopp's Marsh, 40 river miles from the lake. In 1965, of the male walleyes taken just below the Berlin Dam, 7.9 percent were in age group III; of those males taken above the dam, 2.9 percent were in age group III. No age group III fish was ever taken in Hopp's Marsh, 1965-67. Only in 1966, did male walleyes from age group IV occur in the sample from Hopp's Marsh where this age group represented 5.7 percent of the males as compared to the same age group which comprised 33.9 percent of the males taken just above the Berlin Dam. From 1965 through 1967, very few male or female walleyes in age groups III to V utilized Hopp's Marsh.

Length Frequency of Spawning Population

On Spoehr's Marsh, male walleyes between 15 and 18 inches comprised 66.0, 43.2, 62.9, 67.0 and 68.5 percent of the males taken from 1963 through 1967, respectively (Appendix B). On Hopp's Marsh, Fox River, the majority of male walleyes were between 15 and 18 inches; this majority ranged from 59.7 percent in 1963 to 80.4 percent in 1966 (Appendix B). In Lake Winnebago, spawning males between 13 and 16 inches comprised 90.2, 94.3, 80.9 and 58.3 percent of the population for 1964-67, respectively (Appendix B). Few male walleyes under 12 inches were taken



All mature walleyes captured in the marshes or Lake Winnebago were measured to the nearest tenth of an inch to determine the length frequency of the spawning population.

in all waters sampled and the smallest fish was a 10.7-inch male taken from Lake Winnebago in 1967. No male walleyes over 19 inches were captured in Lake Winnebago and few male walleyes over 20 inches were taken in the Wolf or Fox rivers. The largest male was 21.8 inches taken on Spoehr's Marsh in 1966.

The average length of male walleyes taken on Spoehr's Marsh from 1963 through 1967 was 16.5, 16.2, 17.1, 17.2 and 17.4 inches, respectively. On Hopp's Marsh, the average length was 16.4 inches in 1963 and 16.7, 16.1 and 16.9 inches in 1965 through 1967, respectively. In Lake Winnebago, the average length of male walleyes from 1964 through 1967 was 14.2, 14.6, 15.1 and 15.7 inches, respectively. The strong but slow-growing 1959 year class dominated the male population in Lake Winnebago.

The length frequency for female walleyes taken on Spoehr's and Hopp's marshes varied each year, mainly because the number of females captured were few compared to the number of males captured. No female walleyes under 15 inches were taken on either Spoehr's or Hopp's marshes. The largest female captured measured 28.7 inches and was taken from Spoehr's Marsh in 1967. The average length for females taken on Spoehr's and Hopp's marshes for the various sampling periods between 1963 and 1967 ranged between 19.6 and 21.7 inches.

Spawning female walleyes captured in Lake Winnebago were considerably smaller than those taken on the spawning marshes. The average lengths were 15.7, 16.8, 17.9 and 19.0 inches for the years 1964-67, respectively. In 1964, 71.4 percent of the females were under 15 inches. A strong but slow-growing 1959 year class dominated the spawning population of females as well as males in Lake Winnebago.

Rawson (1957) reported that in Highway Creek, Saskatchewan, most of the males were from 15 to 24 inches in fork length and averaged 19.2 inches, while the females were mainly from 18 to 26 inches, averaging 21.7 inches. In Lake Gogebic, Michigan (Eschmeyer, 1950) male walleyes ranged from 12.2 to 22.1 inches in total length and averaged 16.9 inches; females ranged from 15.4 to 28.8 inches and averaged 18.8 inches. In Dixon Lake, Minnesota, Stoudt (1939) found 2,075 males to average 17.2 inches in total length and 20 females to average 18.4 inches. Measurements of 11,611 male and 6,254 female spawning walleyes from 15 localities in Minnesota showed the average total lengths to range from 15 to 21.5 inches and 16.5 to 24.7 inches, respectively (Smith and Carlander, 1943). Of the 1,168 walleyes tagged on Lake Puckaway during the spawning seasons, 1961-64, 181 (15.5 percent) were under 17 inches (Priegel, 1966).

Population Estimates

The size of the population of male walleyes taken on Spoehr's Marsh during the spawning season was calculated for 1965 through 1967. Only males were considered, since too few females were taken to obtain reliable data. Those females that were found, remained on the Marsh for too short a time to be accurately sampled.

On April 19, 1965 Spoehr's Marsh was boom shocked over an area of approximately 60 acres and 156 male walleyes were marked. On April 20, the marsh was again boom shocked and 413 male walleyes were taken, of which 15 had been marked the day before. The male population was estimated to be 4,228.

In 1966, 300 male walleyes were marked on April 4, and on April 5, 366 male walleyes were taken, of which 17 were recaptures. The 1966 population estimate was 6,458 male walleyes.

On April 11, 1967 we marked 341 male walleyes. On the second run (April 12) 193 males were taken, of which 12 were recaptures. The 1967 population estimate was 5,484 male walleyes. The size of the male population on Spoehr's Marsh was relatively stable during the 3-year period.

To estimate the size of the male walleye population on Spoehr's Marsh, the pectoral or caudal fins of fish captured by boom shocking were clipped. From the number of these marked fish recaptured during a second boom shocking, population estimates could be made.

Movement Before and After the Spawning Season

Eschmeyer (1950) reported that walleyes dispersed widely in Lake Gogebic following the spawning season, while in the Muskegon River there was a wide variation in the rate of downstream migration from the spawning grounds, although most fish had left the river by June 1. In Lake Winnibigoshish, Minnesota (Stoudt, 1939) and Spirit Lake, Iowa (Rose, 1949), walleyes were observed to distribute themselves widely within a short time after spawning. In Lac LaRange, Saskatchewan there was a gradual return to the main lake after spawning (Rawson, 1957). In Scriba Creek (Oneida Lake, New York), the spawning population showed a gradual dispersal from the spawning area in May and June, and attained its widest distribution in late summer (Forney, 1963).

Herman (1947) found that the majority of the walleyes returned almost immediately to Lake Winnebago after spawning in the Wolf River marshes. During the course of this study there was sufficient evidence to show that after spawning, female walleyes leave the marsh immediately and begin to migrate back to Lake Winnebago. Male walleyes, although they do remain on the marsh after all spawning has been completed, return almost immediately to Lake Winnebago as soon as they leave the marsh. When water levels are high as in 1960 and 1965, males will remain on the marshes through late May even though spawning is completed by early May.

From Priegel's 1967-68 report on 14,885 walleyes tagged in Lake Winnebago and connecting waters in 1960 through 1964, findings pertinent to the movements of spawning walleyes are presented as follows: Migration of walleyes out of Lake Winnebago into the upriver lakes and rivers during the late fall and winter was expected but the extent was unknown. During tagging operations on Lakes Poygan and Winneconne in January and February of 1961, 12 walleyes previously tagged in Lake Winnebago during the fall of 1960 were taken, while in January and February of 1963, 9 walleyes previously tagged in Lake Winnebago during the fall of 1962 were taken in commercially fished nets. Returns of walleyes tagged in Lake Winnebago during the fall of 1960, 1961, and 1962 and walleyes taken by angling through the ice in the upriver lakes during the following winter were 19.9, 3.3 and 4.7 percent, respectively, of the total annual returns from the upriver lakes. Angler returns also indicated that of the walleyes tagged in Lakes Poygan and Winneconne, only 14.9 percent and 13.8 percent, respectively, were caught in these lakes. Angler returns of walleyes tagged in Lake Poygan showed that 62.5 percent came from the Wolf River and 9.2 percent came from Lake Winnebago; angler returns of walleyes tagged in Lake Winneconne showed that 54.0 percent came from the Wolf River and 20.7 percent came from Lake Winnebago. Net and angler returns seem to indicate an extensive migration of walleyes out of Lake Winnebago during the late fall and winter into the upriver lakes.

Frequently the question regarding the taking of female walleyes during the spawning migration before they had a chance to spawn comes up for discussion. Tag returns from anglers which provided the length of the fish in inches and date of capture during the spawning period on the Wolf River in 1961, 1962 and 1963, were tabulated from ice-out to May 1 to determine when the majority of female walleyes were caught — before or after spawning. All fish over 19 inches were considered females as determined from age and growth studies (Priegel, 1969a). Of all the tagged females reported, 68.5, 84.2, and 80.7 percent were taken after the spawning period for the years 1961, 1962 and 1963, respectively. Most of the tagged males were also taken after, not before the spawning season: 62.6, 89.2 and 87.1 percent were taken after spawning had occurred for the years 1961, 1962 and 1963, respectively. Based on these tag returns, it is clear that spring angling harvest has little impact on the degree of reproductive success of the walleye population in the Wolf River. Although tag returns from the Fox River were so few that comparable percentages could not be computed, it is likely that pre-spawning fishing pressure also has little impact on walleyes moving up the Fox River.

Angler exploitation of walleyes was consistently higher during the spawning migration period than during the nonmigratory season. Spawning migration occurred in April and May, in 1961 through 1965; migration occurred earlier (March and April) in 1966, due to an early breakup of ice on the rivers. Angler returns of tagged walleyes during the spawning migration ranged from 33.3 percent of the total in 1961 to 63.9 percent of the total in 1966.

The walleye spawning run up the Wolf River is on! Tag returns from anglers have shown that although fishing pressure in spring is high, it does not harm the spawning population of walleyes on this river.

The tendency of the walleye to return to specific spawning areas in lakes and streams has been noted by several investigators: Stoudt, 1939; Stoudt and Eddy, 1939; Eschmeyer, 1950; Smith, Krefting and Butler, 1952; Eschmeyer and Crow, 1955; Rawson, 1957; Olson and Scidmore, 1962; Crowe, Karvelis and Joeris, 1963; and Forney, 1963. All observed that stream-spawning walleyes tagged on specific spawning grounds tended to return to them.

The tendency for spawning walleyes to return to the spawning area where they had been marked in previous years, or at least to utilize the same major river, was also noted in the Lake Winnebago area. On Hopp's Marsh, Fox River, 9 of 13 recaptures taken with electrofishing gear during the spawning period were originally tagged and released on Hopp's Marsh. On Spoehr's Marsh, Wolf River, 4 of 27 captures taken with electrofishing gear during the spawning period were originally tagged and released on that marsh. None of the 322 walleyes tagged during the spawning period in 1962 and 1963 on Fox River marshes were ever recaptured by anglers or project personnel in the Wolf River or adjacent marshes, although 24 percent were returned by anglers from Lake Winnebago and the Fox River. A single fish was returned from Lake Poygan. None of the 235 walleyes tagged on Wolf River marshes were ever recaptured in the Fox River or adjacent marshes, although 8 percent were returned from the Wolf River and downstream lakes.

EGGS

Egg Development

Walleyes broadcast their eggs and exercise no parental care. The eggs ordinarily lie loose upon the substratum; in the spawning marshes this substratum consists of grasses and sedges which actually act as mats. The eggs lie loosely on these dense vegetative mats and do not lie on the actual bottom of the marsh.

Reighard (1890) stated that when first laid, the eggs are very adhesive and added (1893) that for the first hour or two, the eggs adhere to one another and to the vessel which contains them. Water then hardens the external egg membrane and its loses its adhesive qualities. The reason for the infrequent observation of adherent eggs on spawning sites is that most collections are made several hours after spawning has occurred.

Live walleye eggs are hyaline and turgid early in development but often are flaccid during the eyed stage, especially just before hatching. Dead eggs first show a small white speck (the dead embryo) and later become milky-white and completely opaque. In later stages of deterioration the eggs are usually covered with fungus.

With an egg basket, eggs were readily taken on all spawning sites and on all types of substrates. The egg basket was pushed through the dense vegetative mats or scraped along the gravel bottoms to disturb the eggs and substrate, and was then passed through the resulting roily area to collect any eggs brought temporarily into suspension. Since the specific gravity of walleye eggs is a little greater than the specific gravity of water, eggs can be effectively collected by means of an egg basket even when they are relatively scarce.

On Spoehr's Marsh, eyed eggs were found 7 to 14 days after the peak spawning period; however, in most years 13 to 14 days were required before the eggs became eyed (Table 3). The first fry were taken from 10 to 20 days after the peak spawning period. Water temperatures during egg development ranged between 36 and 66 F. In 1960, water temperatures during egg development

An effective technique for collecting walleye eggs involves agitating bottom substrates with an egg basket. Any eggs present will become temporarily suspended in the water and will settle into the basket where they can be easily seen.

ranged between 45 and 66 F with very little fluctuation in daily temperatures. This resulted in the appearance of eyed eggs 7 days after peak spawning and the appearance of fry, 3 days later. Since the marsh is shallow (under 3 feet in most areas), daily water temperatures fluctuate greatly, warming during the day and cooling during the evening.

In Lake Winnebago, eyed eggs were first noted 1 to 16 days after the peak spawning period, 1964-67, with water temperatures ranging between 40 and 55 F during egg development (Table 5). Although some eyed eggs were found on Hopp's Marsh in 1962, 1963 and 1967, a definite time period from spawning to the appearance of the first eyed eggs could not be established for two reasons: (1) Actual spawning was not observed, so the beginning dates of the time period could not be determined. (2) Even if spawning had been observed, a time period would have been difficult to establish, since mortality occurred before most eggs reached the eye stage.

On Spoehr's Marsh from 1960 through 1964 and on Lake Winnebago from 1964 through 1967, egg development was recorded from sampling stations throughout the marsh or along the shoreline where large numbers of eggs could be readily taken with an egg basket immediately after walleyes were known to have spawned in the area. In 1965, a new technique was used on Spoehr's Marsh that enabled us to follow the egg development of known-age eggs. Taken from ripe females captured by boom shocking, the walleye eggs were fertilized, allowed to harden and then placed on mats. The eggs settled quite firmly among the nylon fibers. Usually 12 mats were placed in various locations in Spoehr's Marsh (Fig. 2). The mats provided a means to successfully follow egg development.

A few estimates have been published on the egg production of the walleye, but most of these estimates have been on a small number of fish and the size range has been limited. Vessel and Eddy (1941) who had the largest sample (62 fish) from Cut-Foot Sioux Lake,* Minnesota, estimated the egg production of walleyes weighing 1.5 to 5.0 pounds at 39,000-128,000 eggs. Eschmeyer (1950) estimated egg production from Lake Gogebic, Michigan walleyes (34 fish) at 36,871-154,906 eggs for fish from 16.0-22.9 inches in total length. Smith (1941) calculated that 3 Norris Reservoir walleyes of 25.0-26.5 inches in total length produced from 77,500-87,400 eggs.

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*This lake has apparently been renamed and respelled. Later literature refers to it as either Little or Big Cutfoot Sioux Lake.

In Lake Winnebago, the number of eggs produced was estimated for female walleyes measuring from 16.5 to 25.4 inches in total length. Egg production ranged from 43,255 eggs for a 17.4-inch, 1.50-pound walleye to 227,181 eggs for a 24.2-inch, 5.20-pound walleye and averaged 113,404 eggs per female (Priegel, 1969a).

Factors Influencing Egg Survival

Bottom Type

Johnson (1961) reported that walleye egg survival was present on the soft muck-detritus bottom, was intermediate on firm, clean sand bottom and was best on clean gravel-rubble bottom as observed in Lake Winnibigoshish, Minnesota and connecting water over a 4-year period. The obvious physical differences between the bottom types were mainly in bottom firmness, amount of organic material and particle size and shape.

In Lake Winnebago, walleyes used clean gravel-rubble bottoms which were always available and were ideal for spawning.

In the spawning marshes, the dead grasses and sedges mentioned earlier acted as mats and prevented the eggs from coming into contact or resting on the soft muck-detritus bottom normally found in these marshes. Eggs deposited on these grass-sedge mats were free from organic materials and were subject to a free flow of water at all times.

Walleyes at times would spawn in flooded woody areas in the marsh where grasses and sedges were absent. Here the bottom was soft muck-detritus. Since eggs came into direct contact with this bottom type, mortality was high. In most years, these areas dried up before the eggs hatched. Even when water levels were sufficient, eggs failed to survive.

In all of the marshes along the Wolf and Fox rivers, plant succession is constantly changing the marsh area from desirable spawning habitat of grasses and sedges to undesirable habitat of woody vegetation. When in the past, the walleye spawning marshes were harvested for marsh hay, they used to be maintained in grass rather than woody vegetation. Such harvesting, however, is no longer practiced.

In 1964, when the marshes were dry along the Wolf River, walleyes were observed spawning on sand bars in the main river channel, along the river's banks where grassy vegetation occurred and in the deeper bayous. Egg development was followed in numerous areas but no indication of a hatch was found. In the deeper bayous, the eggs were deposited on silt bottoms where they

In 1963, Spoehr's Marsh was burned to halt plant succession which was converting the marsh to an undesirable walleye spawning area. The controlled burn removed woody vegetation and accumulations of organic matter, both of which were restricting or encroaching upon habitat suitable for spawning.

Not only did the burn open up more of the marsh to spawning walleyes, but it also permitted fresh growth of the grassy vegetation on which optimum spawning occurs.

were soon covered with fungus. When deposited on sand bars, eggs were soon washed off by water current; they eventually settled on detritus substrate in deeper holes where heavy egg mortality was noted. Those eggs deposited in grassy vegetation along the banks were soon left high-and-dry as the water receded.

Water Temperature

According to Johnson (1961), egg mortality, especially as associated with unusually cold water during the egg incubation period, may be an important factor in the establishment of year classes. He noted that survival was best in years of warmer water and shorter incubation periods.

In 1947, Derback noted the adverse effect of cold weather on walleye spawning and indicated that a poor walleye hatch in Heming Lake, Manitoba, in 1947 was mostly due to a cessation of walleye spawning after the onset of cold weather. The cold weather lasted about a week and after temperatures rose again, the run was not resumed. Walleyes taken later in June were resorbing their eggs. Doan (1942) observed no relation between spring air temperature and subsequent size of walleye age classes in Lake Erie.

Cold weather prolonged spawning on Spoehr's Marsh in 1961 and 1966 when active spawning was noted over an 11- and 12-day period, respectively, while in other warmer years, active spawning occurred over a 5- to 8-day period. Although cold weather prolonged spawning activity on Spoehr's Marsh, it never inhibited it over an extended period of time.

A Taylor thermometer suspended one foot below the surface was used on Spoehr's Marsh to record water temperatures during spawning and embryo development in 1960, 1961 and 1962 (Appendix C). Wide variations in minimum and maximum water temperatures occurred. In 1965, 1966 and 1967, a Ryan 30-day thermometer was used and this instrument was placed on the bottom of the marsh. With the Ryan, there was little variation in minimum and maximum water temperatures (Appendix C).

It was apparent that most rapid embryo development and short incubation periods were associated with daytime water temperatures above 50 F and high minimum water temperatures that did not fall below 45 F for any extended time. During the extended embryo development period in 1966, there was slightly greater variation between daily minimum and maximum water temperatures when compared to 1965 and 1967.

A Ryan 30-day thermometer was used in Lake Winnebago to record water temperatures during the spawning and embryo development periods (Appendix C). The instrument was set about one foot off the bottom. There was little variation between daily minimum and maximum water temperature in Lake Winnebago during this period in 1965, 1966 and 1967 so that no correlation could be made between embryo survival and water temperature. There was very little fluctuation in water temperatures in Lake Winnebago as compared to water temperatures in Spoehr's Marsh.

Water Levels

Walleye eggs were usually found where the water was between 12 and 30 inches deep but in years of low water numerous eggs were spawned on gravel in water as shallow as 2 inches in Lake Winnibigoshish (Johnson, 1961); however, fluctuations of water levels during the spawning period did not appear to have been an important factor in spawning success. On Spoehr's Marsh and all other marshes along the Wolf and Fox rivers, water levels on the marshes are a major factor in spawning success. Water levels were not an important factor in spawning success in Lake Winnebago.

When water levels were high, walleyes spawned as far into Spoehr's Marsh as they could go (Figs. 3 and 4). Water depth in most areas was under 2 feet. As water levels began to subside, the eggs were deprived of water and quickly dried up. No eggs hatched in 1963 when the marsh dried up completely after all spawning had occurred. Water levels were so low in 1964 that no spawning occurred on the marsh. Water sufficient to force the spawning walleyes to spawn in the deeper channels of the marsh is required if a successful hatch is expected.

From 1960 through 1967, water levels dropped so drastically on all of the marshes along the Fox River that no successful hatch ever developed.

Wave Action

Eschmeyer (1950) observed that in Lake Gogebic, Michigan, dead walleye eggs were sometimes moved considerable distances by waves and currents. He also noted an instance of recently deposited walleye eggs adhering to portions of rocks above the surface of the water and suggested that they had been washed into contact with the rocks during spawning. In large Minnesota walleye lakes, windrows of eggs are sometimes seen along shores after spring storms (Johnson, 1961). In Lake Winnibigoshish, Minnesota, substantial numbers of dead walleye eggs were found entangled in clumps of filamentous algae after 3 days of moderate (15 to 25 mph) easterly winds.

In Lake Winnebago, substantial numbers of walleye eggs were found in windrows along the shore after moderate easterly winds had subsided. On April 24, 1964, after a storm, five 1-foot square samples of beach areas were taken to determine the number of walleye eggs that were washed on shore. There was an average of 203 walleye eggs, 938 yellow perch eggs and 16 unknown eggs taken per sample. Most eggs were viable. The same average number of eggs washed ashore was also noted in 1965, 1966 and 1967.

Use of Spawning Areas by Other Fish

In Lake Gogebic, Michigan, few fish were associated with walleyes on the spawning grounds during the spawning season and no loss of eggs by predation was observed (Eschmeyer, 1950). Bean (1903) stated that eggs may be devoured by fish on the spawning grounds and added the observation (1912) that a spawning stream at Constantia, New York, was filled with small perch and minnows which fed on walleye eggs and fry. He believed that the percentage of escapement was small. Goode (1903) mentioned the destructive inroads of sturgeon, catfish and suckers upon walleye spawning beds. Cobb (1923) claimed that walleye eggs were eaten by suckers at night, although the evidence was purely circumstantial. In a study of Oneida Lake, New York, Adams and Hankinson (1928) found an abundance of small fish which ate walleye eggs.

There was no indication of predation on walleye eggs by any fish species on spawning sites in Lake Winnebago or in any of the marshes along the Wolf or Fox rivers. Other fish were, however, associated with walleyes on their spawning grounds. Yellow perch eggs were always collected along with walleye eggs in Lake Winnebago. On Spoehr's Marsh and other marshes along the Wolf River, an occasional spawning northern pike was observed. On the Fox River marshes, numerous carp and suckers were observed. Although there is no evidence to show that carp and sucker are predators on walleye eggs, there is sufficient evidence to show that the presence of spawning carp is detrimental to walleye eggs. The Fox River is infested with carp which move into the walleye spawning marshes to spawn just after walleye spawning has ceased. The spawning carp roil up the bottom and muddy the water. As soon as carp move into a walleye spawning marsh, substantial numbers of dead walleye eggs are found. As they thrash about, carp succeed in dislodging the walleye eggs from the vegetative mats. As a result of this activity, the eggs settle on the silt bottom where they quickly die from lack of oxygen.

Dissolved Oxygen

Johnson (1961) reported that dissolved oxygen appeared not to have been an important factor in spawning success over a 4-year period in Lake Winnibigoshish, Minnesota and connecting waters.

The concentration of dissolved oxygen in water on Spoehr's Marsh was sufficient during embryo development, varying from lows of 6.2 ppm at night to 10.9 ppm during the day. These readings were taken in running water while dissolved oxygen readings of 2-4 ppm were taken in stagnant areas of the marsh. Dissolved oxygen was not directly an important factor in spawning success on Spoehr's Marsh.

On Lake Winnebago, the concentration of dissolved oxygen in all areas sampled was high and was not an important factor in spawning success.

On most of the Fox River marshes, dissolved oxygen was an important factor in spawning success. Dissolved oxygen concentration would decrease from sufficient daytime highs to lows below 4 ppm during the night. Low dissolved oxygen concentrations were directly related to low water levels, dense vegetation, carp activity and excessive algae growth.

FRY

Hatching and Movements

The movements of walleyes immediately after hatching and for a period thereafter are not well known. Cheney (1897) believed that after hatching, the brood remains together for the first season if not destroyed, making a solid compact mass during the first two weeks. Dymond (1926) reported that young walleyes occur on a sandy bottom, associated with darters, yellow perch and young common suckers. Adams and Hankinson (1928) frequently took young walleyes one to two inches in length but they were not found in numbers at any one place. Greeley (1929) seined young at numerous localities along lake shores and in the Niagara River and found them more common in sheltered areas than in exposed places. Bajkov (1930) said that the fry usually school in comparatively shallow places. Raney and Lachner (1942) found young walleyes in water from a few inches to 2 feet in depth during the first two weeks in July; these same walleyes showed a gradual migration to deeper water as the season progressed. Eschmeyer (1950) reported that walleyes leave shoreward areas soon after hatching and probably lead a pelagic existence until they are about an inch or more in length. In two typical large Minnesota walleye lakes, Mille Lacs and Winnibigoshish, young-of-the-year walleye and yellow perch were closely associated and could be readily taken with seines (Maloney and Johnson, 1955). In Oneida Lake, New York, walleye fry are pelagic until they are 25-30 mm long and concentrations of fry are found in bays where they remain near the surface during daylight hours. During late June and early July, juveniles are abundant along the shoreline; during the summer, there is a gradual offshore movement; and by October, most young are found at depths of 20 to 40 feet (Forney, 1966).

On Spoehr's Marsh, the first walleye fry were taken from 10 to 20 days after the peak spawning period. Depending on water temperatures, fry were taken as early as April 23 in 1966 and as late as May 5 in 1965 (Table 3).

Meter nets were set at the outlet of the marsh from 1960 to 1962, and 1965 to 1967 to capture newly hatched fry (Fig. 2). In 1963 and 1964, the marsh was dry so no sampling was conducted. During the other years, water currents flowing through the marsh moved the newly hatched fry out of the marsh where they were readily caught by meter nets set at the surface. Newly hatched fry ranged in total length from 6.0 to 8.6 mm, with an average length of 7.6 mm. Nelson (1968) reported that newly hatched walleye fry propagated from adult brood stock collected in the Missouri River below Fort Randall Dam, South Dakota were 6.1 and 6.8 mm long.

The number of walleye fry taken per 15 minute meter net set at the outlet of Spoehr's Marsh is shown in table 6. In most years from 1960 to 1967, there was a definite increase to a peak and then a gradual decrease. Movement of fry off the marsh was over a 10- to 15-day period.

The greatest numbers of fry were taken in 1965 and 1967. Water levels on the marsh were adequate during spawning, during egg

TABLE 6

Number of Walleye Fry Taken in Meter Nets Set for 15-Minute Intervals at the Outlet of Spoehr's Marsh, Wolf River, 1960-62 and 1965-67**

Sampling Date	1960	1961	1962	1965	1966	1967
April						
23	*	*	*	*	1	*
24	*	*	*	*	*	*
25	*	*	*	*	10	*
26	*	*	*	*	*	1
27	*	*	*	*	1	2
28	3	*	1	*	*	5
29	4	*	21	*	1	5
30	*	*	65	*	3	40
May						
1	6	*	52	*	*	172
2	8	1	*	*	3	100
3	*	5	18	*	*	*
4	22	18	9	*	5	14
5	*	50	*	1	1	6
6	15	21	3	5	*	2
7	7	*	*	229	1	*
8	*	7	*	*	*	*
9	3	4	*	80	*	*
10	2	*	*	21	*	*
11	*	3	*	*	*	*
12	4	2	*	10	*	*
13	*	*	*	4	*	*
14	*	*	*	3	*	*

* No sampling on these dates.

** In 1963 and 1964, the marsh was dry and no sampling was possible.

development and through fry migration out of the marsh.

On most sampling dates in 1965, 1966 and 1967 walleye fry were examined to determine if their yolk sacs were complete, partially absorbed or completely absorbed (Table 7). The percentage of fry with complete yolk sacs was 66.7, 71.3 and 46.3 percent from 1965 to 1967, respectively. It is difficult to explain the low percentage in 1967 for 2 reasons: (1) water levels in the marsh were high and the current was sufficient to carry newly hatched fry out of the marsh quickly, and (2) water temperatures during egg development were similar to water temperatures during the other years.

On their journey down the Wolf River, the walleye fry are not able to search for their own food since their fins are not developed enough to allow the fry to move about freely. Fry are thus de-

TABLE 7

Percent of Walleye Fry with Complete, Partial or Absorbed Yolk Sacs taken at Outlet of Spoehr's Marsh, Wolf River, 1965-67

Date	Complete	Partial	Absorbed
1965			
May 5	100.0	0	0
May 6	69.8	17.0	13.2
May 7	63.4	18.3	18.3
May 9	85.2	10.0	4.8
May 10	51.9	20.5	27.6
May 12	44.9	34.9	20.2
Sample Size*	3,038	786	731
1966			
April 23	0	0	100.0
April 27	50.0	25.0	25.0
April 29	86.4	4.5	9.1
April 30	91.2	5.3	3.5
May 2	73.3	16.7	10.0
May 4	53.6	13.0	33.3
Sample Size*	132	19	34
1967			
April 27	16.6	33.3	50.0
April 28	49.8	25.3	24.9
April 29	41.6	40.0	18.4
May 1	53.1	32.9	13.9
May 2	13.8	77.8	8.4
May 4	66.7	32.0	1.3
Sample Size*	1,280	1,080	406

* Sample sizes are given in numbers, not percentages.

pendent upon the velocity of the river to carry them to Lake Winnebago, or to the upriver lakes before their food supply stored in the yolk sac is utilized. All indications are that upon hatching, fry must leave the marsh and reach a food source within 3 to 5 days or they will perish. The majority of fry taken in the river channel as it enters Lake Winnebago have absorbed their yolk sac.

Aquarium tests showed that walleye fry, upon hatching, will absorb their yolk sacs within a 3- to 5-day period. Newly hatched fry had no developed paired fins and their movement was restricted to vertical swimming. Fry would sink in the water, and then with vigorous motion of the tail muscle, would move in a vertical direction to the surface again. After a 10- to 12-day period, their paired fins developed sufficiently to allow horizontal movements.

Water levels on Spoehr's Marsh in 1960 began dropping on

April 20 and had dropped 17 inches by April 30. Throughout the marsh, water currents were decreasing to a critical point. Since a steady current is necessary to supply the eggs with oxygen and to provide a means of travel for the fry upon hatching, a poor hatch seemed likely. On May 3, heavy rains began to raise the water levels on the marsh until an increase of 49 inches over the low was recorded. This was an increase of 32 inches over the previous high reached on April 20. On May 4, large numbers of fry began to leave the marsh. The importance of a high water level with currents is verified by the fact that 21 fry were taken in the fry nets at the marsh outlet immediately following the increased water level. These fry had no yolk sac and were in such poor conditions that survival was unlikely. The fry hatched and probably remained in small pockets of water in the marsh until sufficient water levels moved them on, at which time it was too late.

In 1961, after a sufficient rain on May 11, water levels on the marsh increased so that walleye fry with complete and absorbed yolk sacs were taken in meter nets. Forty fry with absorbed yolk sacs ranged in total length from 10.4 to 12.8 mm, with an average length of 11.9 mm. Since 12 of these fry had consumed zooplankters, they were undoubtedly able to survive until water levels were high enough to allow them to pass out of the marsh.

On May 7, 1965, large numbers of walleye fry (± 500 fry) were observed on Spoehr's Marsh swimming over an artificial mat used to follow egg development. Only a slight current and dense, surrounding vegetation prevented the fry from moving out of the small, open pocket of water surrounding the mat. The fry were observed swimming before settling down, resting, and then moving vertically to the surface — all by use of the tail muscles. Easily caught with an eye dropper, all of the fry captured had consumed all or most of their yolk sacs so that there was little chance of survival. Although large numbers of fry were seen in other small stranded pockets in the marsh, these numbers represented only a small percentage of the total hatch on the marsh when the tremendous numbers of fry normally moving out of the marsh are considered.

Most of the walleye fry move down from the marshes in mid-river near the surface of the water where the current is most rapid. Only a few are taken along the shore where the current is weak, and no fry are taken below a depth of 3 feet from the surface. The daily pattern of fry descent is depicted in figure 5. Descent reaches a maximum between 1:00 and 2:00 p.m., declines and then intensifies in the late a.m. This same situation was noted for burbot, *Lota lota* (Linnaeus) which spawns in the fast-running current of the lower reaches of the Selengra River, Siberia (Sorokin, 1968).

By May 1, walleye fry can usually be taken at the mouth of the Fox River in Lake Winnebago with meter nets. The fry at this

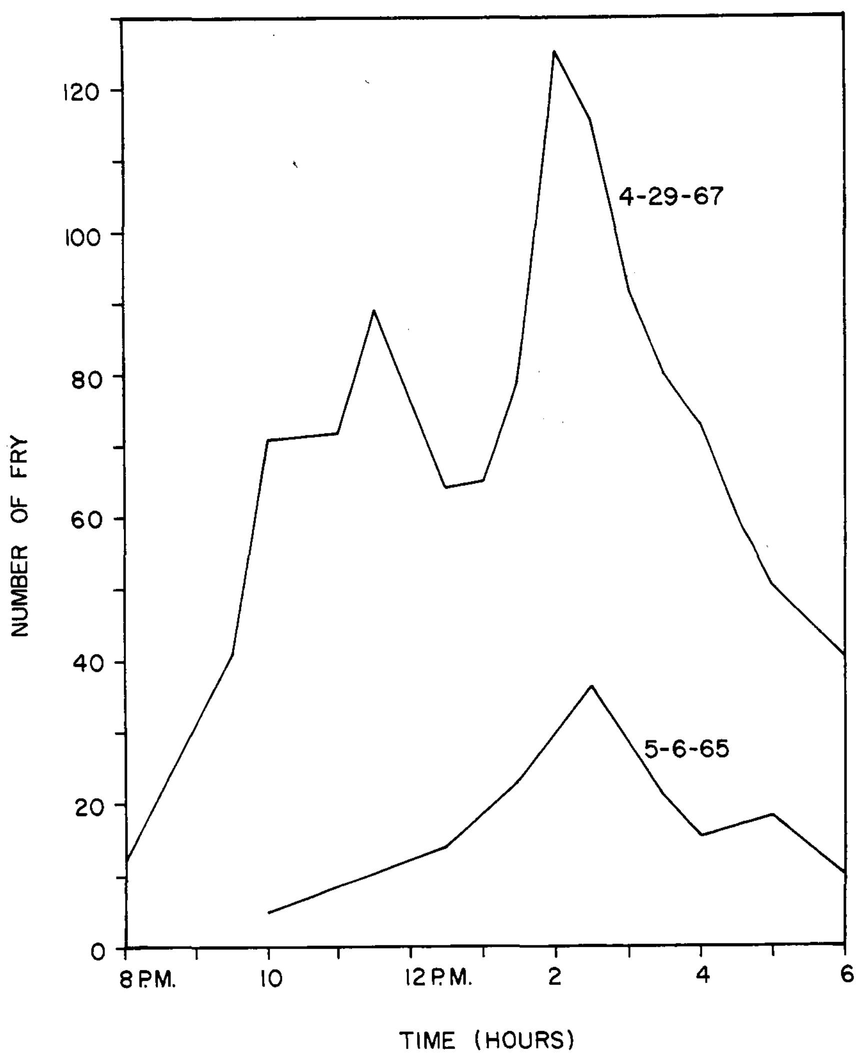


Figure 5. Daily pattern of the descent of walleye fry off Spoehr's Marsh, 1965 and 1967.

time range between 6.0 and 10.0 mm in total length. A typical length frequency of walleye fry taken with meter nets during May and early June is shown for 1967 in table 8.

Currents and wave action move the fry out into Lake Winnebago where they can be taken with meter nets throughout May. Most fry are taken along the shoreline, especially near the mouth of the Fox River. Their numbers decrease as the distance from the river's

TABLE 8

Numbers of Walleye Fry of Given Lengths Taken with Meter Nets at the Mouth of the Fox River in Lake Winnebago, 1967

	Length Groups (in mm)													
Date	6	7	8	9	10	11	12	13	14	15	16	17	18	19
May														
1	1	2		4	2									
3			1	2										
4			3	7										
5				2										
8				5	2	1								
9	1			3	3									
12		1	4	111	82	2								
15				3	11	2	1							
17					14	9	1							
22					17	70	13							
24				1	15	45	35	4						
June														
1							1	13	22	36	18	10		
5								3	2	6	5	7	6	2

mouth is increased. This has been especially true since 1964 when intensive spawning was first noted in Lake Winnebago. The fry that were taken with meter nets during May were near the surface and no schooling was ever noted. Fry up to 20 mm could be readily taken in meter nets, but fry longer than 20 mm in total length avoided the nets and were not easily taken. On one occasion as we were pulling the meter nets from a 30-foot launch, we could actually see the fry avoiding the meter nets. On this occasion the fry were between 22-26 mm in length.

In 1963, water levels dropped so low on the marshes that the entire year class was wiped out. So on May 14, 1963, a plant of 1,200,000 walleye fry was made in South Asylum Bay, Lake Winnebago. The fry were planted along the extreme west shore of the bay where they would not be readily influenced by currents which would carry them into the lake. The fry were released there so that we could determine how successful our meter nets were for sampling walleye fry. One day later, six 5-minute hauls were made, and 82 stocked fry were taken (2.6 fry per minute). On the second day, 21.5 fry per minute were taken. Three days later, 11.9 fry per minute were taken. Six days later, only 0.1 fry per minute were taken, and these fry were feeding on *Daphnia* sp. and *Bosmina* sp. A week later, no fry were taken even after intensive sampling. Absence of fry was due to either one or more reasons: fry mortality was high, fry were eventually carried out into Lake Winnebago or, our fry nets were not able to capture them because of an extremely large zooplankton bloom which limited the hauls to only one or two minutes. I felt that our sampling gear (fine mesh meter nets) was capable of taking the fry until excess zooplankton blooms prevented optimum efficiency or until the fry obtained a length of 20 mm and could avoid the nets.

By early June, small mesh trawls fished off the bottom could readily capture young walleyes in all areas of Lake Winnebago. Throughout the years, extensive and intensive seine sampling proved that young walleyes did not use the shoreline of Lake Winnebago at any time during their first year, either at night or during daylight hours. Young walleyes in Lake Winnebago apparently lead a pelagic life.

From 1960 through 1967, there was never any indication of a walleye hatch on the Fox River. Sampling with meter nets at the outlets of spawning marshes or in the Fox River failed to provide any data that would even suggest any hatch. On April 21, 1967, after 6 continuous hours of sampling the Fox River at Eureka, 1 walleye fry was taken and this was the only fry ever taken in the Fox River.

Dyed Fry Movements

Since it was well documented that Lake Winnebago walleyes do migrate up the Wolf River as far as 97 miles to spawn in adjacent marshes, it was important to determine if walleye fry hatching on these marshes could actually reach Lake Winnebago and eventually contribute to the fishery. The passage of walleye fry out of the marshes, into the river and eventually into the lakes is dependent on the critical period 3-5 days after hatching when water currents must be sufficiently strong to carry the fry to the upriver lakes or Lake Winnebago before they perish from starvation. As the fry hatch, they immediately begin to use the energy stored in their yolk sacs, which can sustain them for only 3-5 days, after which the fry must begin to feed on zooplankton. The Wolf River, because of its swiftness, does not produce an abundant supply of zooplankton at the time of the year when fry need this food resource. The fry, since they cannot swim freely about in search of food, must reach a lake where the food supply is readily available and very abundant. Walleye fry taken as they entered Lake Winnebago had generally absorbed most of their yolk sac.

Wolf River

Since walleye fry are continuously entering the Wolf River from marshes other than Spoehr's, it was decided to dye some fry a given color, release them at one location and sample them at various locations along the river to determine how far and how fast they could travel downriver.

On May 16, 1961 a release of 400,000 dyed walleye fry was made at Bamboo Bend near Shiocton. Of that total, 300,000 were dyed red and 100,000 were dyed amber.

After traveling only 3.75 miles in the river, the dyed fry had been distributed over a long stretch. Dyed fry were taken over a 3-hour period at the first station. Observations indicated that dead and weaker fry passed through first, and stronger fry which probably fought the river's current, were taken at the end of the sampling period. The red-dyed fry were weaker than the amber-dyed fry.

Meter nets 3 feet in diameter were used to capture walleye fry in the Wolf River. From the numbers of fry taken in these nets, annual production on Spoehr's Marsh could be estimated and movements of dyed fry down the Wolf River could be followed.

At the next sampling station, 6.25 river miles below the release point, a time period of 4.5 hours was required before no more fry were captured. At Hortonville, after 11.25 miles, it took 5.5 hours of sampling before no dyed fry were taken. As the dyed fry moved downriver, they dispersed throughout the length of the river, due to greater volumes of water and currents which carried some fry farther and faster than others. The farthest distance to which amber fry traveled, with no further recaptures being made, was New London, 22 miles below the release point. The farthest distance to which red fry traveled, with no further recaptures, was Fremont, 46.75 river miles below the release point.

Efforts to capture dyed fry at Winneconne were unsuccessful since the river widens considerably as it enters Lake Poygan and still more as it enters Lake Winneconne. The fry had traveled 46.75 river miles in only 43 hours so there is considerable reason to believe that they could arrive in Lake Winnebago which is 32.5 river miles below Fremont. Fry migrating out of marshes above Shiocton should be able to reach Lake Winnebago within 3-5 days.

The velocity of the Wolf River was 1.73 feet per second on May 1, 1961. The dyed fry traveled the 46.75 river miles at 1.59 feet per second and, being unable to swim horizontally, depended on the river's current to move them downstream.

Of the 2 dyes, red was preferred as red-dyed fry could be readily distinguished among the debris and other natural fry that accumulated in the fry nets. While trying to recover the dyed fry, we took various natural fry in the fry nets. The fry of natural walleyes, yellow perch, white bass, northern pike, white sucker and burbot were taken. Most of these natural fry, especially walleyes and suckers, were taken between 1:00 and 3:00 a.m. on 11 sampling days. During daylight hours, only a few natural fry were captured. This increased movement of fry down the river at night corresponds with the walleye fry movements off the marshes during spawning. At Spoehr's Marsh, only a few walleye fry were taken during the period before noon, but more were taken when activity out of the marsh increased during the afternoon and early evening. Cooling of the water in the marshes at night delays hatching until the water warms during the day.

Fox River

Dyed walleye fry experiments were conducted on the Fox River, 1964-67, to determine if the current in the Fox River is sufficient to carry newly hatched walleye fry into Big Lake Butte des Morts and Lake Winnebago. The effects of low-head dams, especially at Eureka, were investigated to determine if they had any detrimental effects on migrating walleye fry.

1964. On May 10, 1964, 1,000,000 red-dyed fry were released in the Fox River approximately one-half river mile below the mouth of the White River. The fry were extremely active and were observed being carried by the current downstream and into quiet water areas along the river. The fry, as they were being carried along with the current, would sink to a depth of 6-8 inches and then swim upward to the surface. No horizontal swimming was noted.

The first sampling station (Berlin main street bridge) was 10 river miles below the release point. Sampling began at 6:00 p.m. on May 10 and was continuous through 2:10 a.m. on May 11. The first dyed fry was taken at 12:00 a.m., May 11 but only 8 dyed fry were taken during the period from 12:00 a.m. to 2:10 a.m.

At 7:17 a.m. on May 11, sampling began at the Eureka bridge, 19 river miles below the release point. Sampling at the Eureka bridge was continuous until 8:00 p.m., May 11 with only 1 dyed fry being taken at 5:00 p.m.

The fry apparently never got beyond the Berlin Dam, 9 river miles below the release point. An attempt was made to capture the dyed fry between the release point and the Berlin Dam. On May 12, fry nets pulled behind a boat in wide, quiet areas of the river and adjacent bayous succeeded in taking only 1 dyed fry. Even though water levels were rising during the study period, the current was slow especially in the larger widenings of the river. The current was probably not sufficient to carry the fry downstream. Furthermore, active fry were undoubtedly more successful in fighting this slow current than they were in fighting the swifter current of the Wolf River.

1965. On May 10, 1965, 1,000,000 red-dyed walleye fry were released in the Fox River just below the outlet of Hopp's Marsh. The release point was approximately 6.5 river miles above the Berlin Dam. After tempering the dyed fry, they were released in the Fox River at 2:00 p.m. Water temperature was 69.5 F.

Instead of waiting for the fry to reach a known location like the Berlin Dam, as had been done in 1964, we attempted to sample the fry as they moved along by sampling just ahead of them from a boat. A meter net was usually fished for 3 minutes off the side of the boat, emptied, and put back into the water while the sample was sorted. When sufficient numbers of fry were taken at one location, we moved downstream to a new location and continued sampling.

The dyed fry reached the Berlin Dam at 9:00 p.m., a distance of 6.5 river miles from release point. It took the fry approximately 7 hours to travel this distance. A 5-minute net set at the dam took 66 dyed fry.

By 1:00 a.m., May 11, the fry had traveled an additional 3.5 river miles to Spoehr's bridge just below the city of Berlin. The fry were moving at a rate of 0.9 miles per hour. Sampling resumed at 3:00 a.m. below the Eureka Dam, a distance of 4.5 river miles below Spoehr's bridge, at 3:00 a.m. and continued until 7:30 a.m., May 11. No dyed fry were taken.

The fry evidently never got beyond the Eureka Dam. In 1964, the dyed fry never got beyond the Berlin Dam, at which time the water level had been approximately 1.5 feet lower. In 1965, there was no drop in water level at the Berlin Dam, but at the Eureka Dam, there was a drop of 1.5-2.0 feet. There was a good possibility that the fry were being killed as they went over the dam or as they were caught in the eddies below the dam. To determine whether or not fry were being killed in this manner, additional releases of dyed fry were made.

On May 12, 1965, an experiment was conducted to measure fry movement over the Eureka Dam. The Spooner hatchery provided us with 300,000 walleye fry, all of which were dyed red. The fry were released just above the Eureka Dam and 3 fry nets were stationed just below the dam in the eddies. Three releases of 100,000 dyed fry each were made and the following number of fry were captured in the fry nets after each release: 44, 79 and 256 fry.

After the fry had been released, a sampling station was established at the Eureka bridge, approximately 2 river miles below the Eureka Dam. Continuous fry net sampling from 1:00-4:00 p.m. resulted in the capturing of only 1 dyed fry which was taken at 1:45 p.m. It was concluded that the fry never got out of the eddies to continue the downstream migration.

On May 19, 1965, one-half million walleye fry were obtained from the Woodruff hatchery: 300,000 fry were dyed red, while 200,000 fry were dyed amber.

At 2:00 p.m., the red fry were released immediately above the Eureka Dam and the amber fry were released below the Eureka Dam just beyond the influence of the eddies.

A sampling station was established about three-quarters of a mile below the Eureka Dam. Two fry nets were fished continuously from 2 boats. Sampling began at 2:12 p.m. and by 3:00 p.m., the first amber fry were being taken, with the last amber fry taken at 3:30 p.m. Sampling continued until 4:30, but no red-dyed fry were taken.

At 5:00 p.m., an attempt was made to pick up red-dyed fry just below the Eureka Dam by pulling the fry nets with the boats. After continuous sampling until 5:45 p.m., 2 alive, swimming red-dyed fry and 1 dead red-dyed fry were taken in the eddies just below the dam along the south bank. The same nets were used to attempt to capture amber-dyed fry at the release site, but no dyed fry were taken.

On May 20, at approximately 2:00 p.m., one amber-dyed fry was taken off the Pioneer Marina, Lake Winnebago, in a meter net being pulled by a boat during routine walleye fry sampling on the lake. This fry had traveled 25 river miles in approximately 24 hours.

All of the fry used in the 3 experiments were in good condition, although fry obtained on May 19 may possibly have been more advanced than those used on May 10 and 12.

There was sufficient evidence to show that low-head dams such as the Eureka Dam can be very detrimental to walleye fry passing over them by either killing the fry immediately as they go over the dam or by trapping them in the eddies below the dam.

1966. On May 11, 1966, 500,000 red-dyed walleye fry were released above the Eureka Dam. Sampling stations were established below the dam and considerable numbers of fry were captured, indicating that fry were able to pass over the dam, whereas they had not been able to do so in 1964 and 1965. The major difference during the 3 years, 1964-66, was the current. In 1966, the velocity of the Fox River at the time the fry were released was only 845 cfs, while in 1964 and 1965, the velocity ranged from 1,340 to 1,500 cfs. The data indicate that when water velocity is high, walleye fry are unable to survive passage over the dam. At lower velocities, the fry can pass safely over the low-head dams.

1967. On May 19, 1967, dyed fry were released at the Eureka Dam site when the velocity was 852 cfs. The release consisted of 300,000 red-dyed fry released above the Eureka Dam and 200,000 amber-dyed fry released just below the dam. Sampling stations were established about 400 yards below the dam. The amber- and red-dyed fry arrived at the same time. For every red-dyed fry taken, six amber-dyed fry were taken. All fry captured were alive and in good condition. Although low water velocity permitted fair survival of the red-dyed fry, there was considerably greater survival of the amber-dyed fry.

FOOD

Food of Young Walleyes

10-50 mm Size Class

Young walleyes up to 35 mm in length could be captured in all areas of the lake with meter nets towed at the surface. Walleyes longer than 35 mm either avoided the meter nets or had dispersed to the bottom. Trawling in deeper open-water areas of the lake readily took walleyes in the 30-50 mm size class.

Walleyes in the 10-50 mm size class were found to feed principally on copepods and cladocerans (Table 9). *Diaptomus* sp. was found in 41.4, 49.3 and 71.5 percent of the stomachs in 1960-62, respectively, while *Cyclops* sp. occurred in 31.6, 35.7 and 25.7 percent of the stomachs in 1965-67, respectively. *Leptodora* sp. was the most important cladoceran, occurring in 52.9, 34.2 and 29.8 percent of the stomachs in 1960-62, respectively, and 40.4 percent in 1967. In 1965 and 1966, *Daphnia* sp. was the most utilized cladoceran, occurring in 48.3 and 28.6 percent of the stomachs, respectively. Chironomid larvae were an important item in the 1960-62 samples, but were of minor importance in the 1965 and 1967 samples. No walleyes less than 35 mm contained chironomid larvae.

Fry of white suckers, *Catostomus commersoni* (Lacépède), quillback, *Carpiodes cyprinus,* (LeSueur), troutperch, *Percopsis omiscomaycus* (Walbaum), yellow perch, sauger, white bass, and freshwater drum were eaten by 10-50 mm walleyes to a limited extent. Yellow perch fry occurred in 15.8 percent of the walleye stomachs in 1961, 8.5 percent in 1962 and 15.4, 14.3 and 4.3 percent in 1965-67, respectively. These yellow perch fry were found in walleye stomachs only during 1 sampling day each year when yellow perch fry were extremely abundant at the mouth of the Fox River. Because of the river's currents, yellow perch and walleye fry were congregated in this area for a short duration, presumably before being dispersed throughout the lake.

51-75 mm Size Class

Fingerling walleyes were collected by trawling in the open-

TABLE 9

Food of Young Walleyes (10-50 mm class) in Lake Winnebago, 1960-62 and 1965-67 in Percent Frequency of Occurrence and (in Parentheses) Average Number of Organisms per Stomach

Item	1960	1961	1962	1965	1966	1967
Number of Stomachs	70	177	266	529	33	291
Number Empty (%)	0	24 (13.5)	31 (11.4)	22 (4.2)	19 (57.5)	34 (11.6)
Fish	1.4	16.9	16.6	17.5	21.4	8.1
Unidentified Fish	1.4 (1)		5.5 (1)	0.9 (1)		1.1 (1)
Catostomus commersoni			1.7 (1)	0.9 (1)		
Carpiodes cyprinus			0.4 (1)			
Percopsis omiscomaycus		1.3 (1)	0.4 (1)	0.2 (1)		0.4 (1)
Perca flavescens		15.8 (1)	8.5 (1)	15.4 (1)	14.3 (1)	4.3 (1)
Stizostedion canadense						0.4 (1)
Roccus chrysops					7.1 (1)	0.8 (2)
Aplodinotus grunniens						1.1 (1)
Copepods	45.7	49.3	71.5	33.3	42.8	31.1
Diaptomus	41.4 (13)	49.3 (5)	71.5 (15)	1.8 (4)	7.1 (2)	6.6 (4)
Cyclops	4.3 (2)	2.6 (2)	4.3 (1)	31.6 (3)	35.7 (1)	25.7 (2)
Cladocerans	58.5	49.3	32.0	53.3	35.7	69.2
Daphnia	5.7 (7)	15.1 (3)	9.8 (3)	48.3 (3)	28.6 (8)	32.3 (2)
Leptodora	52.9 (2)	34.2 (4)	29.8 (4)	8.5 (2)		40.4 (7)
Bosmina		3.3 (1)	0.4 (3)	0.4 (1)		6.6 (1)
Alona			0.4 (1)			
Chydorus		0.7 (1)			7.1 (1)	
Rotifers			0.4 (2)			
Oligochaeta		0.7 (1)				
Amphipoda		0.7 (1)				
Hirudinea						
Chironomids—larvae	35.7 (2)	19.1 (3)	17.4 (2)	5.5 (2)		7.4 (2)
Chironomids—pupae	1.4 (1)	2.6 (1)	7.2 (2)	1.4 (1)		13.6 (3)

water areas of the lake from June through July. Cladocerans were the most important food item, occurring in 50.0 to 100.0 percent of the stomachs (Table 10). *Leptodora* sp. was the most utilized cladoceran and *Daphnia* sp. was the second most important cladoceran utilized. Of the copepods utilized, *Diaptomus* sp. was the most important. Chironomid larvae and pupae were important items during various years.

Fry of some of the fish consumed by 10-50 mm walleyes — troutperch, yellow perch — plus fry of the northern pike, *Esox lucius* Linnaeus, white bass and freshwater drum were consumed by 51-75 mm fingerlings. The importance of these fry over the years and by species varied. Troutperch and freshwater drum fry were the most important species of forage fish utilized.

76-100 mm Size Class

In 1959, fish were found in 96.1 percent of the walleye stomachs, with identifiable young troutperch occurring in 67.3 percent of the stomachs (Table 11). Fish occurred in 82.6 percent of the walleye stomachs in 1962, with young freshwater drum being found in 42.9 percent of the stomachs. When young fish were consumed by walleyes, young troutperch and freshwater drum were the most important forage fish.

In 1959 and 1962 when various species of forage fish were a major item in the diet of the walleyes, items of minor importance were copepods, cladocerans and chironomid larvae. In the other years, when species of forage fish were absent or occurred in only a small percentage of the walleye stomachs, consumption of chironomids, copepods and cladocerans increased, with chironomid larvae and pupae being the most important item consumed.

101-175 mm Size Class

Fish occurred in 66.6 percent of the walleye stomachs in 1959, with troutperch being found in 58.5 percent and young freshwater drum in 15.4 percent of the stomachs (Table 12). In 1964, fish were again found in 66.6 percent of the walleye stomachs, with young troutperch occurring in 25.0 percent of the stomachs.

Copepods, (namely *Cyclops* sp.), were of minor occurrence in stomachs from 101-175 mm walleyes. Chironomids and cladocerans, (mainly *Leptodora* sp.), were important only in the years when species of forage fish were not the major food consumed.

TABLE 10

Food of Young Walleyes (51-75 mm class) in Lake Winnebago, 1959-62 and 1965-67 in Percent Frequency of Occurrence and (in Parentheses) Average Number of Organisms per Stomach

Item	1959	1960	1961	1962	1965	1966	1967
Number of Stomachs	46	143	44	126	50	6	128
Number Empty (%)	2 (4.3)	13 (9.1)	4 (9.1)	1 (0.8)	9 (18.0)	3 (50.0)	3 (2.3)
Fish	40.9	8.4	37.5	36.0	29.2		17.6
Unidentified Fish	22.7 (1)	5.4 (1)		12.8 (1)	4.9 (1)		6.4 (1)
Percopsis omiscomaycus	11.8 (1)		17.5 (1)		17.1 (1)		4.0 (1)
Perca flavescens	6.7 (1)	1.5 (2)		12.0 (1)			
Esox lucius		0.8 (1)					
Roccus chrysops				6.4 (1)			
Aplodinotus grunniens	2.2 (1)	0.8 (1)	20.0 (1)	4.8 (1)	7.3 (2)		7.2 (1)
Copepods	27.2	59.2	37.5	16.0	53.7		4.8
Diaptomus	27.2 (18)	59.2 (23)	37.5 (9)	16.0 (13)	43.9 (10)		3.2 (1)
Cyclops	11.3 (25)	4.6 (14)	5.0 (176)		21.9 (7)		1.6 (3)
Cladocerans	54.5	64.6	50.0	60.0	63.4	100.0	85.6
Daphnia	22.7 (7)	23.1 (11)	12.5 (2)	16.0 (9)	63.4 (18)		36.0 (10)
Leptodora	54.5 (6)	59.2 (5)	50.0 (9)	56.0 (10)	14.6 (8)	100.0 (17)	80.0 (12)
Bosmina		0.8 (7)					
Ostracoda			2.5 (1)	0.8 (1)			
Chironomids—larvae	22.7 (1)	23.8 (3)	5.0 (3)	18.4 (1)			4.0 (1)
Chironomids—pupae		5.4 (1)	2.5 (2)		2.4 (3)		24.0 (4)

TABLE 11

Food of Young Walleyes (76-100 mm class) in Lake Winnebago, 1959-62, 1964-65 and 1967 in Percent Frequency of Occurrence and (in Parentheses) Average Number of Organisms per Stomach

Item	1959	1960	1961	1962	1964	1965	1967
Number of Stomachs	52	17	86	26	25	118	14
Number Empty (%)	0	3(17.6)	0	3(11.5)	18(72.0)	5(4.2)	1(7.2)
Fish	96.1		29.1	82.6	14.3	12.4	30.8
Unidentified Fish	9.6(1)		2.3(1)	28.6(1)		1.8(1)	15.4(1)
Percopsis omiscomaycus	67.3(1)		3.4(1)	9.5(1)	14.3(1)	1.8(1)	
Perca flavescens	3.8(1)			9.5(1)		3.5(1)	7.7(2)
Stizostedion canadense						2.6(1)	
Stizostedion vitreum						1.8(1)	
Aplodinotus grunniens	19.2(1)		23.2(1)	42.9(1)		0.9(1)	7.7(2)
Copepods		50.0	2.3		42.8	5.3	
Diaptomus		35.7(64)				0.9(2)	
Cyclops		7.1(14)	2.3(43)		42.8(37)	4.4(12)	
Cladocerans	5.8	7.1	3.4	9.5	14.3	0.9	76.9
Daphnia	5.8(27)	7.1(16)	3.4(38)		14.3(14)		76.9(23)
Leptodora		7.1(3)		9.5(33)		0.9(14)	76.9(8)
Amphipoda						0.9(1)	
Chironomids—larvae	5.8(3)	71.4(2)	67.8(5)		57.1(2)	16.8(2)	7.7(2)
Chironomids—pupae	3.8(2)	7.1(2)	47.1(3)			82.3(5)	

TABLE 12

Food of Young Walleyes (101-175 mm class) in Lake Winnebago, 1959, 1961-62 and 1964-66 in Percent Frequency of Occurrence and (in Parentheses) Average Number of Organisms per Stomach

Item	1959	1961	1962	1964	1965	1966
Number of Stomachs	98	35	56	34	150	35
Number Empty (%)	33(33.3)	4(11.4)	13(24.1)	22(64.7)	12(8.0)	2(5.7)
Fish	66.6	3.2	27.9	66.6	6.5	21.2
Unidentified Fish	7.7(1)		4.7(1)	33.3(1)	1.5(1)	3.0(1)
Percopsis omiscomaycus	58.5(1)		4.7(1)	25.0(1)	5.1(1)	18.2(1)
Perca flavescens	3.1(1)		2.3(1)	8.3(1)		
Roccus chrysops			2.3(1)			
Aplodinotus grunniens	15.4(1)	3.2(1)	18.6(1)	8.3(1)		
Copepods		3.2	2.3			27.3
Cyclops		3.2(7)	2.3(1)			27.3(5)
Cladocerans	9.2	6.4	34.9	33.3	76.1	84.8
Daphnia		6.4(34)	25.6(131)	33.3(32)	3.6(83)	42.4(200)
Leptodora	9.2(40)	3.2(232)	34.9(9)	33.3(62)	73.9(277)	57.6(60)
Hirudinea					1.5(9)	
Chironomids—larvae	4.6(2)	80.6(9)	23.4(6)		35.5(9)	
Chironomids—pupae	3.1(1)	22.6(2)	18.6(3)		8.7(2)	

Walleyes less than 75 mm are generally considered plankton feeders but beyond this length, they feed more heavily on species of forage fish, if this food source is extremely abundant. In Lake Winnebago, however, fish were not a consistently important food item in the diet of walleyes larger than 75 mm. Only in 1959 and 1963 when young troutperch and freshwater drum were extremely abundant (Table 13) did young walleyes feed on fish. The 1959 walleye year class was the largest observed during the study period. Its growth was also the most rapid (as the average total length by mid-October was 175 mm), suggesting that the food supply was adequate despite the walleye abundance.

TABLE 13

Average Catch Per 7-Minute Tow of Some Young Fish Species Taken with a 12-foot Trawl in Lake Winnebago, 1959-1967

Fish and Month	1959	1960	1961	1962	1963	1964	1965	1966	1967
Walleye									
June	0	0.4	9.3	4.9	0.1	3.5	36.3	0.2	1.5
July	5.2	0.4	9.2	3.7	0.1	4.9	17.4	0.6	12.7
Aug.	7.7	0.5	1.2	0.6	0	1.1	2.2	0.4	0.1
Sept.	9.1	0.1	0.2	0.1	0	0	8.9	0.9	*
Oct.	4.7	0	0.4	0.2	0	1.1	1.0	0.7	0.7
Yellow Perch									
June	0	0	68.6	272.8	27.3	219.6	4.3	7.3	7.7
July	13.9	0	68.5	50.5	21.4	31.2	53.7	116.2	0
Aug.	0.9	0.2	0.5	0.5	1.1	1.7	1.2	2.2	1.7
Sept.	0.2	0.1	0.1	0.1	1.1	2.8	0.8	1.5	*
Oct.	0.4	0	0.1	0.1	2.7	0.4	0	1.8	0.7
Troutperch									
June	0	0	5.5	3.3	0.7	17.2	0.7	0	0.1
July	1443.3	0	4.8	5.3	3.8	55.1	229.3	647.5	41.0
Aug.	1867.7	45.1	22.1	8.1	32.5	95.7	207.7	426.7	329.9
Sept.	893.6	74.6	20.9	17.0	13.4	104.4	362.8	347.9	*
Oct.	254.0	23.2	14.7	8.7	12.7	38.9	47.9	232.8	50.0
Freshwater Drum									
June	0	0	0.1	0.8	0.3	0.2	0	0	0.2
July	17.6	0	0.1	25.6	84.7	0.6	1.3	29.1	0.7
Aug.	43.3	0.5	32.1	19.1	339.9	6.1	4.6	59.8	2.3
Sept.	40.1	2.4	15.9	10.8	135.9	11.0	2.4	53.5	*
Oct.	26.6	0.1	12.3	0	152.0	4.2	0.7	30.3	2.3
White Bass									
June	0	0	0.7	0.4	0.7	31.6	0.2	8.7	0.1
July	8.5	0	0.7	14.9	27.2	59.4	4.7	466.3	2.0
Aug.	3.4	0.1	0.5	0.6	0.5	12.9	0.7	2.8	1.4
Sept.	26.3	0.1	0.3	0.4	2.1	59.3	0.6	3.5	*
Oct.	16.3	0	0.2	0.5	5.2	22.9	0.1	4.0	0.3

* No trawl sample.

Chironomid larvae and *Leptodora* sp. were utilized by young walleyes in all size classes during most sampling periods and must be considered major food items of young walleyes in Lake Winnebago.

Rawson (1957), working in Lac LaRange, Saskatchewan reported that walleyes 51-64 mm long in late July, contained unidentifiable fish remains, and 2 specimens 76 and 89 mm long had eaten smaller walleyes. Smith and Moyle (1943), studying rearing ponds, reported that walleye fry began feeding on rotifers and nauplii and that as the fish increased in size, entomostraca, insects and fish successively became important items in the diet. When available, fish of any species occasionally entered the diet of 15-20 mm walleyes but they did not become important food items until the walleyes reached an average length of 61-81 mm. Forage fish appeared to be eaten in proportion to their abundance. Analysis of the intestinal tracts of walleye fry from southwestern Lake Erie showed that four species of diatoms, *Melosira binderana, M. ambigua, Fragilaria capucina* and *F. crotonensis,* were dominant items in fry up to 9 mm (Hohn, 1966). Fry above 9 mm contained zooplankton as well as these species of diatoms.

Eschmeyer (1950) reported that fish made up 83 percent, planktonic crustaceans, 10.3 percent and insects, 1.7 percent of the food of young walleyes in Lake Gogebic, Michigan. He estimated that yellow perch made up 68 percent of all the food.

The food of young walleyes in Lake Winnibigoshish was almost entirely fish. Items such as planktonic crustaceans and insects made up less than 1 percent of the food. Of fish remains in the stomachs, 52 percent were identifiable as young yellow perch (Maloney and Johnson, 1955).

Most of the stomach contents of young walleyes from Mille Lacs Lake were comprised of fish (98.9 percent by volume), with young yellow perch accounting for 77 percent of this volume (Maloney and Johnson, 1955). During their first summer of life, young walleyes and yellow perch usually inhabit shallow waters along the shores of Lake Winnibigoshish and Mille Lacs Lake, Minnesota and are readily taken by shoreline seining (Maloney and Johnson, 1955).

Dobie (1966) reported that during the first half of the summer, young walleyes in Lake Vermilion, Minnesota fed mostly on zooplankton and aquatic insects. However, during the latter part of the summer, when the young walleyes had reached a length of about 30 mm, they shifted to feeding on fish and for the rest of the summer ate mostly young yellow perch. After June 28, fish made up 70.2 percent of the food found in the stomachs of young walleyes.

The only important competitor of young walleyes for fish were young smallmouth bass, the stomach contents of which contained 49.1 percent fish during this same summer period.

In 1959 and 1960, all walleyes examined in Oneida Lake, New York (Forney, 1966) had fed exclusively on fish from July through September. In 1961, consumption of fish was high, but a few specimens in September had fed on chironomids and entomostraca. In 1958, 1963 and 1964, chironomids and entomostraca were utilized during July and became increasingly important in late summer. Yellow perch occurred more frequently in the diet of young walleyes than any other forage fish.

Food Selection of Young Walleyes

Data on the abundance of food organisms in plankton samples and occurrence of these food items in stomachs of walleyes collected on identical sampling dates were analyzed to determine if certain items were selected. Measurements of food selectivity of fry must be calculated from estimates of the ratio of occurrence of food items in the environment and the ratio of occurrence of the same item in fry stomachs. If food items are found to be represented by different ratios in the environment and in fry stomachs, it is likely that some selection in feeding occurs.

An index of selection, termed "electivity" by Ivlev (1961), provides a convenient method for determining if feeding is selective. This "electivity index" is represented by the following equation:

$$E = \frac{r_i - P_i}{r_i + P_i}$$

where r_i is the relative quantity of any food item in the stomach as a percentage of the food consumed, and P_i is the relative quantity of the same food item in the environment expressed as a percentage. Values of E may range from —1 to +1. An E value of zero is expected for a food item when no selective processes operate. Positive selection is indicated by E values falling between 0 and +1 while negative selection operates when E falls between 0 and —1.

Daphnia sp., *Leptodora* sp., *Cyclops* sp. and *Diaptomus* sp. were the only zooplankton food items used in significant quantities (Tables 9-12). Electivity indices were calculated for each day on which stomach and plankton samples were available on the same day and are diagramed in figures 6-9.

Electivity of *Cyclops* was positive through early June in 1967 while in 1965, *Cyclops* was positively selected only on May 14 and July 27 (Fig. 6). During the other sampling periods in both years, *Cyclops* was negatively selected. In Oneida Lake, New York,

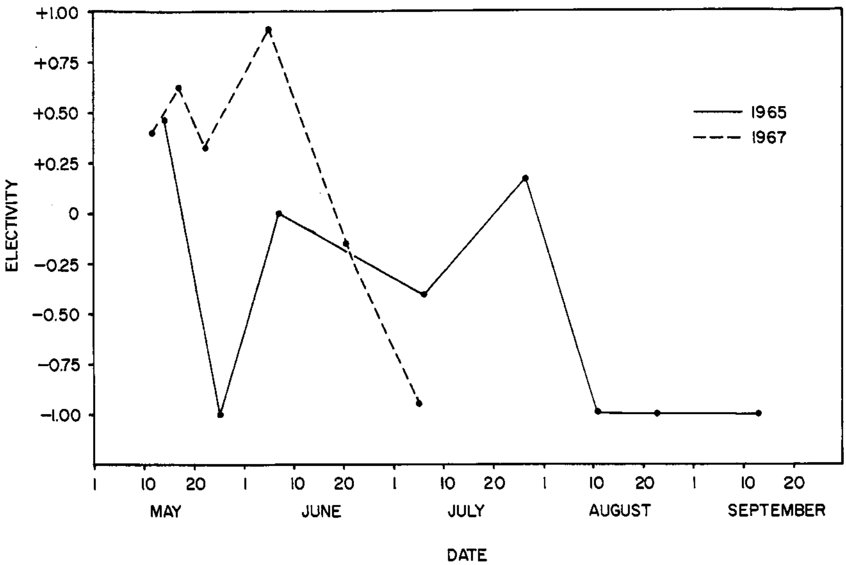


Figure 6. Electivity index of Cyclops sp., 1965 and 1967.

young walleyes showed a positive selection for *Cyclops* in early to mid-May but became strongly negative for later dates (Houde, 1967).

Diaptomus was negatively selected on all sampling dates (Fig. 7). Houde (1967) noted that *Diaptomus* was negatively selected for every date on which plankton and walleye stomachs were examined in Oneida Lake.

Electivity for *Daphnia* generally was negative during the 2 years; some positive selection occurred each year, but showed no definite pattern (Fig. 8). *Leptodora* was positively selected on most sampling dates, with negative selection occurring during the earlier sampling dates when the young walleyes were under 16 mm in total length (Fig. 9). *Leptodora* occurred more frequently in stomachs of larger fry.

Although plankton samples were taken during walleye sampling periods in 1966, not enough stomachs were examined to establish a relationship between plankton and stomach samples.

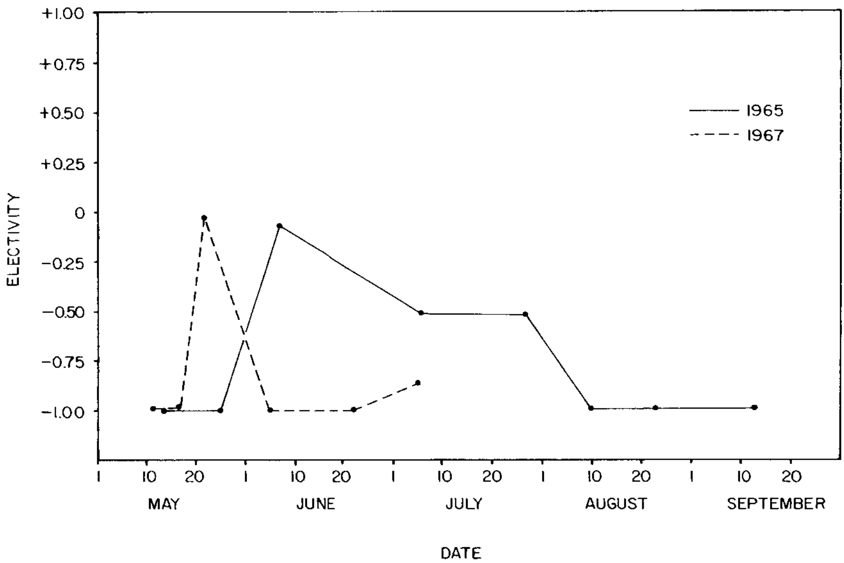


Figure 7. Electivity index of Diaptomus **sp., 1965 and 1967.**

Daphnia was the most abundant zooplankton in Lake Winnebago, and was consumed by young walleyes in greater quantity than

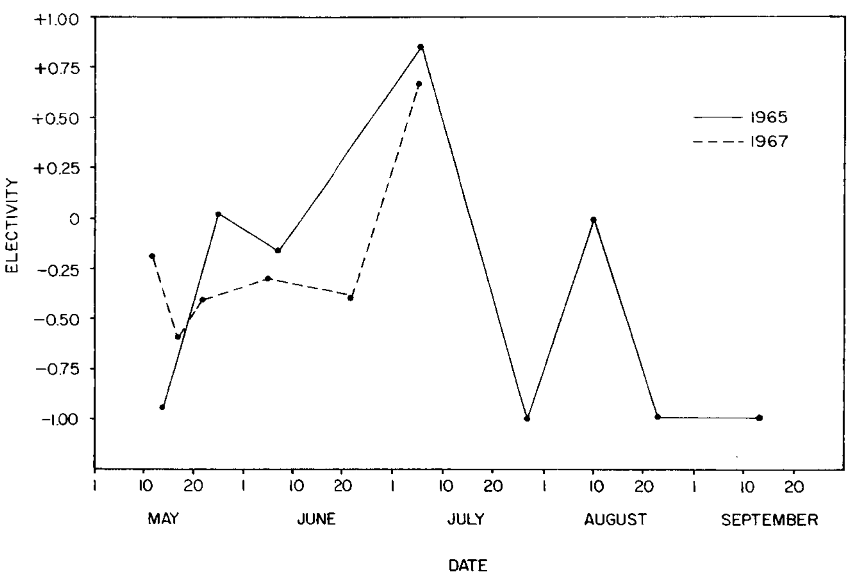


Figure 8. Electivity index of Daphnia **sp., 1965 and 1967.**

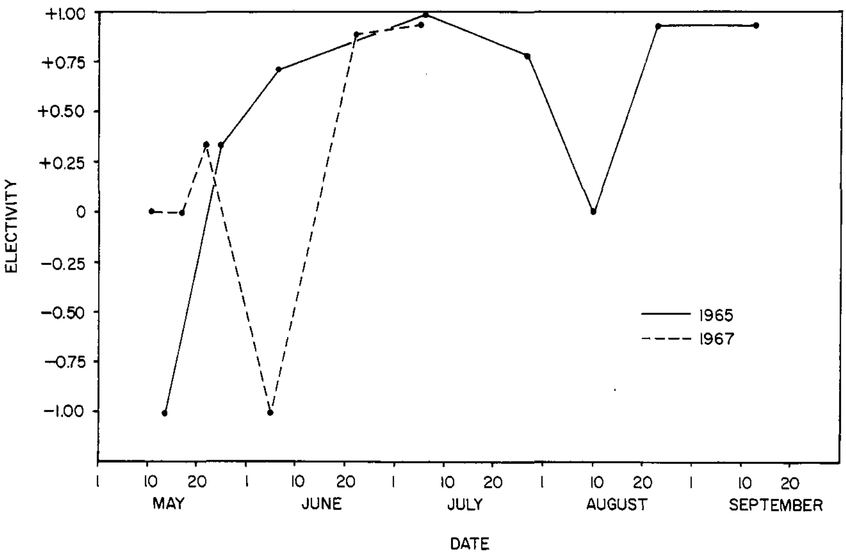


Figure 9. Electivity index of Leptodora **sp., 1965 and 1967.**

any other zooplankton. However, *Daphnia* were consumed only in proportion to their abundance, with little evidence that young walleyes positively sought them out.

On the other hand, *Leptodora,* which was the least abundant zooplankton in Lake Winnebago, was positively sought and selected by young walleyes. The preference shown by young walleyes for *Leptodora* was probably due to its relatively large size which made it a more attractive food item than other species of zooplankton.

GROWTH AND SURVIVAL OF YOUNG WALLEYES

Determination of Growth and Survival

Small bait trawls have been used successfully since 1959 to sample young fish in Lake Winnebago. Trawling has provided information which is useful in determining relative population abundance, growth, survival and other information essential to any life history study. Trawling data from 1959 to 1967 has provided reliable data essential in estimating relative year-class strength of walleyes.

Trawling data indicates that year-class strength is usually set by late September or October. A strong year class was observed only in 1959 (Table 13). Year classes are considered strong when an average catch of over 1.5 young fish per trawl haul are taken in October. An average catch of 0.5 to 1.5 fish per haul would indicate a good year class; catches of this size were made in 1964, 1965, 1966 and 1967. A weak year class was assigned the 1961 and 1962 year classes as the average catch was only 0.2 to 0.4 fish per haul. No year classes were observed in 1960 and 1963.

A check on estimates of year-class strength can be made by observing the catch of yearling walleyes the following year as taken in trawl samples (Table 14). In 1959, when the strong year class occurred, the catch of yearling walleyes remained high the following year. The average catch of 4.7 young walleyes per haul in October, 1959 was followed in 1960 by an average catch of 5.7, 12.3, 6.8, 5.5 and 14.3 yearling walleyes per trawl haul from June through October, respectively. Similarly, in 1964-66, when

TABLE 14

Number of Young and Yearling Walleyes Caught per Trawl Haul and Number of Hauls in Lake Winnebago, 1959-67

Month and Catch	1959	1960	1961	1962	1963	1964	1965	1966	1967
June									
Young	0	0.4	9.3	4.9	0.1	3.5	36.3	0.2	1.5
Yearling	0	5.7	0	0.1	0.4	0	0.6	0.9	0.2
Hauls	2	9	40	40	20	25	20	12	10
July									
Young	5.2	0.4	9.2	3.7	0.1	4.9	17.4	0.6	12.7
Yearling	0.1	12.3	0	0.1	0	0	1.6	1.6	0.3
Hauls	40	36	40	40	20	20	20	10	20
August									
Young	7.7	0.5	1.2	0.6	0	1.1	2.2	0.4	0.1
Yearling	0.1	6.8	0	0	0	0	0.3	0.5	0
Hauls	35	72	59	50	20	20	20	17	10
September									
Young	9.1	0.1	0.2	0.1	0	0	8.9	0.9	*
Yearling	0.2	5.5	0	0	0.1	0	2.2	0.5	*
Hauls	36	30	59	30	20	10	10	20	*
October									
Young	4.7	0	0.4	0.2	0	1.0	1.0	0.7	0.7
Yearling	0	14.3	0	0.1	0.2	0	0.7	0.4	0.3
Hauls	12	14	35	30	30	20	20	10	3

* No trawl hauls made.

year classes for these years were good, catches of yearlings the following years were high although not as many walleyes were caught as were taken in 1960.

Since 1960, meter nets were used to capture young walleyes during May (Appendix D). Data from these meter net hauls provides some indication of the success of the hatch for each year and the survival of fry migrating into Lake Winnebago from the spawning marshes. No indication of possible year class strength can be obtained from this data. Although trawling data suggested that 1964 was a good year class, meter nets were able to capture only a few fish. The catch of young walleyes with meter nets during May, 1960 was extremely good when compared to catches during the other years; by October, 1960, however, the 1960 year class was completely missing.

The average lengths of walleyes captured during each trawl sampling series in 1959 through 1967 and the growth curves are illustrated in Appendix E.

The fastest growth was exhibited by the strong 1959 year class which attained an average length of 185 mm (range, 134-224 mm) on October 31, 1959. During the 4 years when a good year class was evident (1964-67), growth of walleyes was between 134 and 145 mm by the end of October. The slowest growth was shown by the weak 1961 year class which attained a length of 127 mm (range, 106-145 mm) by the end of October. Outside of the fast growing 1959 year class, young walleyes in Lake Winnebago attained a length of 127 to 145 mm by the end of October, thereby exhibiting consistent growth.

In the years 1960 through 1967, rate of growth in May was relatively the same, varying from 20 to 26 mm. The greatest growth increment occurred during July for all years except 1959 when the greatest growth increment occurred in August (Table 15). By the end of July, a young walleye in Lake Winnebago is generally longer than 75 mm. In 1960, however, young walleyes had only attained an average total length of 66 mm by the end of July (Table 16). The estimated mean total length of young walleyes in Oneida Lake, New York on August 1 was 73 to 108 mm for the years 1956 through 1964 (Forney, 1966).

The growth rate of most year classes declined from mid-August through September. The 1959, 1964 and 1967 year classes maintained a relatively rapid growth rate into September as compared with that of other year classes.

Very little growth occurred after October 1. The percentage of growth completed by October ranged from 85 percent in 1967 to 96 percent in 1961 (Table 16). In Oneida Lake, 97 to 100 percent

TABLE 15

Average Monthly Growth Increments (in Millimeters) of Young Walleyes During the 1959-1967 Growing Season

Year	May	June	July	August	September	October
1959	*	*	41	57	28	9
1960	26	18	22	17	*	*
1961	23	22	34	29	14	5
1962	25	30	45	15	14	8
1963	20	18	*	*	*	*
1964	23	26	29	20	19	18
1965	21	27	33	32	11	11
1966	23	19	62	12	13	12
1967	26	20	28	18	22	20

* Growth unknown.

of the season's growth was completed by October 1 for the years from 1960 to 1964 (Forney, 1966).

In Lake Winnibigoshish, Minnesota, young walleyes averaged

TABLE 16

Total Lengths (in Millimeters) of Young Walleyes on the First Day of Successive Months During the 1959-1967 Growing Season and Percent of First Year Growth Completed on Each Date

Month and Growth	1959	1960	1961	1962	1963	1964	1965	1966	1967
June 1									
Length	*	26	23	25	20	23	21	23	26
Percent	—	—	18	18	—	16	16	16	19
July 1									
Length	50	44	45	55	38	59	48	42	46
Percent	27	—	35	40	—	41	36	30	34
August 1									
Length	91	66	79	100	**	88	81	104	74
Percent	49	—	62	73	—	61	60	74	55
September 1									
Length	148	83	108	115	**	108	113	116	92
Percent	80	—	85	84	—	74	84	82	69
October 1									
Length	176	**	122	129	**	127	124	129	114
Percent	95	—	96	94	—	88	92	91	85
November 1									
Length	185	**	127	137	**	145	135	141	134
Percent	100	—	100	100	—	100	100	100	100

* Length unknown.
** No fish taken after the previous sampling date.

117 mm in total length on August 19, 1954 (Maloney and Johnson, 1955) while in Mille Lacs Lake they averaged 122 mm on August 20. The total length of young walleyes caught by electrofishing during the fall, 1959-1962 in Pike Lake, Wisconsin averaged 175 mm over 4 years, with the greatest growth of 188 mm occurring in 1959 and the poorest of 160 mm, in 1961 (Mraz, 1968). Young walleyes in Lake Gogebic, Michigan had attained a total length of 157 mm in 1941 and 120 mm in 1947 by mid-October (Eschmeyer, 1950).

It should be noted that young walleyes in Lake Winnebago, Pike Lake and Oneida Lake all attained their greatest rate of growth in 1959. The 1959 year class was strong in all of these lakes.

Factors Affecting Growth and Survival

Factors affecting development of walleye year classes in Lake Winnebago can be grouped according to 3 developmental stages of the fish, as: (1) those factors affecting spawning and egg survival; (2) those affecting survival from the fry to fingerling stage, and (3) those affecting mortality over the first winter.

In most years, the factors affecting spawning and egg survival are of minor importance in the Lake Winnebago area because available spawning sites are of high quality and they are extensive (i.e., they are large and numerous). A drastic drop in water levels on the marshes in 1963 completely eliminated the 1963 year class when eggs were stranded as water levels receded. This was the only drastic example of a complete failure during the egg stage for any of the years studied (1959 to 1967). In 1964, the water levels were so low that spawning fish could not enter the spawning marshes and were forced to spawn in the rivers. Although there was a complete loss of eggs in the river system, there were still sufficient numbers of spawning walleyes that didn't migrate into the rivers. The first indications of any major spawning in Lake Winnebago were recorded in 1964; egg survival that year was good, resulting in the good survival of the 1964 year class. Even when water levels did recede to critical levels on the spawning marshes, sufficient numbers of fry were captured in Lake Winnebago to indicate that egg and initial fry survival were good. When spawning occurred in Lake Winnebago, 1964-67, numerous eggs were washed by wave action on the beach; in each of these years, however, the year class was classed as good in October.

Once year-class strength was set by late September or October, there was little indication to show that considerable mortality over the first winter occurred in Lake Winnebago. In Oneida Lake, New York (Forney, 1966) samples of walleyes taken in the fall indicated first-year growth was usually completed by October 1, although mean lengths of most year classes increased substantially between fall and spring. Changes in population length-frequency distribution between fall and spring indicate the increase in population mean length may result from a high overwinter mortality of small walleyes. This suggests that year classes which grow rapidly during their first year should experience lower mortality over the winter than slower-growing year classes. Data collected suggests this did not occur on Lake Winnebago. Forney (1966) stated that the possible effect of first-year growth on survival and establishment of year class strength needs further study.

Those factors affecting survival from the fry to fingerling stage are the most critical in Lake Winnebago. On the basis of trawl samples recorded in table 13, it is clear that any failure that does occur is noted by mid-to-late July. Maloney and Johnson (1955) demonstrated in Mille Lacs Lake, Minnesota that failure of fingerlings to survive is evident by midsummer.

Temperatures

Lake Winnebago water and air temperatures as recorded at Oshkosh were obtained throughout the study. However, no significant changes over the years were recorded, thus no correlations between temperatures and growth or survival could be made. Forney (1966) stated that annual May-June air temperatures suggest that lake temperatures determined the rate of walleye growth in early summer and to some extent may influence early or late hatching of walleye fry.

Food Utilization

It has long been known that in typical Minnesota walleye lakes, populations of walleyes are usually associated with fairly large populations of yellow perch. Smith and Krefting (1953) noted a remarkably close correlation between the six year-classes of walleye and yellow perch in the Red Lakes, northern Minnesota.

There was a size relationship between young walleyes and yellow perch in Lake Winnibigoshish and the Cutfoot Sioux lakes in the summer of 1958, and of the fish in young walleye stomachs, yellow perch made up all of the identifiable remains (Johnson, 1969). In late June of 1958, the young walleyes were about 13 mm longer than young yellow perch and by September, they had increased their size advantage to 61 mm. In the shallower and more weedy Little Cutfoot Sioux Lake, the young walleyes and yellow perch were about the same size and in the absence of usable forage fish in Little Cutfoot, the diet of young walleyes was almost entirely of small crustaceans, especially *Daphnia* and *Hyalella,* and of immature aquatic insects, mostly chironomid larvae.

In Lake Winnebago, there was no relationship between young walleyes and yellow perch. Yellow perch fry consumed by young walleyes were found in walleye stomachs only during 1 sampling day each year when yellow perch fry were extremely abundant at the mouth of the Fox River (Appendix D). Comparisons of growth and size betwen young walleyes and yellow perch from June through October indicate that yellow perch were small enough in all years that they could have been consumed by young walleyes (Fig. 10). The size difference between the two species

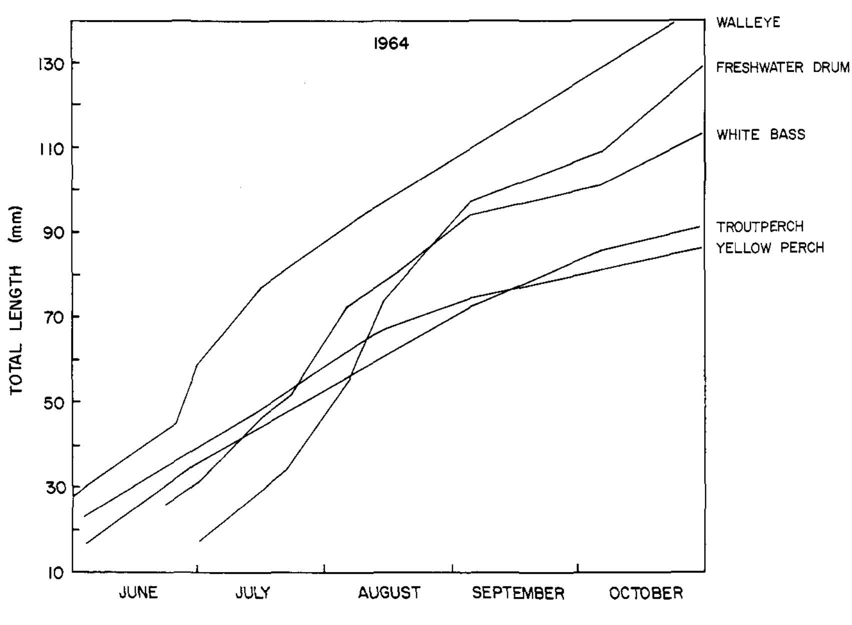


Figure 10. Growth (total length in mm) of young walleye, white bass, freshwater drum, yellow perch and troutperch in Lake Winnebago, 1964. Similar growth was observed for these species in 1959-1962 and 1965-67.

was similar to that found by Johnson (1969) when yellow perch were the main diet of young walleyes.

Young yellow perch were either not abundant enough, or if abundant, did not associate with young walleyes. Although young walleyes were never taken in any numbers during shoreline seining, young yellow perch were always taken in great quantities especially in the shallow, weedy areas.

Only in 1959 and 1962 when young troutperch and freshwater drum were extremely abundant (Table 13) did young walleyes in Lake Winnebago feed on fish. The abundance and not the size relationship between young walleyes, troutperch and freshwater drum was likely the reason for the increased consumption of species of forage fish in 1959 and 1962, since for the years, 1960-61 and 1964-67, size differences as large or larger were noted but young walleyes did not consume fish during these years.

Growth rate of walleyes in Oneida Lake (Forney, 1966) in late summer tended to be rapid in years when walleyes fed on fish and slower when invertebrates were common in the diet. Although yellow perch were the principal forage fish found in walleye stomachs, growth in summer was not correlated with density of young perch. Probably the growth rate of young perch determines the proportion of the perch population that is vulnerable to walleye predation in late summer.

In Lake Winnebago young walleyes only fed on young troutperch and freshwater drum when the density of these forage species was high, as densities were in 1959 and 1962. It is quite obvious that by late July, there are usually not sufficient numbers of available species of forage fish in Lake Winnebago to sustain a rapidly growing walleye population that would shift from a diet of zooplankton and insect larvae to fish if fish are available in sufficient numbers. It is also quite obvious that zooplankton and insect larvae are not limiting factors in Lake Winnebago from the time the fry enter the lake through September.

EXPERIMENTAL MANAGEMENT

State ownership of walleye spawning marshes along the Wolf River provided an opportunity to use mechanical means to improve spawning areas. Management practices primarily involved: (1) controlled burning to arrest plant succession on marshes which were going over from areas of desirable grass and sedge vegetation to areas of less desirable cattail and woody vegetation, and (2) creating ditches or deepening and widening existing natural channels leading into the marsh to insure adequate water levels and flow in the marshes. Other improvements were made according to the individual needs of each marsh to make the areas more attractive to walleyes.

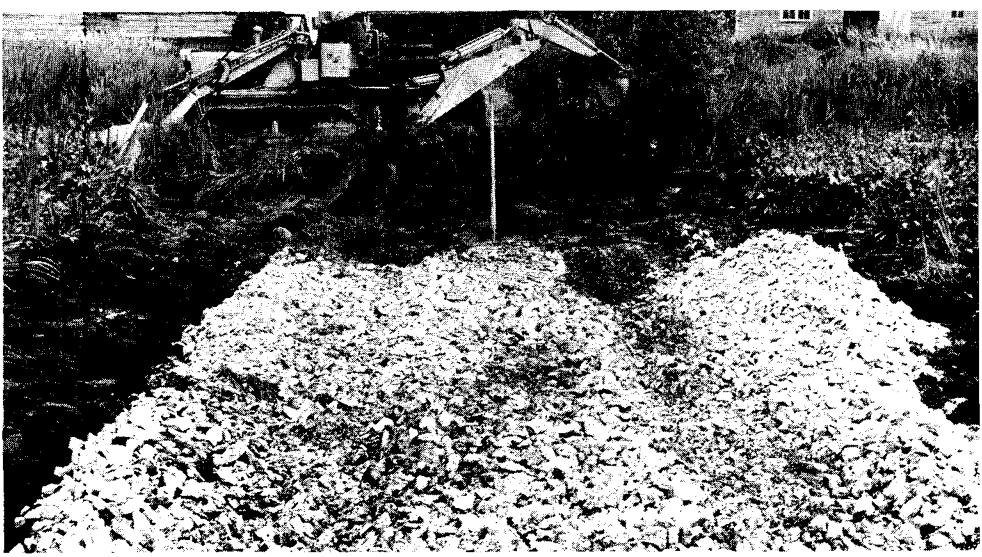
Spoehr's Marsh

Improvements on Spoehr's Marsh, Wolf River, were completed during 1963. The inlet was widened, an old gravel road which held back water in low water years was removed, and controlled burning on approximately 80 acres was accomplished (Fig. 11).

Due to low water levels during the following spring, spawning walleyes were prevented from entering the marsh; hence, no evaluation of the improvements could be made in 1964. In 1965, the highest water levels ever recorded on the marsh made it difficult to evaluate management practices designed to improve water currents over the entire marsh.

The effects of other practices were more readily noticeable. The controlled burning on April 18, 1963 killed off undesirable shrub

A portion of an old road across the upper end of Spoehr's Marsh was removed in 1963. A new lower road bed was laid down so that the road could still be used.



areas on the marsh. There was no evidence of new growth of shrubs on these areas through 1967. The fire also consumed much of the organic material building up on the marsh so that greater areas of solid grasses were noted in 1964 and 1965. The presence of these grasses created additional areas of desirable spawning habitat.

Other spawning areas further into the marsh were provided. The dredging at the inlet and the removal of the old gravel road certainly increased water currents in the upper end of the marsh, thereby creating areas which had previously been unused by spawning walleyes. In 1966 and 1967, water levels were high when spawning occurred and fish utilized the burned-off area to a greater extent than they had prior to 1963.

During October, 1967, approximately 20 acres of woody vegetation was chopped off and removed with a "Brush-Hog" brush cutter designed and maintained by the Bureau of Fish Management (Fig. 25). The cutter was able to cut and shred woody vegetation up to 3 inches in diameter. Most of the brush was willow approximately 1 to 2 inches in diameter.

The 7-foot brush cutter was equipped with 2 swinging knives. Due to the fact that no tractor with power take-off was available,

A year later, new areas of the marsh were opened to spawning walleyes and water flow across the marsh was increased in spite of the fact that water levels in 1964 were low.

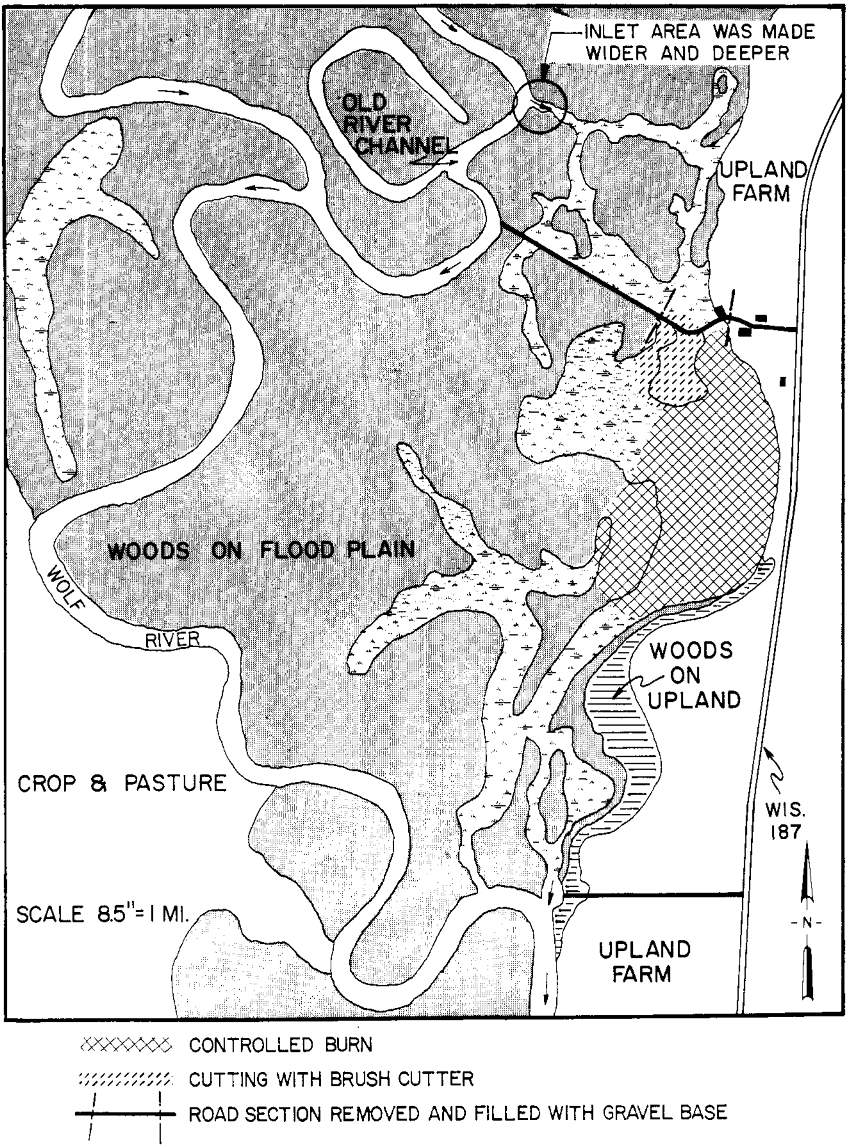


Figure 11. Mechanical marsh improvements on Spoehr's Marsh, Wolf River.

a 37 horsepower Wisconsin air cooled engine was mounted directly on the towing hitch of the brush cutter. The engine and cutter

In 1967, a brush cutter was used to remove heavy growths of woody vegetation from Spoehr's Marsh.

Before cutting.

After cutting.

Within a year after brush cutting, water was flowing across the cut-over area. (The crooked tree in the center of the photo is the same one that is in the 2 photographs, above showing a portion of Spoehr's Marsh before and after cutting.) The removal of the woody vegetation clearly improved water flow through the marsh and opened up new areas of walleye spawning habitat.

fitted together well and made an extremely effective working unit. The engine shaft was connected directly to the cutter's drive-shaft with a slip clutch and a shock absorbing universal to avoid damage if solid objects not seen by the operator were hit by the blades. The unit was pulled behind a bulldozer with tracks.

The unit would cut a 7-foot swath through the vegetation just above the ground. Although some willow sprouts were observed in 1968, the dense stand of woody vegetation which had characterized the area before cutting was thinned out and additional spawning areas were thus created.

Hortonville Marsh

The Hortonville Marsh complex has always been considered the largest and most productive walleye spawning area along the Wolf River. Although no improvements are anticipated at the present time on this area, it is worth recording how diking and level ditching can destroy a choice walleye spawning area.

During 1964, when level ditching and diking on the marsh was completed, approximately 400 acres of marshland normally used by spawning walleyes were virtually destroyed. A dike, which with minimum work could support auto travel, was constructed from the highland across the marsh to the bank of the Wolf River. The construction of this dike prevented walleyes from spawning within and below the dike area since the water currents necessary for fry survival were eliminated by the presence of the dike.

On April 21, 1965, the area was checked to determine if water levels and currents were sufficient to allow walleyes to spawn. By means of A.C. boom shocking equipment, the entire marsh was checked for spawning walleyes. No walleyes were taken within the diked area; however, spawning walleyes (110 males, 28 females) were taken in a small area where water was flowing over, just above, and below the dike. Besides the fish, numerous eggs were taken in this area.

On April 29, 1965, the marsh was again checked to determine if there were sufficient currents to carry newly hatched fry out of the marsh into the Wolf River and to see if any good, viable walleye eggs could still be found in the area where spawning fish were taken on April 21. Although a few good eggs were found, general water conditions were poor. Algal growth was abundant and water currents did not appear to be sufficient. Since water levels continued to drop on the Wolf River after April 29, it was concluded that most of the eggs on Hortonville Marsh would not hatch out and if they did, there was no chance of the fry ever reaching the river.

In previous years of sampling on this marsh, spawning walleyes could be shocked in all areas that were diked plus the large open area just below the dike. The ditching and diking definitely had detrimental effects on an area which had been a good walleye spawning marsh. Large stands of river bulrush, which had never been very abundant prior to diking, replaced the grasses and sedges which the walleyes preferred for spawning.

It would have been desirable to stagger the spoil bank instead of creating one continuous dike. By staggering the spoil bank, the owner could have increased muskrat production and still allowed a free flow of water which would have been beneficial to spawning walleyes. As predicted, high water in 1967 washed out the dike. If sufficient large culverts, 4 to 6 feet in diameter, were used in the washed-out areas, the owner could still maintain a dike, and sufficient current could be provided to allow spawning walleyes to make some use of the marsh.

Ditching operations on Hortonville Marsh in 1964 created this high spoil bank which extended the entire length of the marsh and blocked water flow across the marsh. Below the dike area, water from the river backed up; without a current, walleyes were not able to spawn in this portion of the marsh.

Hopp's Marsh

In previous years a town road was constructed and maintained across the entire upper end of Hopp's Marsh to provide a means of travel to the Fox River where a small parking area was also constructed. During the course of this study the road was not maintained and a section near the river had been washed out; however, the road did hold back water during all years. In 1965, small sections of the road were removed to increase the flow over the marsh, but water currents were still not sufficient. The area in question is currently being purchased by the Bureau of Game Management for the White River marsh complex. Complete removal of the road would increase currents and flows over Hopp's Marsh and could greatly increase the potential of this walleye spawning marsh.

When water levels on Hopp's Marsh were high, water was able to flow over the road extending across the upper part of the marsh. However, when water levels were low, the road prevented water from entering the marsh. Here the road was ditched to allow water to increase water flow.

MANAGEMENT IMPLICATIONS

Factors affecting spawning and egg survival are of minor importance in the Lake Winnebago area because of the quality and extensive spawning sites that are available in Lake Winnebago and the marshes along the Wolf and Fox rivers. State ownership of the marshes, especially along the Wolf River, is essential if the quality and quantity of these sites are to be maintained.

Trawling with small-mesh otter trawls in late September and October will provide reliable data in estimating relative year-class strength of young walleyes in Lake Winnebago. The abundance of walleyes that will be available to the angler in future years can be predicted quite reliably by these trawling data.

Mechanical methods to improve spawning marshes that are going through a succession of choice grass and sedge vegetation to less desirable cattails and woody plants should be considered by Fish Management personnel.

From 1960 through 1967, there was no successful walleye hatch on the marshes adjacent to the Fox River. Water level and carp control are essential if these marshes are to contribute substantially to future walleye populations in Lake Winnebago.

Lack of species of forage fish in Lake Winnebago is the most critical factor in the survival of walleyes from the fry to fingerling stage. The introduction of minnow species may partially fill in the void during some years.

Level ditching, diking and pond construction on the walleye spawning marshes must be curtailed as these practices change current flows or completely eliminate current over the marshes. Strict flood plain zoning is essential and must be enforced if we are to preserve the walleye spawning marshes.

Restrictions governing motor boat usage on walleye spawning marshes during April and May should be considered. There is some evidence to indicate that excessive motor boat usage on the marshes during egg development is detrimental to the eggs as the areas are roiled considerably, and numerous eggs are washed off the sedge and grass mats, eventually settling on the bottom.

SUMMARY AND CONCLUSIONS

On all areas studied, successful spawning was determined by three factors: (1) *Number of available sites.* The presence of spawning sites along the west shoreline of Lake Winnebago, in addition to 19 major spawning marshes along the Fox and Wolf rivers provided numerous areas in which walleyes from Lake

Winnebago could spawn. Even when walleye movement up the Fox River was blocked by dams during years of low water level, a sufficient number of marshes below these dams allowed successful spawning to occur. (2) *Size of sites.* Approximately 30 percent of the total area of each marsh was suitable for walleye spawning. But, the marshes were large (two-thirds of them were at least 200 acres in size, one containing over 2,000 acres), and sites along Lake Winnebago were extensive (over 20 miles of shoreline). Thus although only a small percentage of marsh acreages could be used by spawning walleyes, the marshes were large enough and lake spawning sites were so numerous that walleyes were still able to spawn in a relatively large area. (3) *Quality of sites.* Not only were spawning sites extensive, but they were also of high quality, i.e., water flow and bottom types were favorable for walleye spawning. All of the spawning marshes along the 2 rivers were unique in that they were not just areas flooded by water overflowing the river bank. They all had an inlet and outlet which provided constant flow of water over the marshes during periods of high water levels in the rivers. Clean bottom types preferred by spawning walleyes were also present on all sites. The bottom types in the lakes consisted of gravel-rubble bottoms and in the marshes, vegetative mats of sedge and grasses (mainly reed canary grass, sweet flag and rice cut-grass).

Several factors were previously thought to effect spawning success: (1) *Spring angling harvest.* Tag returns from fish taken on the Wolf river over a three-year period showed that over 60 percent of the walleyes were taken after, not before, the spawning season. It was concluded that high fishing pressure prior to the spawning season has little impact on the degree of reproductive success of the walleye population in the Wolf river. (2) *Weather.* Although cold weather prolonged spawning activity on Spoehr's Marsh, it never inhibited it over an extended period of time.

Four factors were found to effect egg development: (1) *Water levels and flow.* When gauge readings of 5.0 feet or more showed water levels on the marshes to be high at the beginning of the spawning period, females moved as far into the marshes as possible to spawn. If water levels then decreased, eggs and fry were stranded in shallow areas of the marsh and mortality occurred. When water levels were initially lower (between 4.0 and 5.0 feet), females were forced to spawn in the deeper channels leading into and out of the marshes. As long as drastic dry-up did not occur, eggs hatched and water levels were deep enough in these areas so that currents were sufficient to move fry out of the marshes. At both high and intermediate water levels, a constant flow of water over the eggs was necessary at all times. (2) *Substrate type.* Whenever eggs came into contact with marsh substrate consisting of soft-muck detritus, mortality occurred. In the spawning marshes, as long as eggs were spawned onto and remained on the mats of grass-sedge vegetation, they were protected from bottom substrates and could develop normally. When walleyes spawned in flooded woody areas of the marshes, eggs failed to survive due to direct contact with the detritus substrates. (3) *Carp activity.* Spawning carp were found to have a detrimental effect on eggs developing in Fox river marshes. Although protective vegetative mats were present, the activity of numerous carp dislodged eggs from these mats and caused them to settle on the silt bottom where they died immediately. (4) *Dissolved oxygen.* Another detrimental factor unique to Fox river marshes was low dissolved oxygen concentrations, related to carp activity and dense growth of algae and other aquatic vegetation. These low concentrations (below 4 ppm) prevented normal embryo development.

Factors investigated which did not affect egg development were: (1) *Water temperatures.* On the marshes and in the lake, no correlation between water temperatures and embryo survival could be made, although the most rapid egg development was associated with day time water temperatures above 50 F and high minimum water temperatures that did not fall below 45 F for any extended period. (2) *Predation.* Although other species of fish were associated with walleyes on the spawning grounds, no evidence of egg loss due to predation was ever found.

Fry survival was influenced by two factors: (1) *Water depth.* High water levels creating sufficient currents were necessary to move fry out of the spawning marshes. Low water levels resulted in fry mortality when the fry were trapped in pockets of water between dense mats of vegetation or accumulations of other organic matter. (2) *River velocity.* Once fry left the spawning marshes, they were dependent upon sufficient river currents to carry them downriver within 3-5 days after hatching. Since their paired fins were not developed enough to enable the fry to move about freely in search of food, the fry relied on river velocity to carry them to food sources in Lake Winnebago or the upriver lakes before their yolk sacs were absorbed.

In order to preserve existing high quality and extensive spawning sites, state ownership of spawning marshes is essential. Management practices by which such marshes can be maintained include controlled burning and brush cutting to curtail plant succession, and channel deepening and road removal to improve current flow over the marshes.

APPENDIX A

Age Frequency of Spawning Walleyes Taken at Three Locations

TABLE 17

Spoehr's Marsh, Wolf River, 1963-67

Sex and Age	1963 Year Class	1963 Avg. Size*	1963 Fish Sampled No.	1963 Fish Sampled %	1964** Year Class	1964** Avg. Size*	1964** Fish Sampled No.	1964** Fish Sampled %	1965 Year Class	1965 Avg. Size*	1965 Fish Sampled No.	1965 Fish Sampled %	1966 Year Class	1966 Avg. Size*	1966 Fish Sampled No.	1966 Fish Sampled %	1967 Year Class	1967 Avg. Size*	1967 Fish Sampled No.	1967 Fish Sampled %
Females:																				
IV	1959	16.6	1	11.1																
V	1958	16.6	3	33.3	1959	16.5	17	53.1					1961	16.1	1	4.0	1962	17.5	1	8.3
VI					1958	18.6	6	18.7	1959	17.3	1	11.1					1961	18.6	1	8.3
VII	1956	21.9	3	33.3	1957	21.2	6	18.7	1958	19.9	1	11.1	1959	20.0	6	24.0	1960	19.0	1	8.3
VIII	1955	22.5	2	22.2	1956	25.1	3	9.4	1957	22.8	6	66.7	1958	20.3	11	44.0	1959	20.9	7	58.3
IX									1956	20.0	1	11.1	1957	24.4	4	16.0	1958	27.8	2	16.7
X													1956	25.1	3	12.0				
Males:																				
III					1961	13.5	5	2.6									1964	14.5	5	1.6
IV	1959	14.1	27	18.5	1960	13.7	3	1.6					1962	15.2	11	3.9	1963	15.7	19	6.0
V	1958	16.1	27	18.5	1959	14.6	113	59.5					1961	15.4	6	2.1	1962	16.2	77	24.4
VI	1957	17.0	47	32.2	1958	17.1	38	20.0	1959	15.8	80	39.0	1960	15.5	2	0.7	1961	16.8	28	8.9
VII	1956	17.6	37	25.3	1957	17.8	24	12.6	1958	17.6	77	37.5	1959	16.4	125	44.0	1960	18.1	44	13.9
VIII	1955	18.4	8	5.5	1956	18.6	7	3.7	1957	18.7	48	23.5	1958	18.2	123	43.3	1959	18.1	139	43.9
IX													1957	19.6	16	5.6	1958	20.5	4	1.3
X													1956	19.5	1	0.4				

* The average size of the fish caught is given by the average total length in inches.
** Marsh dry; fish taken near marsh outlet.

TABLE 18

Hopp's Marsh, Fox River, 1963 and 1965-67

Sex and Age	1963				1965				1966				1967			
	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %
Females:																
V	1958	18.7	3	33.3									1962	17.5	3	4.1
VI	1957	21.8	1	11.1	1959	18.6	13	41.9					1961	18.4	16	21.9
VII	1956	22.7	3	33.3	1958	21.1	8	25.8	1959	19.0	24	64.9	1960	20.2	16	21.9
VIII	1955	24.5	2	22.2	1957	22.3	6	19.4	1958	21.8	10	27.0	1959	20.4	35	47.9
IX					1956	25.8	4	12.9	1957	25.5	3	8.1	1958	23.5	3	4.1
Males:																
IV	1959	13.7	31	35.6					1962	14.6	9	5.7				
V	1958	16.2	10	11.5	1960	15.0	12	6.5	1961	15.1	6	3.7	1962	16.4	4	3.2
VI	1957	16.6	29	33.3	1959	16.1	97	52.7	1960	15.5	3	1.9	1961	16.3	35	28.2
VII	1956	17.8	16	18.4	1958	17.5	52	28.3	1959	15.9	117	73.6	1960	16.8	25	20.2
VIII	1955	19.4	1	1.1	1957	18.4	23	12.5	1958	18.0	21	13.2	1959	17.0	55	44.4
IX									1957	18.8	3	1.9	1958	19.8	5	4.0

* The average size of fish caught is given by the average total length in inches.

TABLE 19

Lake Winnebago, 1964-67

Sex and Age	1964				1965				1966				1967			
	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %	Year Class	Avg. Size*	Fish Sampled No.	Fish Sampled %
Females:																
IV									1962	16.5	2	5.6	1963	16.4	2	4.7
V	1959	15.7	21	100.0									1962	17.7	3	6.9
VI					1959	16.5	34	89.5					1961	18.6	9	20.9
VII					1958	19.5	3	7.9	1959	18.0	34	94.4	1960	18.6	10	23.3
VIII					1957	22.1	1	2.6					1959	19.8	19	44.2
Males:																
III					1962	13.3	14	7.9	1963	13.4	3	1.9	1964	13.4	5	6.6
IV					1961	13.5	4	2.2	1962	14.9	26	16.4	1963	14.9	3	3.9
V	1959	14.2	123	100.0					1961	14.7	4	2.5	1962	15.5	16	21.1
VI					1959	14.7	157	88.2	1960	14.4	2	1.3	1961	15.9	29	38.2
VII					1958	17.4	3	1.7	1959	15.3	124	77.9	1960	15.9	14	18.4
VIII													1959	16.5	9	11.8

* The average size of fish caught is given by the average total length in inches.

TABLE 20

Summary in Percent for Eight Age Groups at All Locations, 1965-67.

Sample Sites	III			IV			V			VI		
	1965	1966	1967	1965	1966	1967	1965	1966	1967	1965	1966	1967
Wolf River												
Hortonville Marsh												
Female								3.6	28.6	63.6	17.9	17.8
Male		9.3	12.4		23.1	7.9		17.0	19.2	52.0	6.6	16.9
Spoehr's Marsh												
Female								4.0	8.3	11.1		8.3
Male			1.6		3.9	6.0		2.1	24.4	39.0	0.7	8.9
Total												
Female								3.8	22.5	48.4	9.4	15.0
Male		3.6	5.5		11.4	6.7		7.9	22.5	43.3	3.0	11.8
Fox River												
Below Berlin Dam												
Female				18.1			9.1			63.6		
Male	7.9			4.7			1.6			76.4		
Above Berlin Dam												
Female				6.0		8.5	8.0	37.5	27.7	51.0	12.5	17.0
Male	2.9	3.2	28.6	2.9	33.9	6.9	0.7	16.9	37.6	68.4	10.6	10.0
Hopp's Marsh												
Female									4.1	41.9		21.9
Male					5.7		6.5	3.7	3.2	52.8	1.9	28.2
Total												
Female				5.4		3.3	5.4	6.7	13.3	50.0	2.2	20.0
Male	3.1	1.7	20.0	2.2	20.9	4.8	3.4	10.9	27.3	64.2	6.6	15.5
Lake Winnebago												
Female					5.6	4.7			6.9	89.5		20.9
Male	7.9	1.9	6.6	2.2	16.4	3.9		2.5	21.1	88.2	1.3	38.2

TABLE 20, Continued

Sample Sites	VII			VIII			IX			X*	No. Sampled		
	1965	1966	1967	1965	1966	1967	1965	1966	1967	1966	1965	1966	1967
Wolf River													
Hortonville Marsh													
Female	36.4	67.8	3.6		7.1	42.9		3.6	7.1		22	28	28
Male	32.0	37.4	6.8	13.0	4.4	32.2	3.0	2.2	4.5		100	182	177
Spoehr's Marsh													
Female	11.1	24.0	8.3	66.6	44.0	58.3	11.1	16.0	16.7	12.0	9	25	12
Male	37.5	44.0	13.9	23.5	43.3	43.9		5.6	1.3	0.4	205	284	316
Total													
Female	29.0	47.2	5.0	19.3	24.5	47.5	3.3	9.4	10.0	5.7	31	53	40
Male	35.7	41.4	11.4	20.0	28.1	39.7	1.0	4.3	2.4	0.2	305	466	493
Fox River													
Below Berlin Dam													
Female	9.1										11		
Male	6.3			3.1							127		
Above Berlin Dam													
Female	20.0	37.5	6.4	8.0	12.5	31.9	6.0		6.4		50	8	47
Male	22.8	32.8	4.1	2.2	2.1	11.7		0.5	1.0		136	189	290
Hopp's Marsh													
Female	25.8	64.9	21.9	19.3	27.0	47.9	13.0	8.1	4.1		31	37	73
Male	28.3	73.6	20.2	12.4	13.2	44.4		1.9	4.0		184	159	124
Total													
Female	20.7	60.0	15.8	10.9	24.4	41.7	7.6	6.7	5.0		92	45	120
Male	20.4	51.4	8.9	6.7	7.2	21.5		1.2	1.9		447	348	414
Lake Winnebago													
Female	7.9	94.4	23.3	2.6		44.2					38	36	43
Male	1.7	77.9	18.4			11.8					178	159	76

* No fish of age group X were caught in 1965 and 1967.

APPENDIX B

Length Frequency (in Percent) of Spawning Walleyes Taken at Three Locations

TABLE 21

Spoehr's Marsh, 1963-67

Total Length Intervals (in Inches)	1963		1964*		1965		1966		1967	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
11.0-11.9	1.4									
12.0-12.9	1.4		5.9		0.2					
13.0-13.9	7.4		15.1		1.9				0.4	
14.0-14.9	4.1		23.8		6.8		1.4		2.2	
15.0-15.9	18.4		12.4	10.4	14.2		15.8		9.8	
16.0-16.9	23.8	33.3	13.0	24.1	20.1	6.1	23.4	4.0	27.2	
17.0-17.9	23.8	11.1	17.8	31.1	28.6	18.1	27.8		31.5	8.3
18.0-18.9	16.3		10.3	3.4	20.1	21.2	21.9	8.0	20.1	8.3
19.0-19.9	3.4		1.6	6.9	5.8	18.1	7.2	12.0	6.7	25.0
20.0-20.9		11.1		6.9	2.2	9.1	2.1	36.0	2.0	16.7
21.0-21.9				3.4		6.1	0.3	8.0		16.7
22.0-22.9		44.4		3.4		6.1		4.0		8.3
23.0-23.9						6.1				
24.0-24.9						6.1		8.0		
25.0-25.9				6.9		3.0		16.0		
26.0-26.9								4.0		
27.0-27.9				3.4						8.3
28.0-28.9										8.3
Sample Size	147	9	185	29	684	33	291	25	510	12
Avg. Length	16.5	19.6	16.2	20.4	17.1	19.9	17.2	21.2	17.4	21.4

*Marsh dry; fish taken near outlet.

TABLE 22

Hopp's Marsh, 1963 and 1965-67

Total Length Intervals (in Inches)	1963		1965		1966		1967	
	Male	Female	Male	Female	Male	Female	Male	Female
11.0-11.9	2.3							
12.0-12.9	6.9						0.4	
13.0-13.9	11.4						4.3	
14.0-14.9	10.4		5.9		11.0		3.9	
15.0-15.9	11.5		22.9		46.6		20.7	
16.0-16.9	33.3		34.3	3.1	22.1	2.7	33.7	
17.0-17.9	14.9	11.1	18.9	9.4	11.7	8.1	21.0	13.7
18.0-18.9	5.7		14.9	21.9	6.7	16.2	13.8	
19.0-19.9	2.3	33.3	3.0	21.9	1.8	29.7	1.1	31.5
20.0-20.9	1.2			3.1		13.5	1.1	34.2
21.0-21.9		11.1		6.2		10.8		13.7
22.0-22.9				12.5		5.4		4.1
23.0-23.9		11.1		9.4		5.4		1.4
24.0-24.9		22.2		3.1		2.7		1.4
25.0-25.9		11.1		9.4		2.7		
26.0-26.9						2.7		
Sample Size	87	9	201	32	163	37	276	73
Avg. Length	16.4	21.7	16.7	20.6	16.1	20.2	16.9	19.9

TABLE 23

Lake Winnebago, 1964-67

Total Length Intervals (in Inches)	1964		1965		1966		1967	
	Male	Female	Male	Female	Male	Female	Male	Female
10.0-10.9							0.9	
11.0-11.9	0.9				0.2		0.9	
12.0-12.9	8.9	9.5	1.1		0.3		4.9	
13.0-13.9	52.8	47.6	8.9		3.1		11.7	
14.0-14.9	32.5	14.3	48.9		25.9		11.7	
15.0-15.9	4.9	19.0	36.5	13.2	51.9		34.9	
16.0-16.9		9.5	2.8	71.1	16.9	8.9	28.2	4.7
17.0-17.9			1.1	5.3	1.5	41.1	3.9	16.3
18.0-18.9			0.6	2.6	0.2	25.0	2.9	25.5
19.0-19.9				2.6		16.1		30.2
20.0-20.9				2.6		7.1		13.9
21.0-21.9						1.8		7.0
22.0-22.9				2.6				2.3
Sample Size	123	21	178	38	651	56	103	43
Avg. Length	14.2	15.7	14.6	16.8	15.1	17.9	15.7	19.0

APPENDIX C

Daily Minimum (Solid Line) and Maximum (Dash Line) Water Temperatures at Two Locations During the Periods of Spawning and Egg Development (Between Arrows).

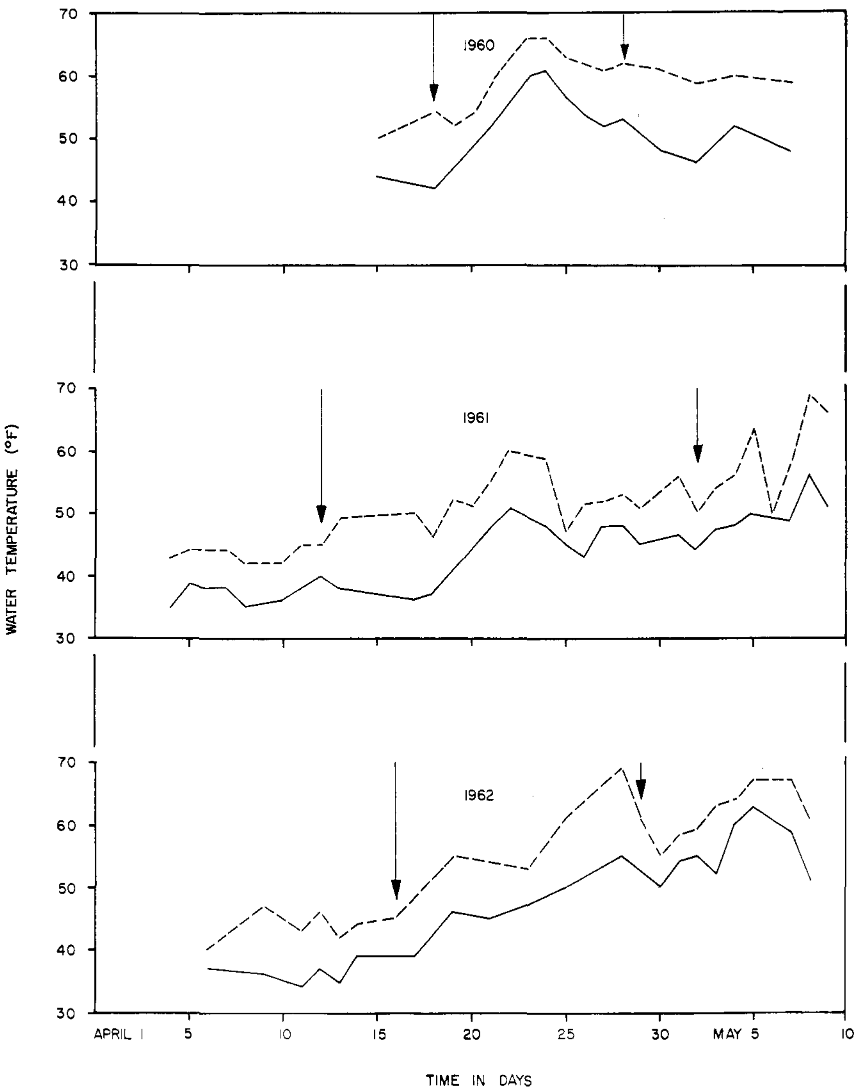


Figure 12. Spoehr's Marsh, 1960-62.

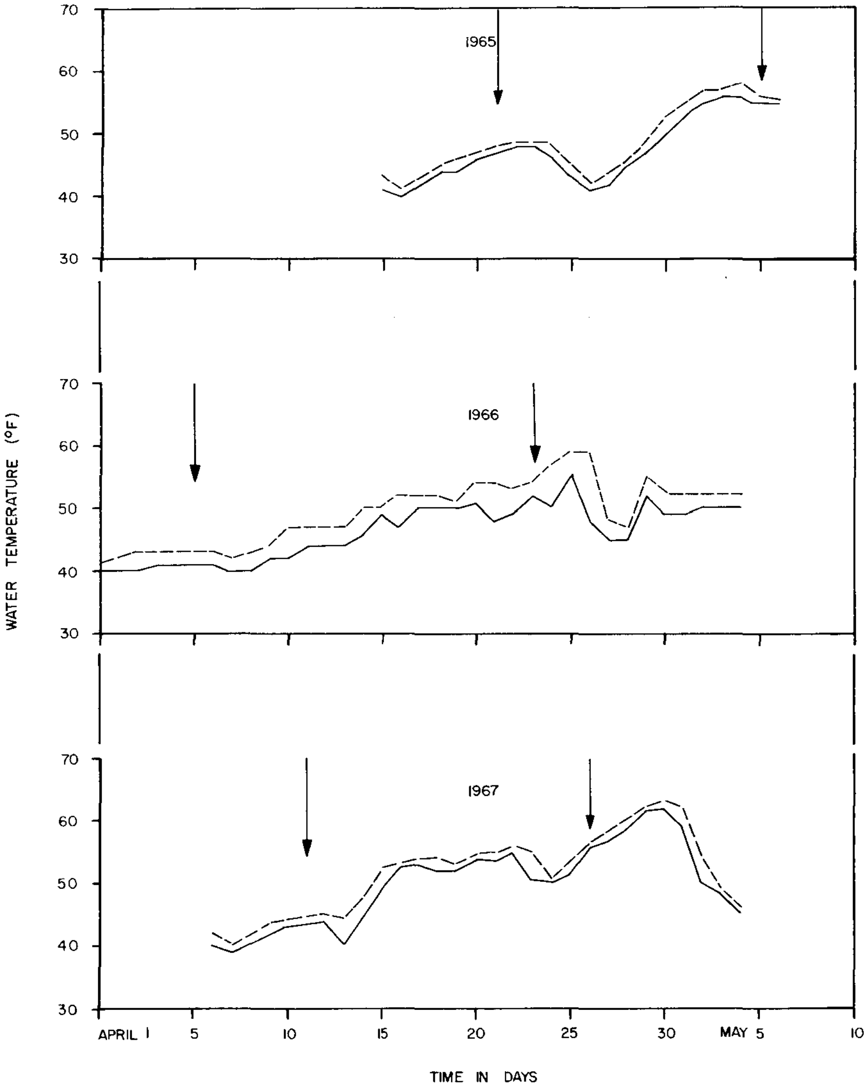


Figure 13. Spoehr's Marsh, 1965-67.

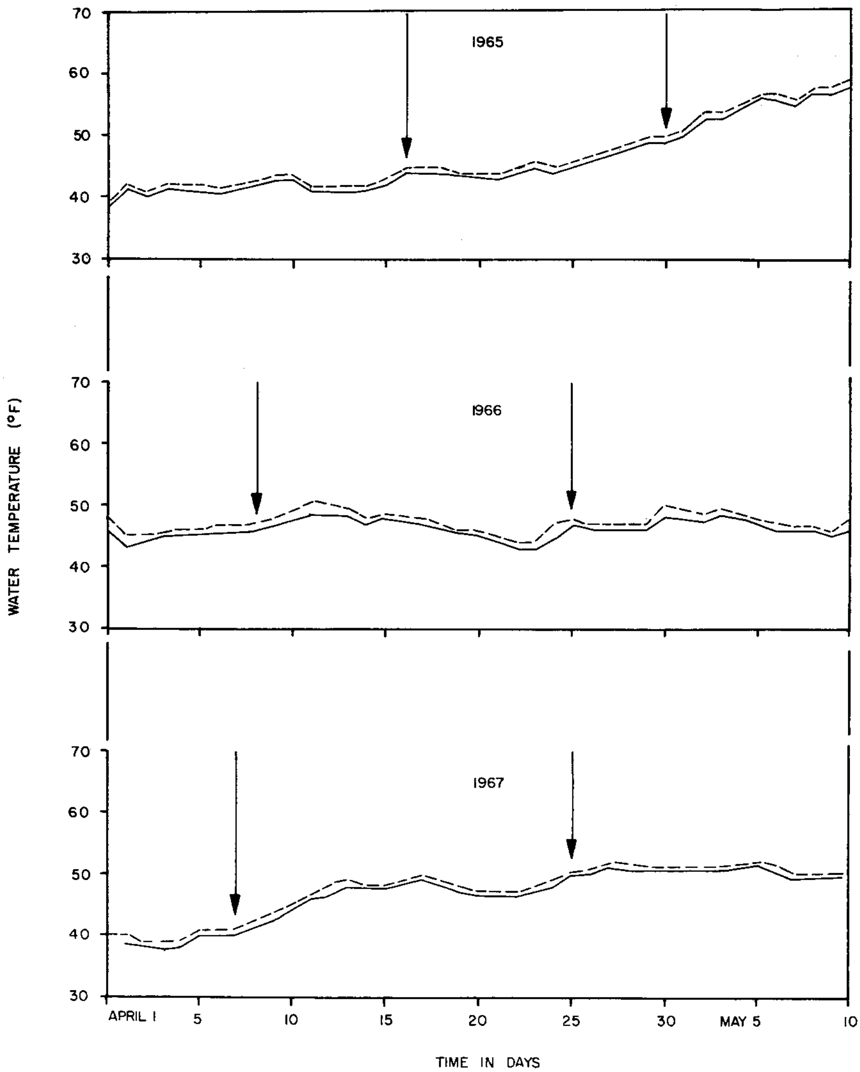


Figure 14. Lake Winnebago, 1965-67.

TABLE 24
Number of Walleye (W) and Yellow Perch (YP) Fry Taken Per Five Minute Meter Net Haul, in Lake Winnebago, 1960-67

Sampling Date	1960		1961		1962		1963		1964		1965		1966		1967	
	W	YP	W	YP	W	YP	W	YP	W	YP	W	YP	W	YP	W	YP
April 28	*	*	*	*	*	*	*	*	*	*	*	*	0	1	*	*
29	*	*	*	*	*	*	0	5	*	*	*	*	0	1	0	0
30	*	*	*	*	*	*	*	*	0	1	*	*	0	4	0	0
May 1	0	0	*	*	0	8	*	*	1	12	*	*	*	*	1	1
2	0	0	0	0	0	6	*	*	*	*	*	*	1	6	*	*
3	0	0	0	0	1	6	0	72	*	*	*	*	0	1	0	2
4	4	0	0	0	0	30	*	*	3	376	*	*	0	9	1	10
5	1	0	1	0	3	316	*	*	*	*	*	*	1	73	1	1
6	7	0	17	1	*	*	0	1,081	*	*	*	*	*	*	*	*
7	*	*	0	8	*	*	*	*	0	104	*	*	*	*	*	*
8	*	*	0	71	7	1,026	*	*	*	*	*	*	*	*	1	218
9	*	*	0	209	*	*	0	546	*	*	*	*	1	110	1	8
10	*	*	*	*	*	*	*	*	0	180	0	0	1	1,008	*	*
11	20	3	*	*	*	*	*	*	*	*	0	73	*	*	*	*
12	47	64	7	661	*	*	*	*	0	215	0	180	3	99	11	183
13	*	*	*	*	*	*	0	250	*	*	18	285	5	541	*	*
14	*	*	*	*	2	1,182	0	75	*	*	9	426	*	*	*	*
15	*	*	*	*	8	360	0	0	*	*	*	*	*	*	3	5
16	*	*	*	*	1	9	*	*	*	*	*	*	1	70	0	1
17	27	5	*	*	0	4	*	*	*	*	118	118	*	*	1	6
18	*	*	*	*	0	4	*	*	*	*	*	*	1	330	*	*
19	*	*	3	4,321	*	*	*	*	*	*	58	127	*	*	*	*
20	*	*	*	*	*	*	*	*	*	*	3	18	0	147	*	*
21	*	*	*	*	0	85	*	*	*	*	*	*	*	*	*	*
22	*	*	*	*	0	12	*	*	*	*	*	*	*	*	72	52
23	20	3	*	*	*	*	*	*	*	*	*	*	*	*	*	*
24	38	0	*	*	*	*	*	*	*	*	58	211	0	8	20	44
25	57	0	*	*	*	*	*	*	*	*	21	273	*	*	*	*
26	*	*	4	915	*	*	*	*	*	*	*	*	0	12	*	*
27	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*	*	*	15	34	*	*	*	*
29	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
30	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
31	*	*	*	*	*	*	*	*	*	*	*	*	*	*	14	45
June 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2	1	0	*	*	*	*	*	*	*	*	*	*	*	*	0	1

* No samples taken.

APPENDIX E

Rate of Growth of Young Walleyes in Lake Winnebago

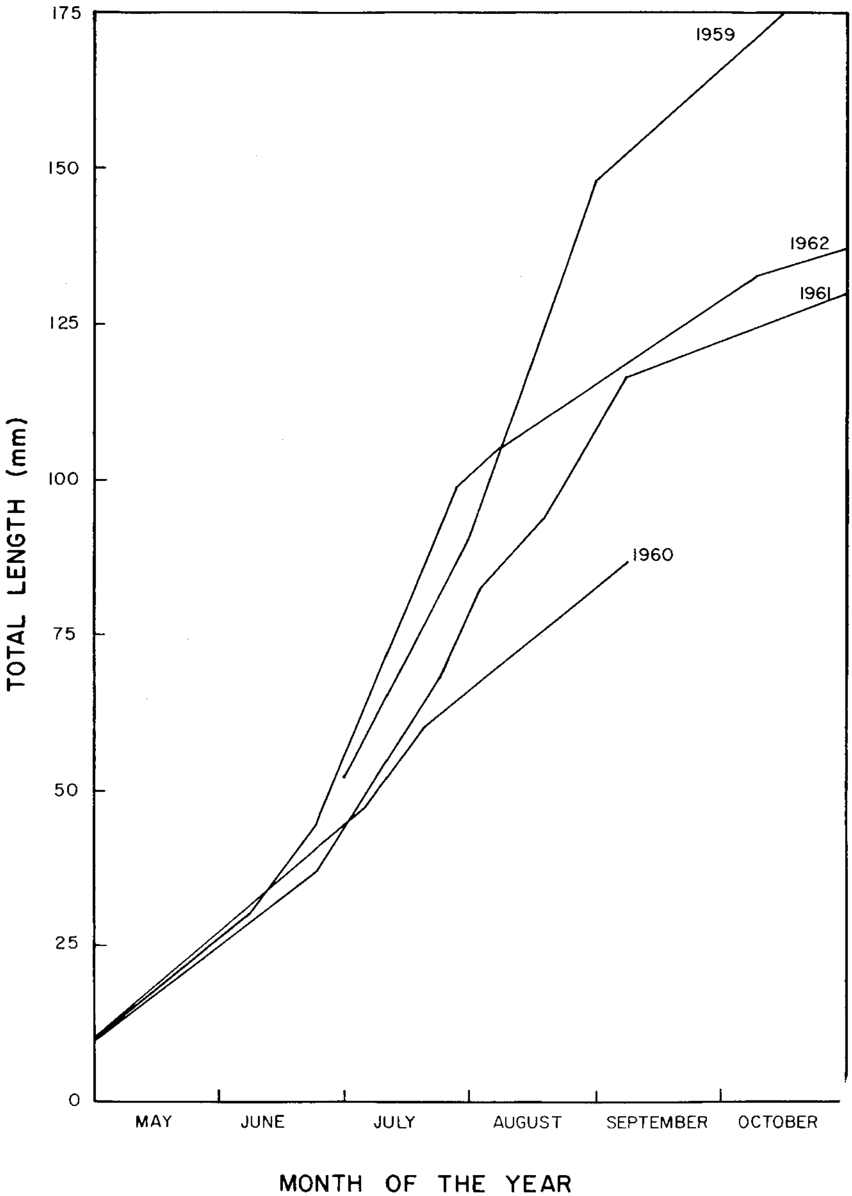


Figure 15. Growth During 1959-1962.

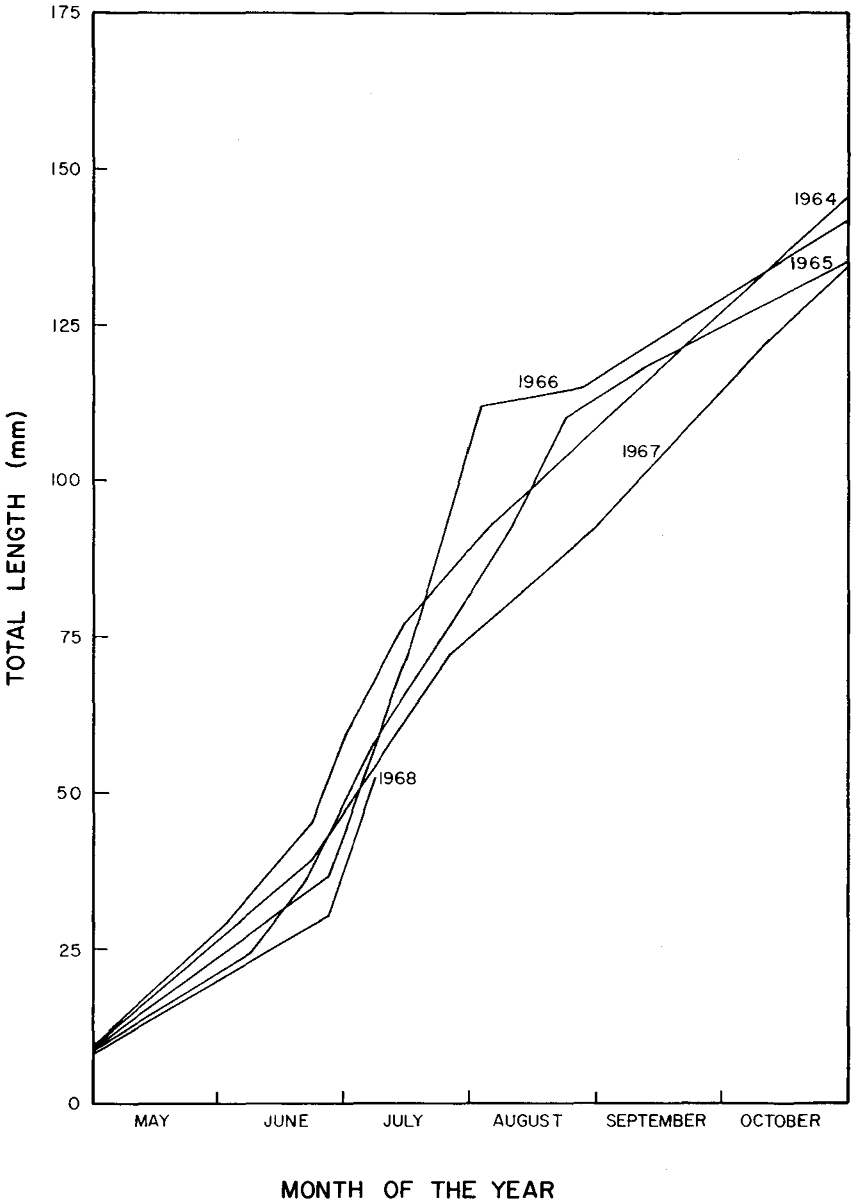


Figure 16. Growth During 1963-67.

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