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Priegel, Gordon R.; Wirth, Thomas L.

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**LAKE STURGEON POPULATIONS, GROWTH,
AND EXPLOITATION
IN LAKES POYGAN, WINNECONNE, AND
LAKE BUTTE DES MORTS,
WISCONSIN**



Technical Bulletin No. 107
DEPARTMENT OF NATURAL RESOURCES
Madison, WI
1978

ABSTRACT

Studies on Lakes Poygan, Winneconne and Butte des Morts from 1952-76 were designed to determine harvest, growth and population structure of lake sturgeon. The intent was to investigate whether overexploitation, a problem that this long-lived, late-maturing fish cannot survive, had occurred on these lakes and to adjust management if necessary.

Lake sturgeon in the upriver lakes have shown a decline. Overharvest of the lake sturgeon population has occurred and was demonstrated by a decrease in the number of fish speared per individual fisherman; an increase in the harvest of small sturgeon (under 50 inches) and a decrease in the harvest of larger size classes; a downward trend in the age of harvested fish; and changes in mortality rates.

Management alternatives include maintaining the present season, limiting fishing pressure and regulating through minimum size limits.

LAKE STURGEON POPULATIONS, GROWTH, AND EXPLOITATION IN LAKES POYGAN, WINNECONNE, AND LAKE BUTTE DES MORTS, WISCONSIN

by
Gordon R. Priegel and Thomas L. Wirth

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CONTENTS

2	INTRODUCTION
2	STUDY AREA
4	METHODS
5	RESULTS
5	Harvest
	Total Harvest, 5
	Harvest of Individual Year Classes, 7
7	Age, Length, and Weight
	Length Frequency, 7
	Length-Weight Relationship, 8
	Age Frequency, 8
	Age-Length, 8
	Age-Weight, 8
	Condition, 8
9	Population Size
9	Mortality Rates
14	DISCUSSION
21	MANAGEMENT AND RESEARCH RECOMMENDATIONS
22	SUMMARY
23	LITERATURE CITED

INTRODUCTION

The lake sturgeon, *Acipenser fulvescens* Rafinesque, was classified as rare over much of its original range by the U.S. Fish and Wildlife Service in 1966. It is a long-lived, late-maturing fish which does not survive a high level of exploitation. Stream modifications (dams, pollution, and disturbance of spawning sites) resulting from human settlement and industrial development have produced conditions unfavorable for its survival.

Current management is centered on limiting the harvest to maintain a sustained yield. When a lake sturgeon fishery exists, it is vital to know the harvest and population size of the fish stock so that exploitation can be regulated. Overexploitation of these long-lived fish is a problem that takes many years to correct. These studies were initiated to determine if overexploitation

had occurred on lakes Poygan, Winneconne, and Lake Butte des Morts, and to suggest corrective action if needed.

Before 1955, estimates of the harvest on these lakes were based on creel census cards (Probst and Cooper 1955). Because of the poor return of these cards and their questionable accuracy, a registration system was initiated in 1955 and has been in continuous effect since that date. This system of registration has provided a better measurement of the harvest. The use of fin bones of most sturgeon registered has provided a means by which age structure can be determined.

The objectives of this study were, therefore, to determine the harvest, growth, and population structure of sturgeon in these lakes from 1952 to 1976.

STUDY AREA

DESCRIPTION OF STUDY AREA

The water areas involved in the study include lakes Poygan (14,102 acres) and Winneconne (4,507 acres) on the Wolf River and Lake Butte des Morts (8,857 acres) on the Fox River (Fig. 1). The Wolf River joins the Fox River in Lake Butte des Morts, 10 river miles above Lake Winnebago, and then enters Lake Winnebago as the Fox River at Oshkosh. Located in the river channels, these smaller lakes have similar depths, the maximum not exceeding 11 ft. All three upriver lakes have similar characteristics in that they are river widepreads with water levels raised by the dam at the outlet of lake Winnebago.

These upriver lakes have large areas of dense aquatics. Islands of *Scirpus* sp. are found near the entire shorelines of these lakes. Emergent vegetation, mainly *Typha* sp. along with *Carex* sp. and *Phragmites* sp., is present over a

large portion of the shoreline. Wild rice, *Zizania aquatica* is common and once covered large areas of the Poygan-Winneconne basin. The bottom of these lakes is mostly firm sand overlain with a thick layer of silt in the deeper areas. A small amount of rubble occurs in very localized areas. Submersed macrophytes, once very abundant, appear to be declining.

HISTORY OF THE FISHERY

Lake sturgeon populations, markedly reduced throughout most of their geographical range in the United States and Canada, now support commercial or sport fisheries in only a few regions. The sport fishery of lake sturgeon now in existence on Lake Winnebago (Fig. 2) and its associated upriver lakes (Poygan, Winneconne, and Lake

Butte des Morts) surpasses that of all other known areas.*

The history of the fishery in these areas has included fishing by several methods. Spearing as a means of harvesting lake sturgeon from these lakes is traditional and was originally practiced by Indians living in the region.

In the three upriver lakes, "set line" fishing was permitted during a fall season of several weeks in the 1930's and 1940's. This method of harvest involved using long lines with 100 drop lines with baited hooks on them. During these years, illegal harvests were sometimes made by anglers using set lines of several thousand hooks. In 1952, a spear fishing season was established in these three upriver lakes to allow for legal harvest and to provide information to assess the lake sturgeon population.

The lake sturgeon spearing fishery is unique to the Lake Winnebago area

*Lakes Poygan, Winneconne and Lake Butte des Morts will be referred to as the upriver lakes throughout the rest of this manuscript.

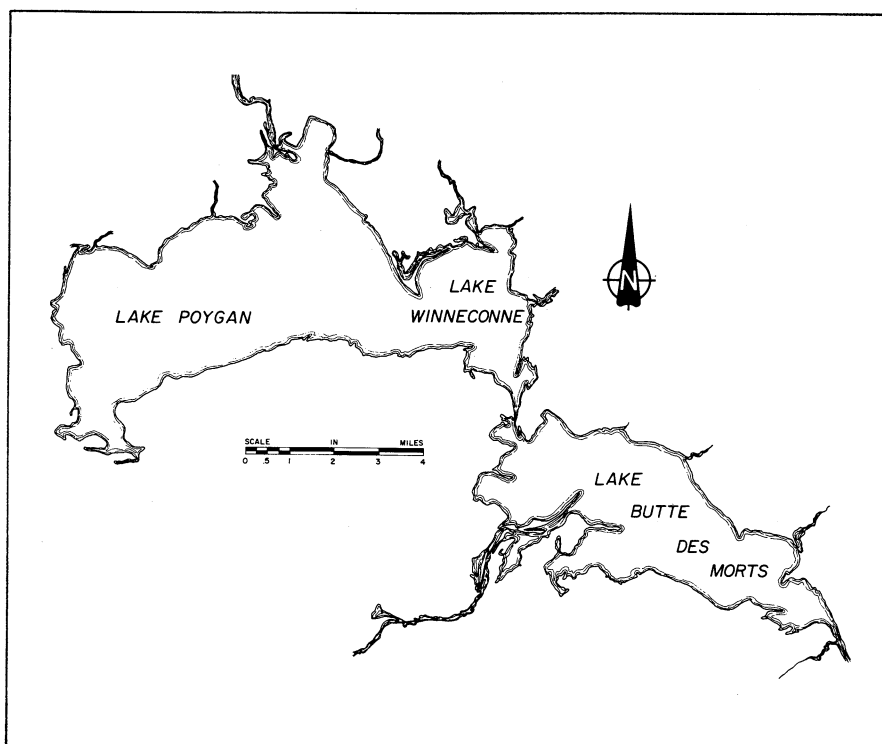


FIGURE 1. Water areas involved in the study: Lakes Poygan, Winneconne, and Lake Butte des Morts.

in Wisconsin. Spearfishing has also been permitted in a limited sport fishery for lake sturgeon in three Michigan lakes — Black, Mullet and Burt, which are in the Cheboygan River drainage (Williams 1951). A winter spear fishery is traditional in this region. Angling success would be low, because the sturgeon are fairly evenly dispersed throughout these lakes, with concentrations found only during the spawning season. Therefore angling as a means of harvesting is not practical in this lake system. In Wisconsin's larger river systems lake sturgeon are taken by hook and line (Priegel 1973; Priegel and Wirth 1971). These systems do not have suitable spear fishery areas.

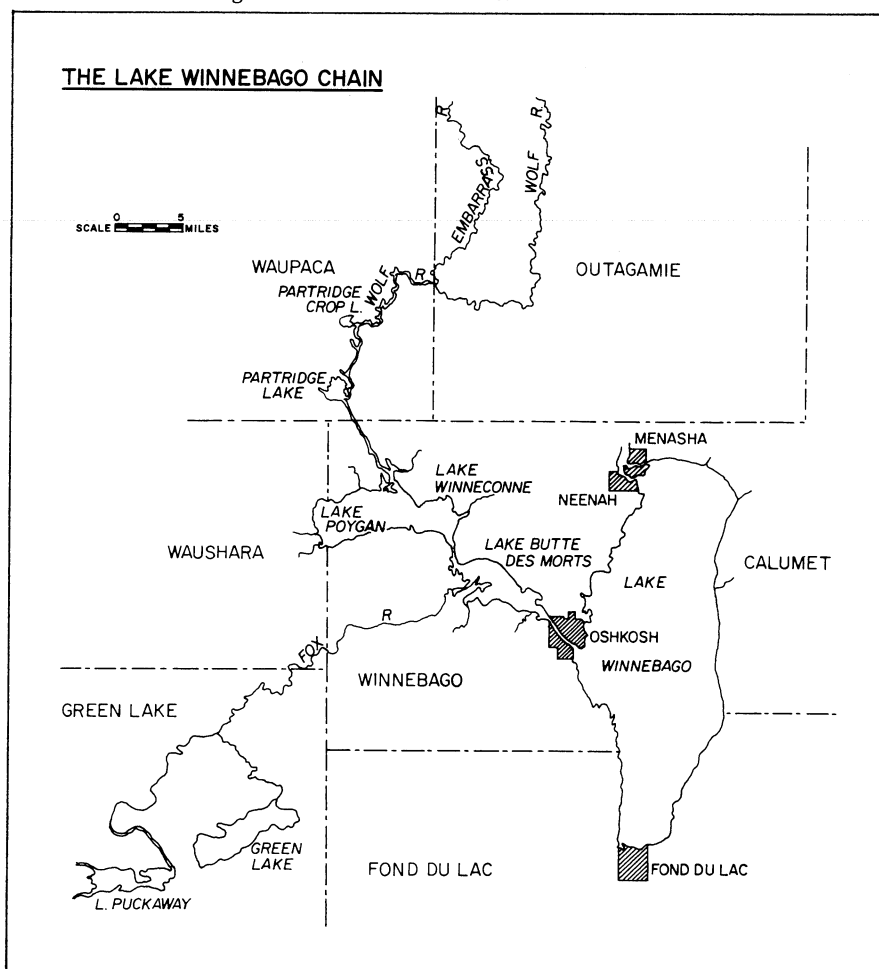
Various-sized shanties, "dark houses" with holes in the ice about 3 ft wide and 5 ft long, are used for spearfishing the sturgeon. To increase the visibility of the bottom under the hole, the spearfishers often scatter a variety of perishable materials such as shelled corn, peeled potatoes, egg shells or noodles on the bottom. Also decoys of various shapes, colors, and substances — ears of corn, wooden airplanes, beer cans, even skillfully carved and painted replicas of fish — are suspended in the holes. It is believed that the decoys not only attract the curious lake sturgeon, but they also help the spearfishers adjust their eyes to various depths. And if the decoy is of a known length, it can help

the spearfisher determine whether a sturgeon swimming by meets the minimum legal size. The spears used have 3-8 barbed tines and are attached to a wooden or metal handle 6-9 feet long. The end of the handle is usually weighted with lead to allow it to be propelled swiftly toward the target. The handle detaches when a fish is speared, making it possible to play the fish on a long line. The spear is not actually thrown at a passing fish, but is dropped or pushed after careful aim is taken (Priegel and Wirth 1971).

REGULATIONS

Over the years, spearfishing regulations have been adjusted to limit the sturgeon harvest in the three upriver lakes. Season bag limits have changed from 3 fish (from 1952 to 1955), to 2 fish (in 1956) and then to 1 fish (1957 to the present). In 1955, the minimum size limit, which had been 30 inches since

FIGURE 2. Association of the Upriver Lakes to Lake Winnebago and associated waters.



1952, was increased to 40 inches. In 1974, the minimum legal size was further increased to 45 inches. The length of the season on the upriver lakes has been decreased from 16 days (in 1952), to 14 days (in 1953, 1954, and 1955) to 9 days (in 1956), to 5 days (in 1957), to 3 days (in 1959) and then to 2 days (1962 to the present). There was an annual season on the upriver lakes from 1952 to 1957. Since 1957, the spearing seasons have been reduced from a season every other year (in 1959 and 1962), to a season every third year (in 1965, 1968, and 1971) and then to one every fifth year. The last season

was in 1976.

Beginning in 1955 a regulation was instituted requiring that each sturgeon be registered on the same day it is speared before it is moved from the lake or the immediate shoreline. Prior to 1960, in order to participate in the sport, spearers were required to purchase a metal seal (called a "tag") which cost one dollar each. Each spearer could purchase "tags" up to the same number of sturgeon allowed in the season bag limit. In 1960, the law was changed so that a spearing license (\$2.50) is required to participate in this sport. A single "tag" is issued with

each license.

Spearing is not permitted by persons under 14 years of age and Wisconsin Laws require that persons age 16 and older are to possess a current hook and line fishing license (fishing licenses are not required for those under 16 years). Regulations require that the "tag" be locked through the tail of each speared sturgeon and that the fish must be taken to a registration station on the day it is caught for recording, where a second numbered seal ("registration tag") is also locked through the tail.

METHODS

HARVEST ESTIMATES

From 1952 through 1954 the numbers of sturgeon harvested were estimated. The estimates were based on a partial return of creel census cards which were supplied to spearers when they purchased sturgeon tags. In addition, estimates were also made by partial surveys of spearers in their shanties to provide an estimate of the number of sturgeon speared/shanty. In 1952 the estimate was based on the observation of about one fish speared/shanty. In 1953 and 1954 greater effort was expended to estimate catch/shanty from the various shanty concentrations on each lake. Shanty counts were made each of these years.

REGISTRATION

A standard checking procedure was followed for each fish brought to the registration station. The fish was carefully examined for tags or marks indicating tag loss. The location in the lakes where the fish was speared was recorded. Total length to the nearest inch and total weight to the nearest pound were recorded. The clerk removed the leading fin ray from the two pectoral fins (for later age assessment) by cutting through the joint and stripping the leading ray from the fin. The fin bones were placed in a special en-

velope on which the above data were recorded.

After attaching to the fish a numbered registration seal the clerk recorded the above data on a registration sheet along with the following information: date, time speared, name and address of spearer, registration seal number and spearer's seal number.

From 1956 through 1959, a ten-dollar reward was offered to any one registering a tagged sturgeon. This action was undertaken to enhance the return of the study fish; otherwise spearers might remove the study tag prior to registration. In addition to the data obtained through the regular registration procedure, the complete entrails were obtained from the tagged fish to study first maturity and then spawning frequency. Some fish were tagged on the spawning grounds in a known state of sexual maturity.

ESTIMATES OF POPULATION SIZE

During the winter periods of 1954-55, 1955-56 and 1956-57 entrapment nets were set under the ice in Lake Poygan from mid-December to just prior to the sturgeon spearing seasons. These nets were fished to harvest overabundant "rough fish" (undesirable to anglers). Lake sturgeon that were 40 inches and over in total length cap-

tured in these nets were tagged. Records of the total length in inches to the nearest inch, type of tag applied, tag number, area of the lake where the fish was tagged and released, and the date were recorded. The fish were tagged with large Monel self-piercing tags (cattle ear type) which were applied at the base of the leading ray of the dorsal fin.

Tagged fish were recovered through the registration system during the spearing season and population estimates were calculated by use of the Petersen mark-recapture formula.

CONDITION AND AGE DETERMINATION

The coefficient of condition "C" was used to determine the well-being or relative plumpness of the lake sturgeon by the following formula:

$$C = \frac{W10^5}{L^3}$$

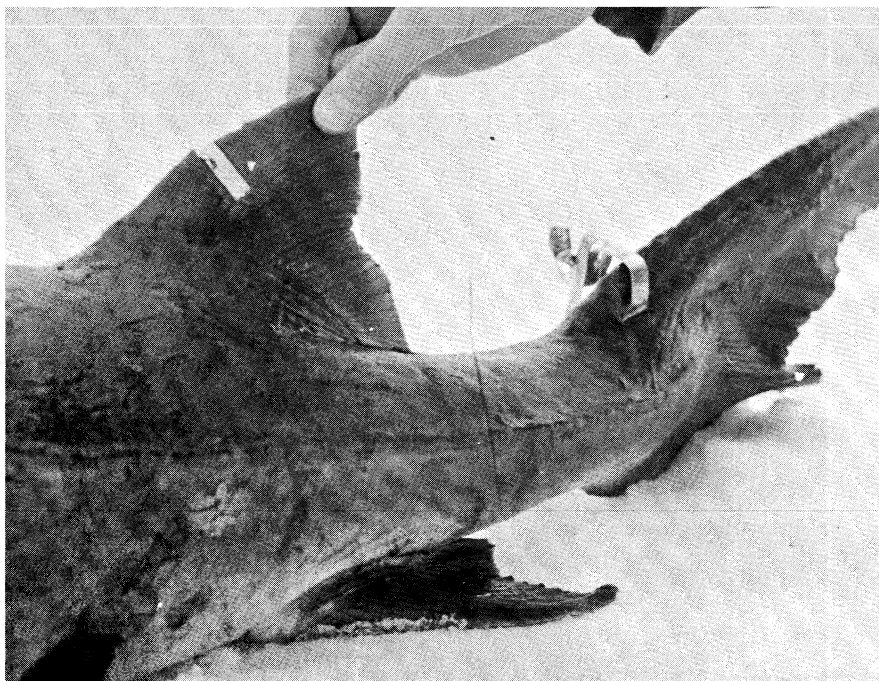
where C is the condition, W is the weight in pounds and L is the total length in inches.

Age of sturgeon was determined by the following method. Once the fin ray had dried sufficiently, a thin cross-section (0.3 to 0.5 mm thick) was cut out with a jeweler's saw. Under a binocular microscope wide opaque zones alternating with narrow clear zones are

seen. These zones correspond to summer and winter growths, respectively. By counting the number of narrow clear zones, the number of winters through which the fish has lived and hence its age can be determined (Cuerrier 1951 and Roussow 1957). The outer edge of the fin section was assigned an annulus.

DATA PRESENTATION

Because Lake Butte des Morts receives the least spearing pressure, the harvest is the smallest, and its area is limited to spearing, its management is included with the upriver lakes. As Lake Winneconne is in reality the east portion of the body of water that forms both Lakes Poygan and Winneconne, it is considered as a single body of water (Lake Poygan). Most of the information collected and the tagging studies on the upriver lakes have been conducted on Lake Poygan which yields most of the sturgeon. Since this study began, all data from these three lakes were collected and analyzed separately. In this report, however, the data are either reported separately for all three lakes, combined for all three lakes, or reported only for Lake Poygan (which would include Lake Winneconne).



A sturgeon spearing tag and registration tag are secured to the tail of a speared sturgeon. A monel numbered tag had been previously placed on the dorsal fin.

Although this report covers the period from 1952 through 1976, an annual season did not occur on the upriver lakes. During this period there were 12 spearing seasons: one each year from 1952 through 1957, and in 1959,

1962, 1965, 1968, 1971, and 1976. In addition, while no age data are presented for 1968, 1971, and 1976, registration totals and length frequency data are reported.

RESULTS

HARVEST

Total Harvest

The first spearing season for lake sturgeon on the upriver lakes was in 1952. The harvest in 1952-54 was estimated to be 200, 784, and 879, respectively; however, these totals are estimates based on creel census methods (Table 1). Because of questionable accuracy, a registration system was initiated in 1955 and has continued since that date. From 1955 through 1976 (for 9 seasons) the total harvest of lake sturgeon from the upriver lakes based

on registration figures was 2,955 fish. The annual harvest varied from a low of 80 fish in 1968 (during a 2-day season with a bag limit of 1) to a high of 715 fish in 1955 (during a 14-day season with a bag limit of 3 fish). During seasons of 2 days and a bag limit of 1 fish/season (1962-76, 5 seasons), the annual harvest has varied from 80 fish in 1968 to 325 fish in 1965 with an average harvest each season of 187 fish. The average harvest each season from 1955 through 1976 was 328 fish.

Since 1954 spearers have taken 88.7% of the fish speared on the upriver lakes from Lake Poygan (Table 2). Annually the harvest from Lake Poygan has varied from 79.9 to 99.8%

of the total harvest from the upriver lakes. Lake Winneconne has accounted for 8.8% of the total upriver lake harvest; only 2.5% of the harvest was from Lake Butte des Morts.

Information on the number of individuals who speared a second and third fish during the 1952, 1953, and 1954 seasons is not available from the voluntary creel census cards. If the season bag limit had been 1 in 1955, perhaps 15.8% fewer fish would have been registered: 104 (14.5%) were the second fish a spearer registered and 9 (1.3%) were the third fish. In 1956, when the season bag limit was 2 fish/season, 146 (24.9%) spearers registered 2 fish. With a reduced bag limit these addi-

TABLE 1. Sturgeon spearing season data from the Upriver Lakes, 1952-71.

Year	Season Length (days)	Bag Limit	Size Limit (inches)	Shanty Count	Sturgeon Registered	Avg. Total Length (inches)	Avg. Weight (lb.)
1952	16	3	30	200	200*	46 (51)**	24 (32)**
1953	14	3	30	315	784*	46 (50)**	25 (32)**
1954	14	3	30	606	879*	46 (51)**	25 (32)**
1955	14	3	40	1,190	715	50	30
1956	9	2	40	851	587	49	28
1957	5	1	40	859	422	49	26
1959	3	1	40	954	297	47	24
1962	2	1	40	950	217	48	26
1965	2	1	40	1,378	325	48	25
1968	2	1	40	-	80	49	26
1971	2	1	40	-	227	45	19
1976	2	1	45	550	85	51	28

*Estimates based on creel census; 1955 was the first year of registration.

**Figures in parenthesis would be the averages if the size limit was 40 inches.

TABLE 2. Lake sturgeon harvest by lakes, 1954-76.

Year	Poygan		Winneconne		Butte des Morts	
	No.	Percent	No.	Percent	No.	Percent
1954	729	82.9	137	15.6	13	1.5
1955	571	79.9	132	18.4	12	1.7
1956	537	91.4	19	3.4	31	5.2
1957	370	87.7	38	9.0	14	3.3
1959	271	91.2	7	2.4	19	6.4
1962	215	99.1	1	0.4	1	0.4
1965	319	98.1	1	0.4	5	1.5
1968	78	97.5	-	-	2	2.5
1971	226	99.5	1	0.5	-	-
1976	84	98.8	1	1.2	-	-
Total	3,400	88.7	337	8.8	97	2.5

TABLE 3. Shanty counts on individual lakes, 1954-65.

Year	Poygan		Winneconne		Butte des Morts		Total No.
	No.	Percent	No.	Percent	No.	Percent	
1952							(200)*
1954	416	68.6	166	27.4	24	4.0	606
1955	857	72.0	293	24.6	40	3.4	1,190
1956	549	64.1	213	25.0	89	10.9	851
1957	658	76.6	99	11.5	102	11.9	859
1959	668	70.0	118	12.4	168	17.6	954
1962	773	81.3	38	4.1	139	14.6	950
1965	1,195	86.7	49	3.6	134	9.7	1,378
1976	538	97.8	10	1.8	2	0.3	550
Average	707	77.1	123	13.4	87	9.5	7,338

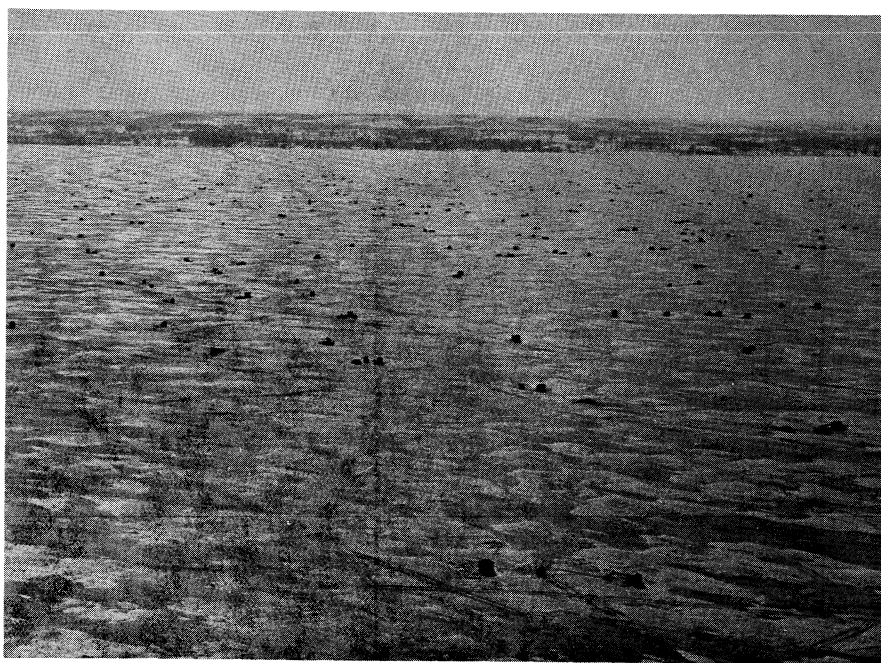
*No count by individual lakes.

tional fish might have been registered by companions.

The total weight harvested over the period 1952-76 (actually only 12 spearing seasons) was 124,904 lb (4.5 lb/acre in 24 years) and the average was 10,408 lb each season (1 lb/2.6 acres). If we consider that 88.7% of the fish speared were taken on Lake Poygan, the harvest from Lake Poygan would be 7.6 pounds/acre during the 24-year period.

Spearing shanty counts with aircraft were used to estimate the fishing pressure through 1976 (Table 3). No counts were taken in 1968 and 1971; in 1976 only 550 shanties were on the lakes. Fishing pressure increased from 200 shanties in 1952 to 1,190 shanties in 1955. In 1956, the count dropped to 851 shanties and remained at about this level through 1962, varying from 851 to 950 shanties. An increase to 1,378 shanties occurred in 1965. During the years in which data are available, 1954-76, Lake Poygan accounted for 77.1% of the fishing pressure based on shanty counts. The yearly variation was 64.1 to 97.8%. On Lake Winneconne the percentage of all shanties counted on the upriver lakes decreased steadily from 27.4% in 1954 to 1.8% in 1976. On Lake Butte des Morts shanty use increased from 4.0% of the total in 1954 to a high of 17.6% in 1959 and then declined to 0.3% in 1976.

Registration of fish on opening weekends was greater than the remaining days of the season in 1955-57 when the season extended more than 3 days (Table 4). Opening weekend accounted for 39.4, 48.0 and 54.7% of the registration during these years. In 1959, during a 3-day season, 42.7% of the fish were registered on opening



day, a Saturday. During the 2-day seasons (1962-76, 5 seasons) spearers registered from 56.3 to 85.2% of their fish on the opening day.

Harvest of Individual Year Classes

the 1916 through 1955 year classes (Table 5). This period of harvest was used because no fin bones were collected in 1968 and 1971. Although fin bones were taken in 1976, the small number (85) was considered insufficient and had not been aged at the time of this report. Individual year classes demonstrated a peak when they entered the fishery at age 15 or 16. For example, the 1941 year class accounted for 11.2% of the harvest in 1956 and the 1950 year class accounted for 13.2% of the harvest in 1965.

year classes (Table 5, column 8) was below 3.1% of the total harvest.

TABLE 4. *Daily harvest in percent of lake sturgeon on the Upriver Lakes, 1955-71.*

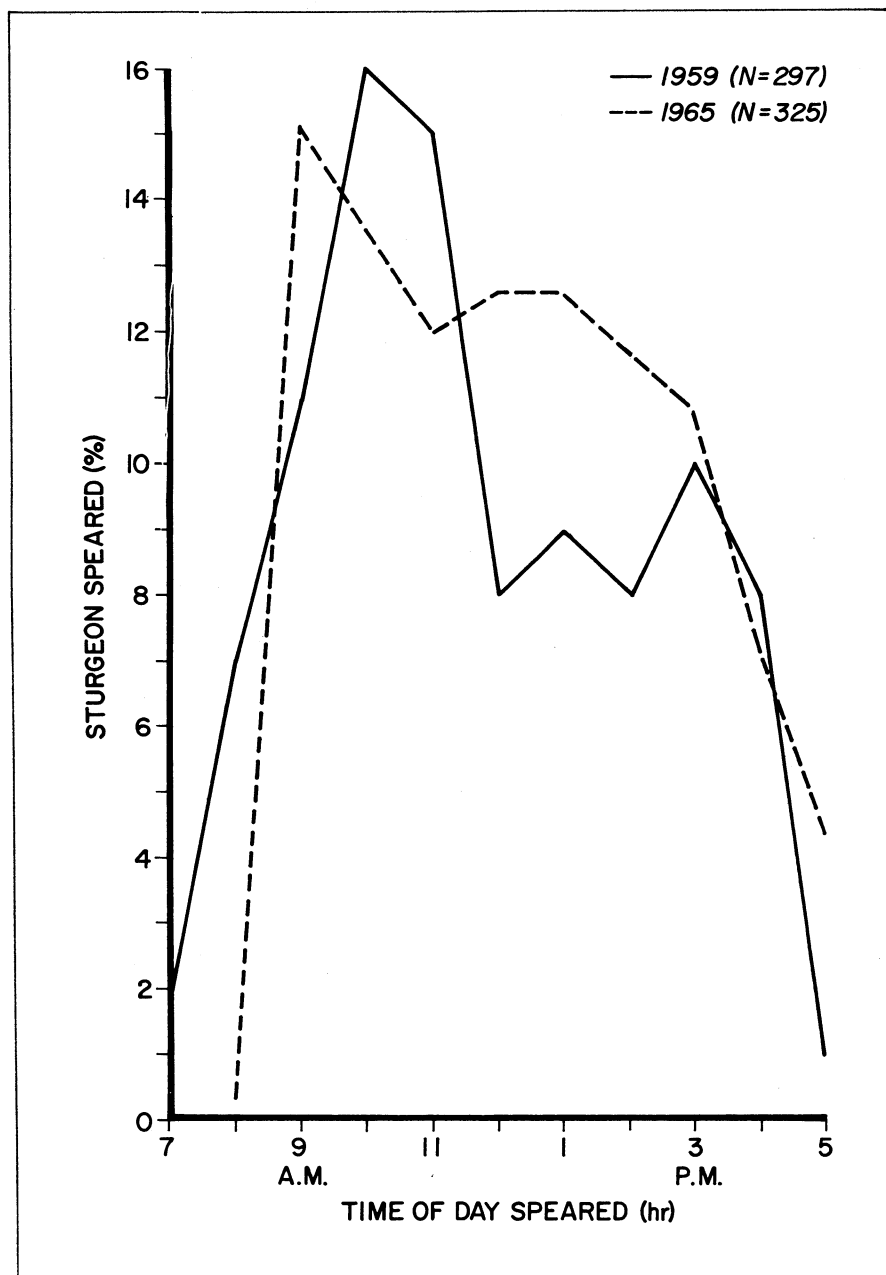


FIGURE 3. Time of the day (hours) lake sturgeon were speared in the Upriver Lakes in 1959 and 1965.

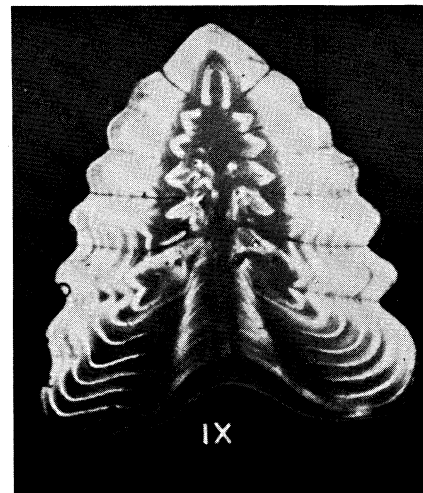
Length-Weight Relationship

The length-weight relationship was calculated from a combined sample of 2,278 lake sturgeon collected from Lake Poygan in February, 1955 through 1965. They ranged in total length from 40 to 70 inches and were grouped in one-inch intervals. The length-weight equation was: $\text{Log } W = -3.900 + 3.135 \text{ Log } L$, where (L) represents total length in inches and (W) weight in pounds (Fig. 4). Differences between empirical and calculated weights from 40 to 70 inches were very slight. The curve under 40

inches is based on calculated data only.

Age Frequency

The registered lake sturgeon ranged in age from 8 to 43 years (Table 7). Of the 2,182 aged fish, age group 15 accounted for the highest harvest (205 fish, 9.4%). There was an increase in the harvest of fish from age group 11 to age group 15, followed by a gradual decline through age group 19, after which there was a rapid decline (Fig. 5). Age groups 14 through 19 accounted for 45.2% of the total harvest.



Cross-section of the pectoral fin shows the age of lake sturgeon. This is a 9-year-old fish.

Age-Length

There was no statistical difference in the average length for registered lake sturgeon speared for any age group. For age group 20 the yearly average length varied from 47 to 50 inches with a mean of 48 inches (Table 7). At age 30 the average yearly length ranged from 54 to 63 inches with a mean of 59 inches.

The average length of the fish gradually increased with an increase of age from 42 inches for an age 10 fish to 66 inches for an age 39 fish (Fig. 6).

Age-Weight

The average weight of the fish increased gradually with age from 12 pounds for an age 10 fish to 64 pounds for an age 36 fish (Fig. 6). The average weight at age 37 and 38 decreased to 61 and 59 pounds, respectively, followed by an increase to 69 pounds for an age 39 fish.

For age groups 10 through 27, there was no great difference in the average annual weight. For example, average weights for age group 20 varied from 21 to 26 pounds with a mean of 24 pounds (Table 8). There were substantial differences for age groups 28 through 39. For age group 30, for example, the yearly average weight varied from 34 to 54 pounds with a mean of 48 pounds. Female lake sturgeon attain sexual maturity at age 25 and the amount of egg development in some of these older fish probably accounts for the variation in weight.

Condition

Average condition factors for lake sturgeon speared on the upriver lakes

from 1955 through 1965 showed considerable yearly variation for individual one-inch length groups from 40 to 55 inches. There was no noticeable increase or decrease trend in condition for most length groups over this period. Condition factors for the 1965 harvest are typical for all years (Fig. 7).

POPULATION SIZE

The return of tagged lake sturgeon as a marked sample included in each season's total catch was used to estimate the portion of the legal-sized population (40 inches, minimum legal size). From 1955 through 1957, 10.9 to 13.5% of the maximum number of tagged fish available each year were returned each spearing season (Table 9). Estimates each year were based only on the fish that were tagged during the year immediately preceding the February spearing season because their presence in the population being sampled was more likely than those marked in earlier years (tag loss, movement out of the area).

The number of tagged fish returned in the total catch each season was not high enough to provide good confidence in these population estimates. However, the estimates are fairly consistent and show a downward trend each year which is consistent with other evidence that overharvest took place each year. The 1956 and 1957 estimates are based on a few more marked fish recaptures than the 1955 estimate and differ by only 470 fish. In addition, a \$10 reward for the return of a lake sturgeon marked with a tag was offered in 1956 and 1957, a move which was assumed to enhance these returns.

Based on these estimates, the number of lake sturgeon in the Lake Poygan-Winneconne basin at the start of the 1957 spearing season was estimated to be approximately 3,700 fish of the size ranges speared that year.

MORTALITY RATES

A catch curve of the total upriver lakes harvest of lake sturgeon for 1955-65 was constructed to estimate mortality rates. The entire data set was broken into two age groups, 15-28 and 29-39 years of age. Regression lines were calculated for these two groups by a log transformation of the number of sturgeon taken for each age. Mortality rate was determined from the change in numbers of fish calculated for each one-year interval. Survival rates are the complement of the mortality rates.



Most lake sturgeon harvested on the upriver lakes are just legal size (right), as compared to larger size classes taken on Lake Winnebago (left) where over-exploitation has not occurred.

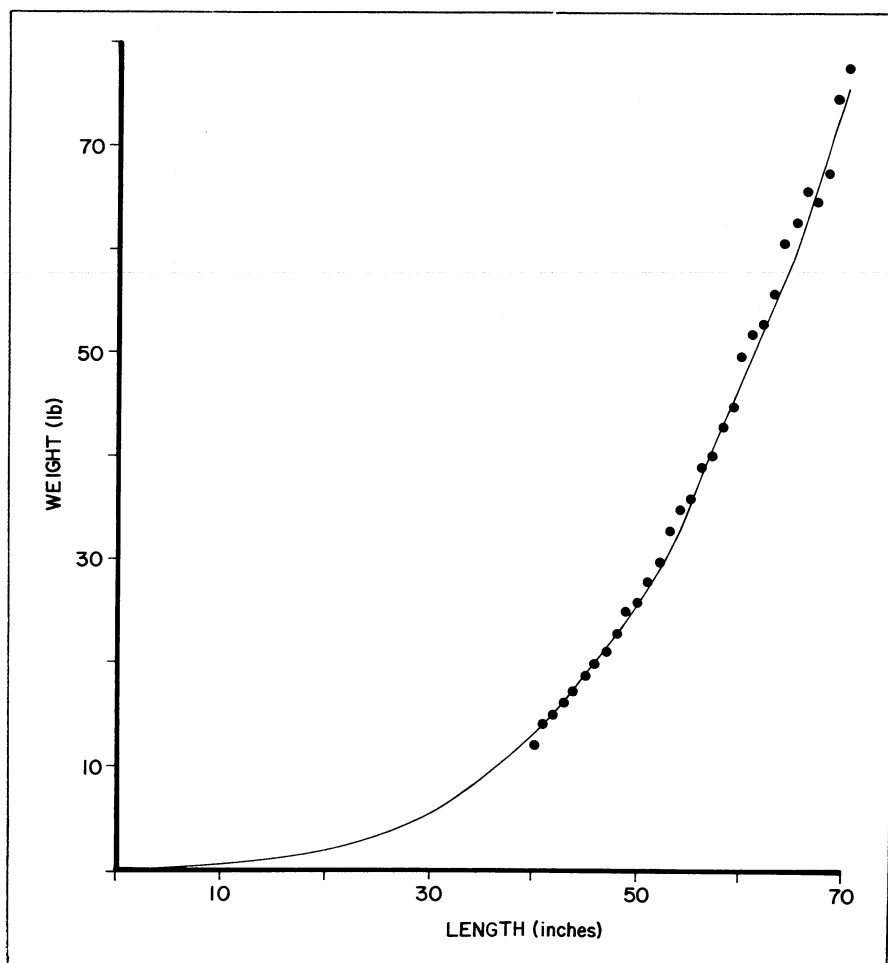


FIGURE 4. Length-weight relation of lake sturgeon from Lake Poygan. The curve represents the calculated weights and the dots the empirical weights.

FIGURE 5.
Age frequency for lake sturgeon speared
in the Upriver Lakes. All years (1955-65)
combined.

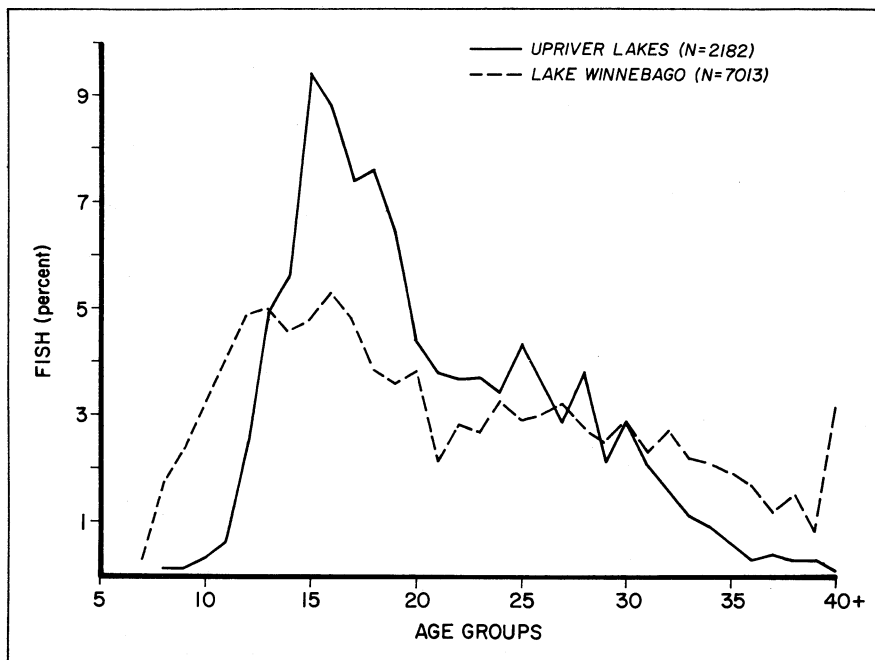


FIGURE 6.
Age-length (total in inches) and age-
weight (lb) relationships of lake sturgeon
from the Upriver Lakes and Lake Winne-
bago. All years (1955-67) combined.

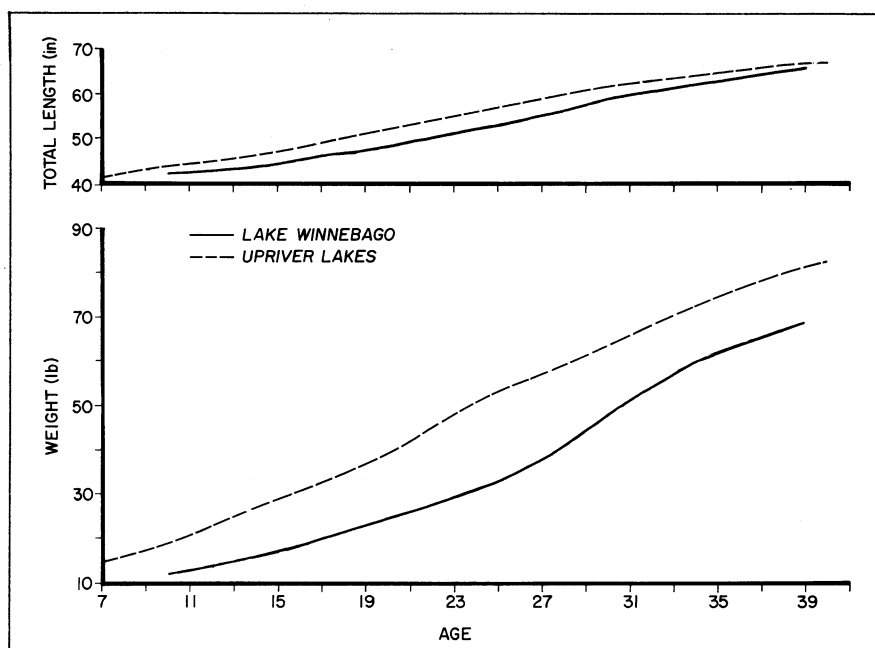


FIGURE 7.
Average condition factors (c) by one-
inch groups for lake sturgeon speared on
the Upriver Lakes and Lake Winnebago
in 1965.

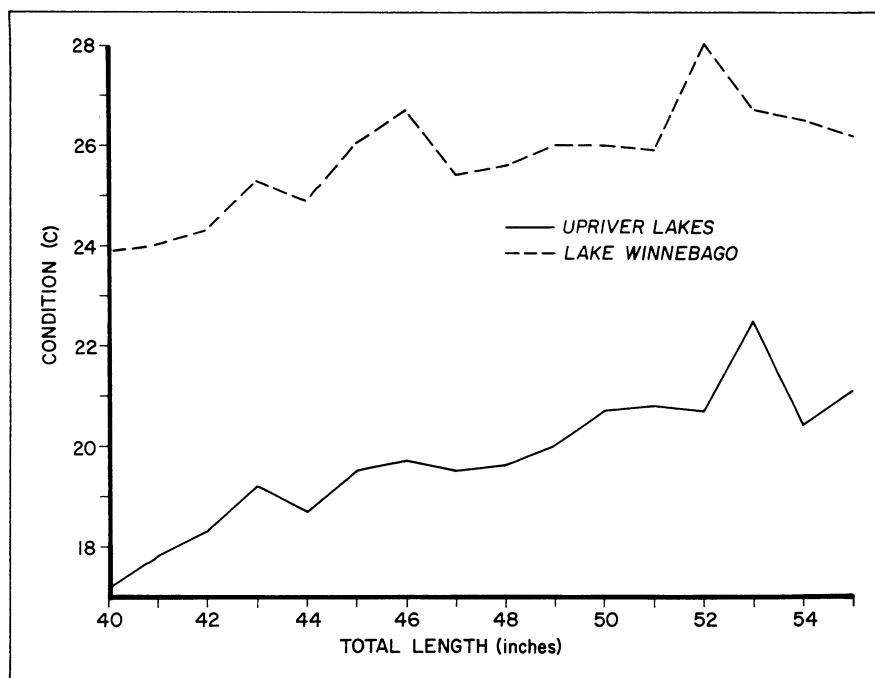


TABLE 5. Number (and percent) of lake sturgeon speared on the Upriver Lakes by year classes, 1955-65.

Year Class	1955*	1956*	1957	1959	1962	1965	Total	Lake Winnebago**
1955						4 (1.3)	4 (0.2)	133 (1.9)
54						4 (1.3)	4 (0.2)	155 (2.2)
53						5 (1.6)	5 (0.3)	134 (1.9)
52					2 (0.9)	26 (8.4)	28 (1.7)	284 (4.0)
51					3 (1.5)	33(10.6)	36 (2.2)	457 (6.4)
1950				1 (0.4)	7 (3.4)	41(13.2)	49 (2.9)	287 (4.0)
49				-	6 (2.9)	28 (9.0)	34 (2.0)	154 (2.2)
48				2 (0.8)	3 (1.5)	19 (6.1)	24 (1.4)	180 (2.5)
47				13 (4.9)	7 (3.4)	22 (7.1)	42 (2.5)	175 (2.4)
46				12 (4.6)	10 (4.9)	24 (7.7)	46 (2.8)	159 (2.2)
1945		1 (0.2)	1 (0.3)	9 (3.4)	12 (5.9)	10 (3.2)	33 (1.9)	84 (1.2)
44	1 (0.9)	9 (1.9)	11 (3.5)	24 (9.1)	27(13.2)	12 (3.9)	84 (5.0)	152 (2.1)
43	4 (3.6)	23 (4.9)	18 (5.7)	35(13.3)	15 (7.4)	19 (6.1)	114 (6.8)	305 (4.3)
42	4 (3.6)	32 (6.9)	32(10.2)	20 (7.6)	24(11.8)	11 (3.5)	123 (7.3)	297 (4.2)
41	5 (4.5)	52(11.2)	37(11.7)	21 (7.9)	18 (8.8)	4 (1.3)	137 (8.2)	346 (4.9)
1940	9 (8.1)	30 (6.5)	24 (7.6)	24 (9.1)	20 (9.8)	11 (3.5)	118 (7.1)	253 (3.6)
39	8 (7.2)	50(10.8)	25 (7.9)	10 (3.8)	10 (4.9)	4 (1.3)	107 (6.4)	426 (6.0)
38	3 (2.7)	34 (7.3)	19 (6.0)	10 (3.8)	9 (4.4)	5 (1.6)	80 (4.8)	231 (3.3)
37	8 (7.2)	37 (7.9)	20 (6.3)	12 (4.6)	4 (1.9)	4 (1.3)	85 (5.1)	252 (3.6)
36	1 (0.9)	18 (3.9)	13 (4.1)	11 (4.2)	3 (1.5)	-	46 (2.8)	148 (2.1)
1935	3 (2.7)	17 (3.7)	6 (1.9)	6 (2.3)	2 (0.9)	5 (1.6)	39 (2.3)	121 (1.7)
34	2 (1.8)	5 (1.1)	4 (1.3)	12 (4.6)	-	1 (0.3)	24 (1.4)	73 (1.0)
33	2 (1.8)	18 (3.9)	12 (3.8)	5 (1.9)	3 (1.5)	4 (1.3)	44 (2.6)	99 (1.4)
32	5 (4.5)	15 (3.2)	18 (5.7)	8 (3.0)	3 (1.5)	3 (1.0)	52 (3.1)	140 (2.0)
31	3 (2.7)	17 (3.7)	16 (5.1)	4 (1.5)	4 (1.9)	3 (1.0)	47 (2.8)	148 (2.1)
1930	7 (6.3)	22 (4.7)	9 (2.8)	2 (0.8)	6 (2.9)	3 (1.0)	49 (2.9)	170 (2.3)
29	3 (2.7)	12 (2.6)	15 (4.8)	4 (1.5)	1 (0.5)	-	35 (2.1)	204 (2.9)
28	5 (4.5)	21 (4.5)	9 (2.8)	5 (1.9)	1 (0.5)	1 (0.3)	42 (2.5)	174 (2.4)
27	11 (9.9)	9 (1.9)	7 (2.2)	4 (1.5)	1 (0.5)	1 (0.3)	33 (1.9)	184 (2.6)
26	4 (3.6)	11 (2.4)	8 (2.5)	1 (0.4)	1 (0.5)	2 (0.6)	27 (1.6)	185 (2.6)
1925	4 (3.6)	10 (2.2)	3 (0.9)	2 (0.8)	1 (0.5)	-	20 (1.2)	132 (1.9)
24	4 (3.6)	8 (1.7)	2 (0.6)	1 (0.4)	1 (0.5)	-	16 (1.0)	98 (1.4)
23	3 (2.7)	4 (0.9)	1 (0.3)	-	-	-	8 (0.5)	102 (1.4)
22	4 (3.6)	6 (1.3)	3 (0.9)	3 (1.1)	-	1 (0.3)	17 (1.0)	96 (1.3)
21	3 (2.7)	1 (0.2)	-	1 (0.4)	-	-	5 (0.3)	40 (0.6)
1920	-	-	-	1 (0.4)	-	-	1 (0.1)	46 (0.7)
19	1 (0.9)	-	2 (0.6)	-	-	-	3 (0.2)	33 (0.5)
18	1 (0.9)	-	-	-	-	-	1 (0.1)	27 (0.4)
17	2 (1.8)	-	-	-	-	-	2 (0.1)	18 (0.3)
16	1 (0.9)	1 (0.2)	-	-	-	-	2 (0.1)	11 (0.2)
Total	111	463	315	263	204	310	1,666	7,098

* Sample only taken.

** Total based on year classes 1887 - 1960.

TABLE 6. Length frequency (total length in inches) in percent of lake sturgeon speared in Upriver Lakes, 1952- 76.

Length Groups	1952	1952*	1953	1953*	1954	1954*	Combined 1952-54*	1955**	1956	1957	1959	1962	1965	1965 ¹	1968	1971	1971 ¹	1976 ²
30-34	3.1		7.6		8.4													
35-39	34.3		23.6		20.6													
40-44	21.9	35.0	20.1	29.3	19.4	27.4	28.1	22.7	28.7	28.4	35.9	33.2	33.5		31.3	51.3		
45-49	3.1	5.0	12.5	18.2	12.7	17.9	17.4	25.6	25.0	24.4	33.7	37.8	34.8	52.3	22.5	33.2	68.2	56.5
50-54	21.9	35.0	18.1	26.3	17.0	23.9	24.8	22.2	20.6	22.0	15.2	14.7	15.7	23.6	20.0	11.5	23.6	23.5
55-59	3.1	5.0	9.0	13.1	12.0	16.8	15.6	17.4	16.8	17.6	7.8	8.8	6.8	10.2	16.3	3.1	6.4	9.4
60-64	6.3	10.0	6.3	9.1	7.5	10.5	10.2	9.7	6.5	5.4	5.9	5.0	5.2	7.9	7.5	-	-	9.4
65-69	3.1	5.0	1.4	2.0	2.4	3.4	3.2	2.2	2.2	1.7	1.5	0.5	3.7	5.6	1.2	0.9	1.8	1.2
70+	3.1	5.0	1.4	2.0	-	-	0.6	0.3	0.2	0.5	-	-	0.3	.5	1.2	-	-	-
Total no.	32	20	144	99	535	380	499	715	579	409	270	217	325	216	80	226	110	85

*With fish under 40-inch length removed.

**Size limit increased from 30 to 40 inches.

¹ With fish under 45 inches removed.

² Size limit increased from 40 to 45 inches.

(Do not confuse total numbers in this table with those in Table 1 as these totals reflect the number of fish measured, not harvested.)

For the ages 15-28, the mortality rate was 8.8% and for the 29-39 age groups, it was 22.2% (Fig. 8). The higher rate reflects a more rapid depletion of older lake sturgeon.

A breakdown of the data was made to segregate 1955 from the later years 1962-65. The mortality rate of 2.2% was much lower for 1955 than for 1962-65 when it was 16.0%. This higher rate is believed to reflect fish depletion, or overexploitation.

Changes in the proportion of older lake sturgeon found in the population

can be visualized by examining Table 10. The proportion of fish that were 25 to 40 or more years in age taken each season dropped dramatically. In both 1962 and 1965 it was less than half of the proportion in 1955 (15% vs. 39%).

The same picture of overexploitation can be seen by looking at length frequencies of lake sturgeon shown in Table 6. In 1962 and 1965 fish that were 55 inches or longer in length were only half as abundant as they were in the earlier years.

TABLE 7. Average lengths by age and age frequency of lake sturgeon speared in the Upriver Lakes, 1955-65.

Age Groups	Average Length (sample size)						Average Length	All Years	Percent
	1955	1956	1957	1959	1962	1965			
8	1	-	-	-	-	-	-	1	0.1
9	-	-	-	1	-	-	-	1	0.1
10	-	-	-	42 (1)	41 (2)	42 (4)	42	7	0.3
11	40 (3)	41 (1)	-	42 (3)	42 (3)	42 (4)	42	14	0.6
12	42 (16)	42 (9)	41 (2)	42 (15)	41 (7)	42 (5)	42	54	2.5
13	43 (22)	42 (24)	42 (14)	42 (14)	41 (6)	43 (26)	42	106	4.9
14	44 (24)	43 (32)	42 (22)	43 (9)	41 (3)	44 (33)	43	123	5.6
15	44 (40)	43 (55)	44 (38)	45 (26)	42 (7)	45 (41)	44	205	9.4
16	45 (48)	44 (32)	44 (39)	44 (36)	42 (10)	45 (28)	44	193	8.8
17	48 (29)	46 (52)	46 (26)	45 (24)	43 (12)	46 (19)	46	162	7.4
18	47 (34)	47 (35)	47 (26)	46 (21)	44 (27)	47 (22)	46	165	7.6
19	49 (15)	48 (39)	47 (22)	47 (25)	45 (15)	47 (24)	47	140	6.4
20	50 (13)	49 (18)	49 (21)	48 (11)	47 (24)	49 (10)	48	97	4.4
21	48 (10)	50 (19)	50 (13)	50 (10)	48 (18)	50 (12)	49	82	3.8
22	51 (17)	53 (5)	53 (6)	51 (14)	49 (20)	50 (19)	50	81	3.7
23	51 (23)	52 (19)	52 (4)	51 (13)	49 (10)	51 (11)	51	80	3.7
24	52 (26)	52 (17)	52 (13)	49 (6)	51 (9)	54 (4)	52	75	3.4
25	54 (29)	53 (20)	54 (18)	54 (12)	53 (4)	55 (11)	54	94	4.3
26	54 (20)	54 (26)	54 (20)	54 (6)	58 (3)	54 (4)	54	79	3.6
27	56 (23)	58 (13)	56 (11)	52 (8)	54 (2)	56 (5)	55	62	2.8
28	56 (31)	57 (24)	55 (17)	57 (6)	-	62 (4)	56	82	3.8
29	59 (19)	58 (10)	57 (11)	60 (3)	61 (3)	-	58	46	2.1
30	60 (24)	59 (13)	59 (12)	60 (7)	54 (3)	63 (5)	59	64	2.9
31	60 (14)	59 (11)	59 (10)	62 (5)	56 (4)	56 (1)	59	45	2.1
32	60 (8)	59 (9)	62 (5)	59 (4)	58 (6)	64 (4)	60	36	1.6
33	61 (13)	58 (4)	60 (2)	60 (1)	51 (1)	61 (3)	60	24	1.1
34	63 (5)	63 (6)	58 (2)	65 (2)	52 (1)	66 (3)	62	19	0.9
35	65 (3)	68 (2)	59 (3)	64 (2)	66 (1)	59 (3)	63	14	0.6
36	65 (4)	61 (1)	-	-	63 (1)	-	64	6	0.3
37	67 (2)	-	61 (1)	60 (3)	64 (1)	74 (1)	64	8	0.4
38	65 (2)	-	69 (2)	55 (1)	63 (1)	63 (1)	64	7	0.3
39	67 (2)	64 (1)	71 (1)	69 (1)	-	61 (2)	66	7	0.3
40+	(2)	-	-	-	-	(1)	-	3	0.1
Total							2,182		

TABLE 8. Average weight in pounds by age of lake sturgeon speared in the Upriver Lakes, 1955-65.

Age Groups	1955	1956	1957	1959	1962	1965	Average
10	-	-	-	15	12	12	12
11	12	10	-	15	15	13	13
12	13	15	13	15	13	14	14
13	15	15	14	14	14	14	14
14	16	17	14	16	14	16	16
15	16	17	16	19	15	18	17
16	18	19	16	16	14	18	17
17	22	22	19	19	18	20	20
18	21	22	20	19	19	20	20
19	23	25	23	23	20	21	23
20	25	26	23	23	23	21	24
21	24	32	24	28	25	26	26
22	28	33	27	30	26	27	28
23	28	33	28	29	27	28	30
24	32	32	28	27	31	33	31
25	33	35	30	34	37	35	33
26	36	37	35	38	48	40	37
27	39	43	35	30	39	35	38
28	38	46	35	41	-	63	41
29	47	49	43	48	56	-	47
30	48	48	46	53	34	54	48
31	52	51	49	60	43	36	51
32	47	50	58	50	52	58	51
33	52	45	55	55	32	58	51
34	56	60	41	55	37	61	55
35	61	75	52	60	82	51	60
36	67	53	-	-	63	-	64
37	63	-	58	45	60	106	61
38	60	-	75	38	52	56	59
39	69	56	102	79	-	54	69

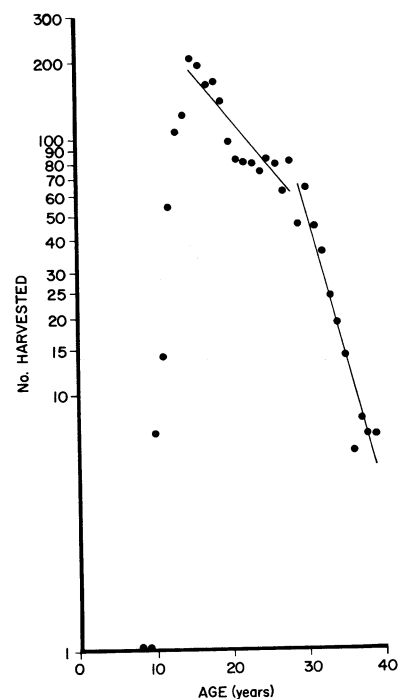


FIGURE 8. Catch curve of lake sturgeon harvested from Upriver Lakes, 1955-65.

TABLE 9. Population estimates of lake sturgeon over 40 inches in total length from Lakes Poygan and Winneconne, 1955-57.

Year	Total Harvest	Number of Tagged Fish	Number of Tags Returned (Percent)	Population Estimate	95% Confidence Limits
1955	703	37	5 (13.5)	5,202	1,670 - 13,340
1956	556	68	9 (13.2)	4,200	1,870 - 8,200
1957	408	64	7 (10.9)	3,730	1,470 - 8,070

TABLE 10. *The proportion of two groups of aged lake sturgeon speared in the Upriver Lakes during six spearing seasons from 1955-65.*

Season	Age		Percent "old"	Total
	8-24 yr.	"old" 25-40+ yr.		
1955	321	201	39%	522
1956	355	140	28%	495
1957	246	115	32%	361
1959	229	61	21%	290
1962	173	31	15%	204
1965	272	48	15%	310

DISCUSSION

The lake sturgeon in Lake Winnebago and the Poygan-Winneconne Basin belong to two different populations. It seems reasonable to assume, perhaps, that only a single population exists in this system: sturgeon from Lake Winnebago regularly travel upriver through these lakes and return through them; and the dam that maintains the level of Lake Winnebago also maintains and originally enlarged the upriver lakes so that the entire system is often called the "Winnebago Pool". However, our studies definitely rule out a single population of sturgeon.

First, growth rates of lake sturgeon of all ages in the Poygan-Winneconne Basin are much slower than similarly aged fish from Lake Winnebago. This is strong evidence that mixing does not occur.

Second, extensive tagging of lake sturgeon in both Lakes Winnebago and the Poygan-Winneconne Basin and the record of returns, which has taken place for 20 years, have not shown any mixing to take place between the two populations.

Third, changes in the size frequency of the lake sturgeon population in the Poygan-Winneconne Basin, brought about by overexploitation, have not been compensated by replacement

from the Lake Winnebago lake sturgeon population, which has not shown signs of overexploitation.

And fourth, condition factors (weight-length relationships) of lake sturgeon in the two populations differ markedly (Figs. 7 and 9).

Lake sturgeon from the two basins that were marked with tags have been observed spawning on the same grounds 50 and more miles upstream in the Wolf River. In spite of using the same spawning areas, these marked fish return to the lake basin of their origin. It is not known in what manner young of the year lake sturgeon establish their home in either basin. Very young (down to Age I) lake sturgeon are commonly found in both basins.

These facts conclusively demonstrate that lake sturgeon populations in the Lake Winnebago and in the Poygan-Winneconne Basin need to be managed independently. We do not know if the lake sturgeon population in Lake Butte des Morts is separate or part of the population from either basin but because of the small harvest, which suggests a small population, it is recommended that Lake Butte des Morts management remain similar to that practiced in the Poygan-Winneconne Basin.

On Lake Winnebago, extreme fluctuations in the annual harvest were governed by weather conditions and water clarity and not by scarcity of legal-sized fish (Priegel and Wirth 1975). On the upriver lakes, especially Lake Poygan, which received 77.1% of the fishing pressure, weather conditions and water clarity were generally not major factors related to the decrease in annual harvest (Table 11). Weather conditions were only classed as poor in 1962 when a severe snow storm prevented any harvest on the second day of a 2-day season. Yet 217 fish were speared during the 1962 season. Poor weather conditions during the entire 1976 season restricted the harvest to 85 fish even though water clarity was good.

Water clarity does not present a problem to spearers on the upriver lakes because of the shallow nature of the lakes (maximum depth of 11 ft). Only in 1968 when 80 fish were harvested during a 2-day season was water clarity a limiting factor (Table 11).

In lakes which have supported a commercial fishery for lake sturgeon, a distressing feature has been the rapid decline in yield. The results have always been the same, a relatively high, initial yield followed by a sudden and

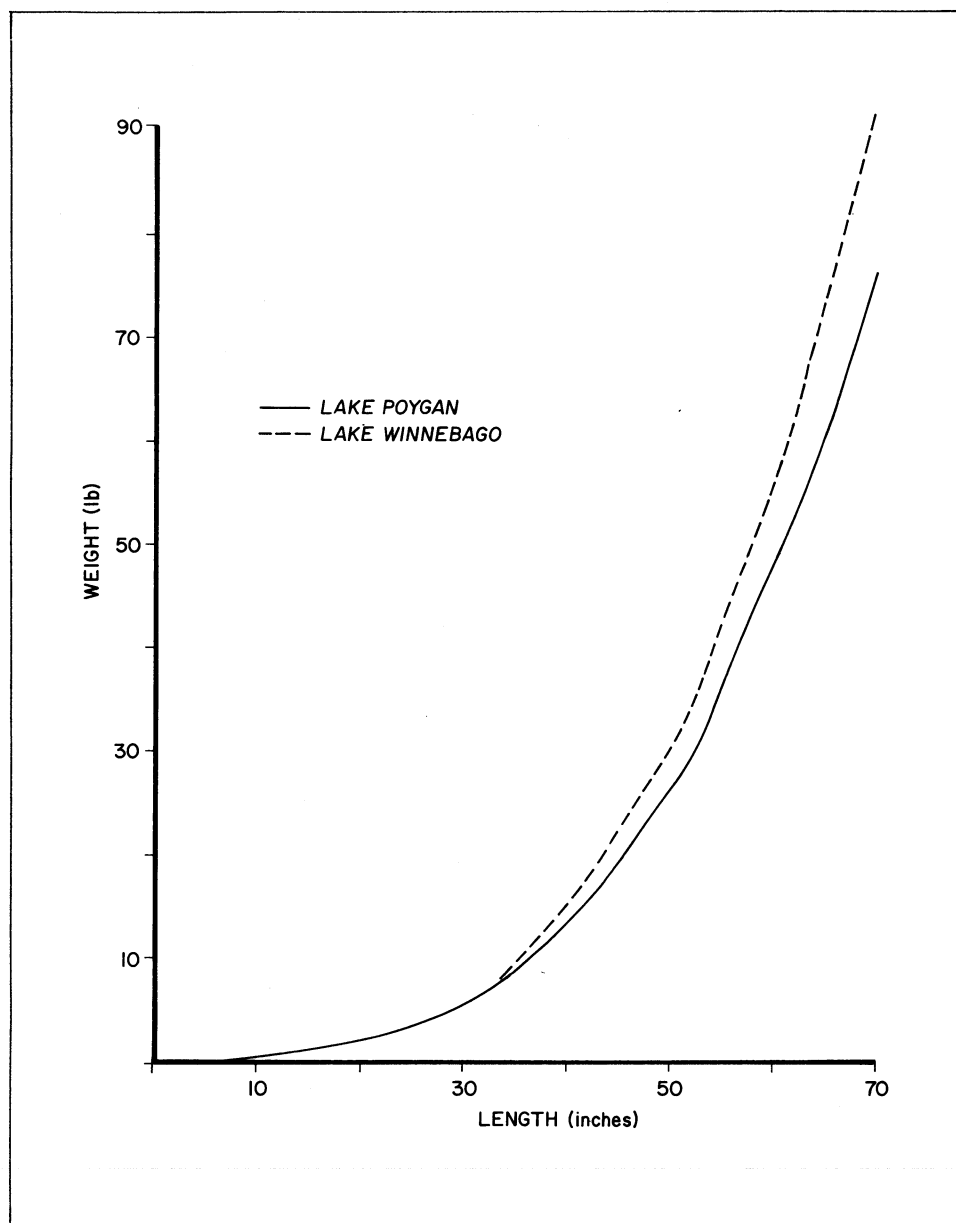


FIGURE 9.
*Length-weight relation
of lake sturgeon from Lake
Poygan and Lake Winnebago
based on calculated data.*

permanent decline to very low levels. Within 10 years (1885-95), the Lake Erie catch fell from over 5 million lb to less than 1 million lb, a decline of over 80%. The fishery never recovered, producing only 20,000 lb in 1951 (Anderson and Peterson 1954). In the Lake of the Woods commercial sturgeon yield fell 90% in seven years (1893-1900) from just under 2 million lb to under 200,000 lb. By 1930, the Lake of the Woods fishery had declined to less than 10,000 lb (Harkness and Dymond 1961); since 1941 the lake sturgeon has been on the protected list (Heyerdahl and Smith 1972). Production in previously productive Ontario waters has declined to a relatively low, continuous yield (Harkness and Dymond 1961).

This rapid decline in yield seems unique to sturgeon populations. Most other species, when fished, while showing some decline from primitive abun-

dance, usually give a relatively high yield as long as environmental conditions remain favorable. The lake sturgeon population on the upriver lakes has shown a sudden decline and these low levels can be expected for a considerable time. It is possible that the population may never recover to its former level as has been demonstrated elsewhere.

Some of the factors involved in an overharvest of the lake sturgeon population in the upriver lakes prior to 1959 are presented here. The 1952 season was characterized by relatively light pressure and a light harvest when compared to later years. From 1952-55 sturgeon spearing popularity almost doubled each year until 1955, when 1,190 spearing shanties were found on the upriver lakes. Since 1955 the shanty count has varied from 851 to 1,378. At the same time that the spear-

ing pressure increased, the number of fish speared per individual decreased. By utilizing the sturgeon report cards sent in each year through 1955, the reported success for the upriver lakes was 0.48 fish/spearer in 1952; in 1953 it jumped to 1.14 fish/spearer; in 1954 it was 0.91; and in 1955 it decreased to 0.43. Even though the size limit had been raised from 30 to 40 inches in 1955, the catch/spearer showed a sharper decline in success than could be attributed to imposition of this size limit. The poorer catch in 1952 no doubt reflects the inexperience of the spearkers during that first season in locating the fish. After 1955, the reported success for the upriver lakes was based on the shanty count, assuming one spearer/shanty. This is a minimum figure as many shanties are used by more than one individual. By 1959, the success had declined to 0.31 fish/shanty

with a further decrease to 0.23 fish/shanty in both 1962 and 1965. No shanty counts were taken in 1968 and 1971. In 1976 success was 0.15 fish/shanty, but the catch was greatly restricted by bad weather and a new 45-inch minimum size limit.

Up through 1959 little significant change was displayed by each season's length frequency sample but in 1959 a noticeable change attributable to the previous seasons was evident. From comparisons of the 1959 length frequency to similar frequencies of previous years, it can be seen that the proportion of the harvest of small sturgeon (under 50 inches) had increased significantly and the fish speared in the 50-54 and 55-59 inch groups had decreased significantly (Table 6). In 1959 the size most heavily represented was 40 to 42 inches (21.8% of the harvest), very close to the minimum legal size limit. In other words, the length frequency more than suggests that spearers were cutting the size limit very close because of a scarcity of larger fish. The change in length frequency was undoubtedly due to a previous overharvest, during which the larger sturgeon were cropped off. This change can be listed as another factor pointing to overharvest. The increase in harvest of 40- to 42-inch sturgeon (over 20% of the harvest from 1959 through 1971) also suggests the likelihood that many undersize sturgeon were speared and returned to the water presumably to die. The length-frequency in the 1958 fall net catch (Lake Poygan) indicates greater numbers of 37- to 39-inch fish present in the lake than fish in the 40-to 42-inch range (Fig. 10). Net catches in Lake Poygan during the winter of 1959-60 and 1960-61 also bears this out.

Comparison of the length frequencies of the speared fish between the upriver lakes and Lake Winnebago clearly shows that the trend has been one of harvesting smaller fish in the upriver lakes (Table 12). The harvest of fish in the 40- to 44-inch group on the upriver lakes in 1955 and 1959 was 22.7 and 35.9%, respectively. On Lake Winnebago, however, this length group accounted for only 12.2 and 10.5%, respectively, of the harvest. Fish over 60 inches accounted for only 12.2 and 7.4% of the harvest in 1955 and 1959, respectively, on the upriver lakes. On Lake Winnebago, 31.0 and 29.1%, respectively, of the fish taken during 1955 and 1959 were over 60 inches.

Other examples of changes in the length and weight of the harvested fish can be seen in Figures 11 and 12. The catch in 1976 was excluded because of the change to a larger minimum size limit.

TABLE 11. *Weather and water clarity during the sturgeon spearing season on the Upriver Lakes, 1952-71.*

Year	Fish Harvested	Weather Conditions*	Water Clarity**
1952	200 ¹	Excellent	Excellent
1953	784 ¹	Good	Excellent
1954	879 ¹	Excellent	Excellent
1955	715	Excellent	Good
1956	587	Excellent	Excellent
1957	422	Excellent	Excellent
1959	297	Good	Excellent
1962	217	Poor	Excellent
1965	325	Excellent	Excellent
1968	80	Good	Poor
1971	227	Excellent	Excellent
1976	85	Poor	Good

***Weather Conditions**

Excellent: car travel over entire lake possible.
 Good: car travel possible in most areas of lake during most of the season.
 Poor: car travel severely restricted during all or most of the season.

****Water Clarity**

Excellent: see bottom (10-foot depth considered bottom).
 Good: visibility down to a depth of 6 ft.
 Poor: visibility less than 4 ft.

¹ Estimates based on creel census; 1955 was the first year of registration.

TABLE 12. *Comparison of length frequencies in percent of lake sturgeon speared in the Upriver Lakes and Lake Winnebago, 1955 and 1959.*

Length Groups*	1955		1959	
	Upriver Lakes	Winnebago	Upriver Lakes	Winnebago
40-44	22.7	12.2	35.9	10.5
45-49	25.6	18.3	33.7	12.7
50-54	22.2	19.6	15.2	20.0
55-59	17.4	18.9	7.8	27.7
60-64	9.7	20.4	5.9	22.7
65-69	2.2	8.5	1.5	4.6
70+	0.3	2.1	-	1.8
Total no.	715	845	270	220

*Total length in inches.

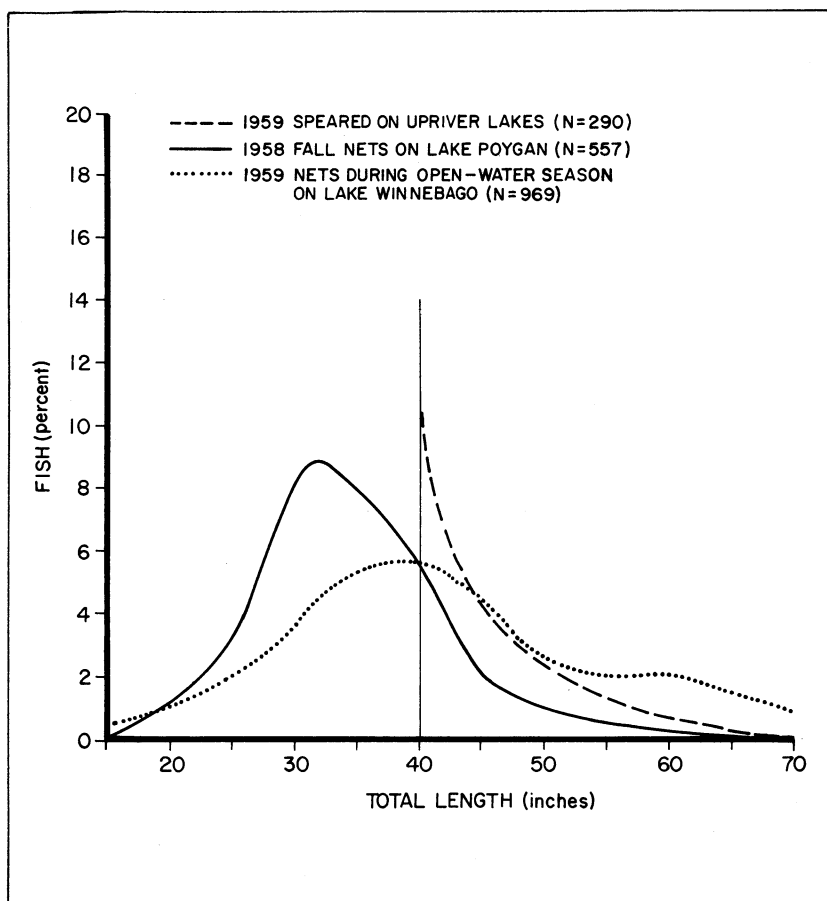


FIGURE 10. Length frequency in percent of lake sturgeon captured in nets on Lake Poygan during Fall 1958, speared in the Upriver Lakes in 1959, and captured in nets on Lake Winnebago during the open-water season in 1959.

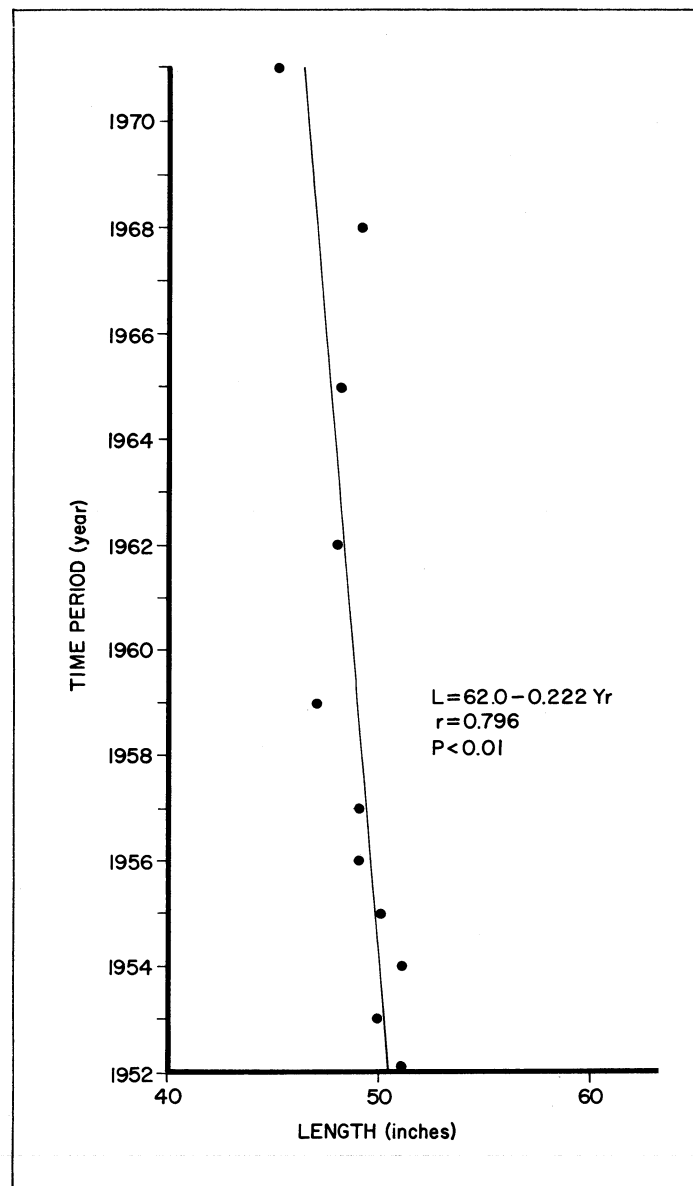


FIGURE 11. Relationship between years of harvest and average length of lake sturgeon speared in the Upriver Lakes (excluding 1976).

During the first four spearing seasons on the upriver lakes the percentage of fish 50 inches or larger maintained its proportion of the total catch at more than 50% (Table 6; the 1952-54 columns were adjusted by removing fish under 40 inches). Even fish over 55 inches continued at about 30% of the catch during these years. In 1956 and 1957 a trend toward smaller fish and a corresponding drop in fish over 50 inches in length was observed. These changes could have been due to some large year classes of young fish entering the fishery for, as we noted, the 1940, 1941, and 1942 year classes were heavily represented (Table 5). However, results of the 1959 season demonstrated a substantial shift to smaller fish; only 30% were 50 inches or more in length and 15% were 55 inches or longer. Therefore, we can assume that the 1956 and 1957 length classes were

forewarning a more drastic change in the population structure as a result of overexploitation.

Population estimates were made on the basis of marked fish recaptured during spearing seasons with the following assumptions:

1. A sufficient number of fish are sampled during the season (total registration);
2. All tagged fish retain their tags;
3. All tagged fish that are speared are reported;
4. Tagged fish are taken in the same proportion as the unmarked segment of the population;
5. Tagged fish do not migrate out of the study area differently than unmarked fish;
6. Natural mortality, if any, of tagged and unmarked fish is equal;
7. Sizes and ages of tagged fish are representative of the population so

that a harvest bias is not present.

These assumptions appear valid, except for the number of tagged fish recovered during each season. The differences in the number of tags returned are not statistically different (Table 9). The differences are, however, consistent with those shown by other data. Because of the importance of recovering every marked fish that was speared, beginning in 1956 a \$10.00 reward was offered for the return of tagged (marked) fish. Mandatory registration of speared sturgeon began in 1955 and, as required, all fish were to be inspected and registered by Department personnel on the same day they were speared. The reward was instituted to help insure the recovery of all marked fish, some of which might not have been presented at the registration station with the marking tag still attached. This was of concern because

some spearers were apprehensive that as more tagged fish were recovered, regulations would become stricter. Based on returns before and after the reward was offered, we believe more tag returns came in with the reward, but this cannot be documented. Therefore, these population estimates should be considered maximum because even with a reward some tags may have not been reported.

The three population estimates for 1955, 1956, and 1957 (Table 9), appear reasonable when compared together and with each year's harvest. For example, the 1956 population estimate of 4,200 suggested a decline of 1,000 fish from the 1955 estimate of 5,202. Actual decline (not including recruitment) was at least 703 fish, which were registered during the 1955 season. In 1957, the population estimate was 3,730 which suggested a decline of 470 fish from the 1956 estimate. The actual population loss (not including recruitment) was at least 556 fish, the total number registered during the 1956 season. Differences in the comparisons of changes in these annual population estimates with the numbers of fish harvested each year are probably a combination of estimate errors, annual recruitment, and unknown mortality.

If the annual recruitment rate and the unknown mortality could be determined, a maximum annual harvest quota could be recommended that would be based on these population estimates. In Lake Winnebago, with the use of a catch curve, the computed annual mortality rate was used to estimate annual recruitment rates. In addition, the proportion of each of 13 years' catches that consisted of young year classes just entering the fishery was also used. As a result, recruitment was estimated to be close to 5% of the legal-sized population each year. This rate was considered a reasonable and safe estimate because the population

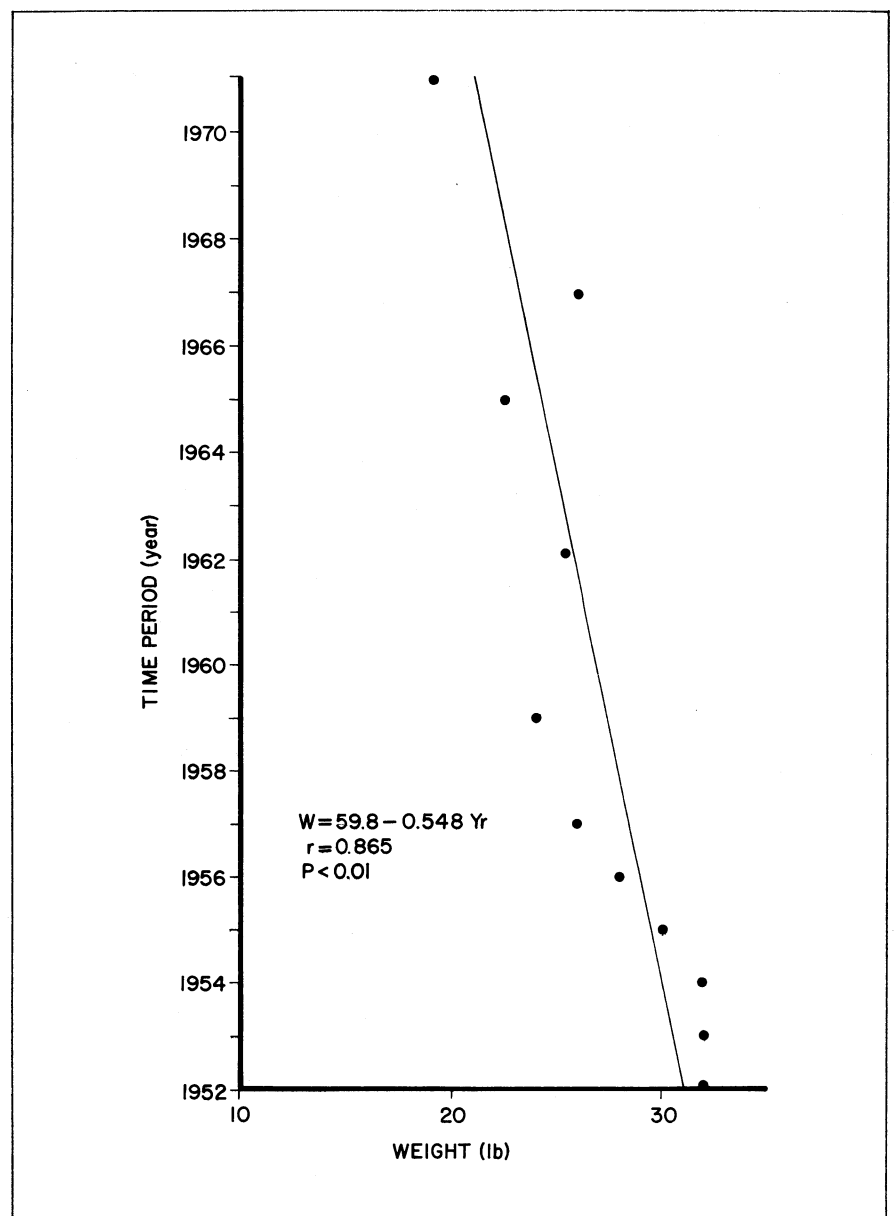


FIGURE 12. Relationship between years of harvest and average weight of lake sturgeon speared in the Upriver Lakes (excluding 1976).

of lake sturgeon in Lake Winnebago has not shown any signs of overexploitation at this rate.

We can test this 5% recruitment rate for the upriver lakes by combining it with population estimates and the annual catch. These estimates can be combined to reconstruct a hypothetical lake sturgeon population back to 1952 and to predict the population into the future. For example, if the population estimate for the Poygan-Winneconne Basin of about 3,700 fish at the start of the 1957 season is used with the addition of the number of fish speared each previous year and adjusted for annual recruitment of 5%, a population estimate of 5,744 fish at the start of the 1952 season is obtained. Starting with this population, using a

5% annual recruitment rate, and adjusting each year's population by the estimated catch or actual registration, Table 13 was developed. The first three years of catch were estimates for all upriver lakes, which include a few fish from Lake Butte des Morts. The remaining catch data are based on actual registration numbers from the Lake Poygan-Winneconne Basin.

An examination of the fall and rise in numbers of this reconstructed lake sturgeon population shows that the population should have regained its early 1950's strength in about 1975, 22 years later. But, based on the 1971 catch length frequency this could occur only if the population consisted of mostly young fish because the 1971 catch consisted of 81% fish less than 50

TABLE 13. *Lake sturgeon population table, 1952 through 1976, for the Lakes Poygan-Winneconne Basin, based on a 1952 beginning population at 5,744 legal length fish, the annual estimated legal harvest, and a 5% annual recruitment rate.*

Year	Population Estimate at Start of Season	—	Season Catch Estimate	=	Population Remaining at End of Season	+	5% Recruitment	=	Next Years Population
1952	5,744	—	200	=	5,544	+	277		
1953	5,821	—	784	=	5,037	+	252		
1954	5,289	—	879	=	4,410	+	220		
1955	4,630	—	715	=	3,915	+	195		
1956	4,110	—	587	=	3,523	+	176		
1957	3,700	—	422	=	3,278	+	164		
1958	3,442	—	0	=	3,442	+	172		
1959	3,614	—	297	=	3,317	+	166		
1960	3,483	—	0	=	3,483	+	174		
1961	3,657	—	0	=	3,657	+	183		
1962	3,840	—	217	=	3,623	+	181		
1963	3,804	—	0	=	3,804	+	190		
1964	3,994	—	0	=	3,994	+	200		
1965	4,194	—	325	=	3,869	+	193		
1966	4,062	—	0	=	4,062	+	203		
1967	4,265	—	0	=	4,265	+	213		
1968	4,479	—	80	=	4,399	+	220		
1969	4,619	—	0	=	4,619	+	231		
1970	4,850	—	0	=	4,850	+	242		
1971	5,092	—	227	=	4,865	+	243		
1972	5,108	—	0	=	5,108	+	256		
1973	5,364	—	0	=	5,364	+	268		
1974	5,632	—	0	=	5,632	+	282		
1975	5,914	—	0	=	5,914	+	295		
1976	6,209	—	85	=	6,124	+	306		

inches in total length. In 1955, however, the catch of fish under 50 inches total length was only 48% (Table 6). Therefore, it appears that the estimates computed in Table 13 do not represent the real situation.

To further demonstrate this technique with a slightly smaller population the same exercise and estimates were made with a beginning population of 5,000 fish (Table 14). This slight change in the starting population demonstrates the need to have much more accurate information to base estimates on, plus the need for regular accounting of population strength and recruitment. Table 14 may more closely demonstrate the real situation and, if it does, full recovery of the upriver lakes sturgeon population

will occur about 1985, 30 years after the initial heavy exploitation.

To sum up the results of 24 years of lake sturgeon harvest on the upriver lakes (principally the Poygan-Winneconne Basin) the following can be stated: during the first six years of harvest, 1952-57, an estimated 3,587 fish were harvested — 600/year; during the next 18 years, 1958-1976, 1,139 fish were registered — an equivalent of 63/year. This 90% reduction in catch will hopefully allow recruitment to rebuild this lake sturgeon population. The size ranges of the fish registered in the 1976 season suggest that larger fish are beginning to make up a greater portion of the population. If this is a real change it should be more apparent in the next season.

TABLE 14. Lake sturgeon population table, 1952 through 1986, for the Lakes Poygan-Winneconne Basin, based on a 1952 beginning population of 5,000 legal length fish, the annual estimated legal harvest, and a 5% annual recruitment rate.

Year	Population Estimate at Start of Season	—	Season Catch Estimate	=	Population Remaining at End of Season	+	5% Recruitment	=	Next Years Population
1952	5,000	—	200	=	4,800	+	240		
1953	5,080	—	784	=	4,256	+	213		
1954	4,469	—	879	=	3,590	+	180		
1955	3,770	—	715	=	3,055	+	153		
1956	3,208	—	587	=	2,621	+	131		
1957	2,652	—	422	=	2,230	+	112		
1958	2,342	—	0	=	2,342	+	117		
1959	2,459	—	297	=	2,162	+	108		
1960	2,270	—	0	=	2,270	+	114		
1961	2,384	—	0	=	2,384	+	119		
1962	2,503	—	217	=	2,286	+	114		
1963	2,390	—	0	=	2,390	+	120		
1964	2,510	—	0	=	2,510	+	126		
1965	2,636	—	325	=	2,311	+	116		
1966	2,427	—	0	=	2,427	+	121		
1967	2,548	—	0	=	2,548	+	127		
1968	2,675	—	80	=	2,595	+	130		
1969	2,725	—	0	=	2,725	+	136		
1970	2,861	—	0	=	2,861	+	143		
1971	3,004	—	227	=	2,777	+	139		
1972	2,916	—	0	=	2,916	+	146		
1973	3,062	—	0	=	3,062	+	153		
1974	3,215	—	0	=	3,215	+	161		
1975	3,376	—	0	=	3,376	+	169		
1976	3,545	—	85	=	3,460	+	173		
1977	3,633	—	0	=	3,633	+	182		
1978	3,815	—	0	=	3,815	+	191		
1979	4,006	—	0	=	4,006	+	200		
1980	4,200	—	0	=	4,200	+	210		
1981	4,410	—	(Say ? 200)	=	4,210	+	211		
1982	4,421	—	0	=	4,421	+	221		
1983	4,642	—	0	=	4,642	+	232		
1984	4,874	—	0	=	4,874	+	244		
1985	5,118	—	0	=	5,118	+	256		
1986	5,374								

MANAGEMENT AND RESEARCH CONSIDERATIONS

The management considerations in the upriver lakes are slanted to the Lake Poygan-Winneconne Basin. Little information was obtained from Lake Butte des Morts due to little harvest; however, because of its size, this lake should be managed similarly. Our data suggest several management alternatives.

MAINTAIN PRESENT SEASON

Initially the recent pattern of seasons, bag limits, and minimum size limit could be continued. This would provide a two-day spearing season once every five years, a bag limit of one fish/season, and a minimum size limit of 45 inches total length/fish. It is imperative that registration and associated fish measurements be conducted to provide a measure of the population structure. The collection of fin bones is no longer necessary, as length frequency of the catch can provide the basis for assessment of population recovery.

After each spearing season the assessment of the total harvest and the population structure should be used to recommend future seasons. Under the 45-inch minimum size limit the population structure goal should be that which equals the 1955 population structure adjusted as if a 45-inch minimum size limit had been in force. This would be demonstrated by a catch consisting of these approximate proportions: 30% fish 45 to 49 inches in total length, 30% fish 50 to 54 inches, and 40% fish 55 inches and over. When this goal is reached more frequent seasons can be considered, but the annual catch should not be allowed to exceed 5% of the estimated population of fish over 45 inches total length. This is an annual equivalent catch: for example, in a season every other year, 10% could be harvested. Using the 1957 population estimate as our best available basis, adjusted by removing fish under 45 inches from it, an estimate of 2,667 sturgeon 45 inches and over would stand. A harvest of 5% of this number would be 133 fish.

A lake sturgeon marking program should be undertaken in the Lake Poygan-Winneconne Basin to provide a pool of marked fish for population estimates. One of the pelvic fins should be removed as a permanent mark that could be recognized when speared sturgeon are registered. The use of tags is not recommended because a permanent mark, such as an excised fin, would provide a pool of marked fish that could be used for a number of years. Natural mortality of marked and unmarked fish over a period of time should be equal, and tag loss would not be a factor in calculating populations estimates. A goal of 200 fish 45 inches and over should be initially set for this marking program. Perhaps this goal could be tied to a rough fish removal program in the Poygan-Winneconne Basin.

Because of the infrequent and short spearing season recommended, there may be a tendency on the part of managers and the public to recommend no harvest at all in the future. This would be a mistake because there is no other practical means of assessing this resource. Without periodic spearing seasons and related data collection the only logical basis for establishing subsequent seasons would be lost.

LIMIT FISHING PRESSURE

An alternate plan to regulate the harvest is limitation on the number of sturgeon spearers. Prior to each season a predetermined number of spearers could be chosen by random methods. That number should be related to a fish quota based on the objectives of the current season recommendations. This plan might enable more frequent spearing seasons, but would limit the number of participants. Such a limited participant program would be similar to that involved in certain hunting programs, such as the deer party permit program and the Canada goose season in the Horicon Marsh area. Sturgeon spearing as a means of harvest is more related to hunting as a method than it is to angling.

REGULATE THROUGH MINIMUM SIZE LIMIT

Theoretically, a minimum size limit would be the best management tool available for regulating the spearing harvest of lake sturgeon. However, there is reason to believe that human error in estimating the size of the fish under actual spearing conditions would undermine the value of raising the minimum size limit to say, 50 inches in total length. It was raised from 40 to 45 inches in 1976, but the high proportion of 45-49 inch fish registered (56%) raised concern that as minimum size limits are raised, compliance declines. While our research to date has shown the need for conservative protection measures, it has also disclosed a need for additional studies for fine-tuning the management of the sturgeon population in the upriver lakes.

The effectiveness of a minimum size limit rests on the assumption that the spearer is able to judge the length of the free-swimming fish. Yet, it is highly probable that some sublegal fish — perhaps an appreciable number — are killed due to human error in estimating the size of the fish. To determine the extent of such human error, a study might be conducted in which cooperating spearers are asked to judge the lengths — “just under 45 inches” or “above 45 inches” — of moving simulated sturgeon targets under actual field conditions. Should the degree of human error be appreciable, it might be advisable to increase the minimum size limit to achieve the effectiveness of the intended lower size limit. Perhaps spearer “training” might be considered as a cooperative venture with regional public and club participation.

CONTINUE RESEARCH ON EARLY LIFE HISTORY

Another important study to be undertaken is related to the early life history of lake sturgeon in the Fox and

Wolf River System. It involves two questions to be answered: (1) what factors influence year class strength? and (2) what factors determine the source of Lake Poygan and Lake Winnebago fish? For example, do weather, high river water levels in the spring, low river water levels in the fall, abundance of adults, quality of spawning areas, etc., influence year class strength? Are Lakes Poygan and Winnebago replenished with young sturgeon from the same adult fish in a random manner, or do the offspring from the adults from each lake return to their parents' lake? The findings from such studies will be important and should provide a better basis for management of lake sturgeon. If Poygan fish are dependent on Lake Poygan adults, overexploitation of adults might greatly lengthen the time of population recovery. But, if Lake Poygan fish come from Lake Winnebago adult stock, population recruitment would be expected to occur more regularly. Findings from these studies

might suggest direct management measures such as transfer of young fish from one lake to another, or water level manipulation to enhance downstream movement of young-of-the-year fish, and spawning ground construction.

These studies, "factors that influence year class strength", "source of young fish to each lake", and "early life history of lake sturgeon" could be examined together because they relate to one another. The relative scarcity of this species, plus the history of rapid depletion of sturgeon populations in the world, provide reasons for giving sturgeon research high priority.

Biologists (Harkness and Dymond 1961) have considered sturgeon culture and stocking as a possible conservation measure to perpetuate these fish. It would be tragic, however, if studies related to the natural ecology of sturgeon, such as those mentioned here, were set aside in favor of studies relating to a sturgeon stocking program.

Studies currently underway in the upriver lakes by the Department of Natural Resources are related to water quality, aquatic vegetation, and rough fish relationships (principally fresh water drum, *Aplodinotus grunniens* and carp, *Cyprinus carpio*). These studies may uncover important relationships to the lake sturgeon population, especially in the area of competition by rough fish for bottom fauna used as food by sturgeon. The latter could be a very important area of fish research because of the history of slow sturgeon growth in the upriver lakes. Conceivably, the efforts to increase the sturgeon population through conservative harvest regulations might be negated, at least in part, by the presence of a large rough fish population competing for the same food supply. In addition, other changes in the upriver lakes that relate to sturgeon welfare, e.g. water quality degradation and water level manipulation, should receive continued study.

SUMMARY

During 24 years of lake sturgeon harvest by spearing in the upriver lakes (principally Lakes Poygan and Winnebago) an estimated 4,726 fish were taken during 12 seasons. From 1952-57, 75% (3,587) of this catch was taken in those 6 annual seasons, while during 1958-76 24% (1,139) was taken in 6 more seasons spread out during this 18-year period.

Lake Poygan has accounted for 88.7% of the total harvest from the upriver lakes. Lake Winnebago and Big Lake Butte des Morts accounted for 8.8 and 2.5% of the total harvest, respectively.

The total weight harvested over the period, 1952-76 (12 seasons) was 124,900 lb (4.5 lb/acre). Considering that 88.7% of the fish speared were taken on Lake Poygan, the harvest from Lake Poygan would be 7.8 lb/acre.

Based on shanty counts, 1954-76,

Lake Poygan accounted for 77.1% of the fishing pressure.

Individual year classes were harvested heavily when they entered the fishery at age 15 or 16. For example, the 1941 year class accounted for 11.2% of the harvest in 1955 and the 1950 year class accounted for 13.2% of the harvest in 1965.

Over exploitation was demonstrated by a downward trend in the lengths of fish, a drop in catch/effort, a downward trend in the age of harvested fish, and changes in mortality rates.

In 1955, when the size limit was increased to 40 inches, 48.3% of the harvest were fish under 50 inches; however, the harvest of these smaller fish continued to increase each season so that by 1971 the harvest was dominated by fish under 50 inches (84.5%).

The registered lake sturgeon ranged in age from 8 to 43 years. Of the 2,182

aged fish, age groups 14 through 19 accounted for 45.2% of the total harvest. The average length of the fish gradually increased with an increase of age from 42 inches for an age 10 fish, to 66 inches for an age 39 fish.

The average weight also increased gradually with an increase of age from 12 lb for an age 10 fish to 64 lb for an age 36 fish.

Population estimates based on mark and recapture studies indicated a population of 3,700 to 5,200 fish 40 inches or longer in 1955-57.

Management considerations include the following: a two-day spearing season every 5 years with a bag limit of 1 fish/season and a 45-inch minimum size limit; continued registration and associated and additional studies on early life history of lake sturgeon, recruitment studies, population estimates, size limit usefulness, water quality, and rough fish relationship.

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About the Authors

Gordon R. Priegel was formerly a biologist with the Bureau of Research, and is now the staff specialist for fish management for the Southern District of the Department of Natural Resources. Thomas L. Wirth also was a biologist with the Bureau of Research, and in recent years has been chief of the Water Resources Research Section.

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