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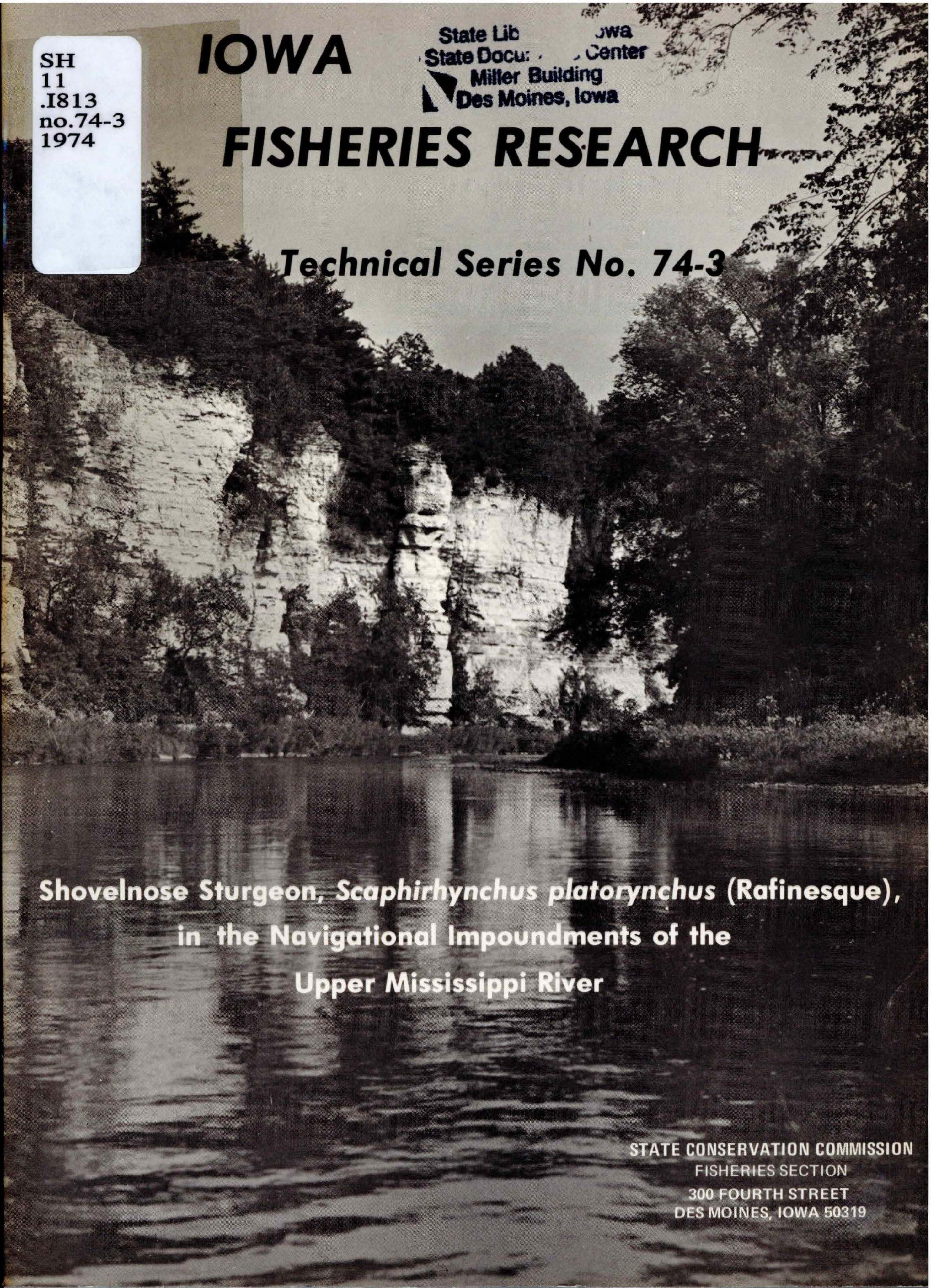

Shovelnose Sturgeon, *Scaphirhynchus platorynchus* (Rafinesque), in the Navigational Impoundments of the Upper Mississippi River

STATE CONSERVATION COMMISSION
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SHOVELNOSE STURGEON IN THE MISSISSIPPI RIVER, IOWA[1]

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Technical Series 74-3
September, 1974

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Shovelnose sturgeon are in high demand as a commercial food fish in the upper Mississippi River. Since little was known about harvest potential and suitability of existing regulations, investigations were conducted to survey commercial harvest, study life history of the species and evaluate the present system for reporting catch statistics. Over 5,204 commercially harvested fish were examined and 4,056 were captured by experimental netting. Age and size distribution of commercial harvest, age and growth, length-weight relationships, maturity, fecundity, ration, movement and population estimates were determined. Exploitation rates determined from tag returns varied from 1.2% to 42.9% in the various pools, but total annual mortality from age structure was estimated at nearly 60%. Although present harvest rates do not demand restricted harvests, a size limit may be justified on the basis of differential growth rates of immature vs mature fish, market demand for larger fish and greater weight loss among smaller fish during processing. Personal contacts with fishermen implementation of a revised system of collecting catch statistics requiring monthly reporting may have improved accuracy of catch statistics, but their reliability remains a chronic problem.

INTRODUCTION

Shovelnose sturgeon, *Scaphirynchus platorynchus*, is the smallest and most numerous sturgeon species found in Iowa. Other common colloquial names include sand sturgeon, hackleback, switchtail and flathead sturgeon. Harlan and Speaker (1951) reported they are common, but not abundant, throughout the Mississippi, Missouri and the lower reaches of the Iowa, Cedar and Des Moines Rivers. Locally, they are quite valuable as a food fish in the upper Mississippi River basin with an annual harvest by Iowa commercial fishermen that ranges up to 60,000 lbs. At current wholesale market prices the value of the catch exceeds $20,000. Sturgeon are sold primarily as a whole smoked product and demand is seldom satisfied by seasonal availability.

Little was known about the commercial harvest and life history of this species. By and large, harvest regulations are without sound biological basis. The Fisheries Section of the Iowa Conservation Commission conducted a three year study of shovelnose sturgeon in the Mississippi River bordering Iowa during the period 1 July, 1971-30 June, 1974, in cooperation with the National Marine Fisheries Service (PL:88-309). Objectives of the study were to evaluate commercial exploitation of shovelnose sturgeon, examine the reporting system of catch statistics to improve their accuracy and reliability and complete a detailed life history study of shovelnose sturgeon.

COMMERCIAL FISHING AND CATCH STATISTICS

HISTORY OF SHOVELNOSE STURGEON UTILIZATION

Historically, shovelnose sturgeon were not considered a desirable commercial fish in the upper Mississippi River because of their small size until quite recently. They were originally taken frequently along with lake sturgeon for eggs. Carlander (1954) noted shovelnose sturgeon were considered a nuisance when lake sturgeon were abundant and described a personal interview with Ed Saylor of Guttenberg, who as a boy in about 1895, helped his father dump large numbers of shovelnose sturgeon, head down on sand bars. Coker in "Studies of Common Fishes of the Mississippi River at Keokuk" (Barnickol and Starrett, 1951) wrote that this species was once a nuisance and fishermen destroyed them when taken in nets.

John Putman, Sr., a retired commercial fisherman in Bellevue, told the author he had clear boyhood memories in his teens (1900-1905) of seeing vast

The project number in the subscript on page 1 should be changed to 2-156-R.

[1]Study was partially financed by Project 4-11-R; Commercial Fisheries Research and Development Act (PL 88:309) administered by National Marine Fisheries Service, NOAA.

started smoking sturgeon shortly after this time, but their market did not become popular until the late 1920-30's. Before sturgeon were smoked, they sold for 7¢ whole in Clinton and Davenport and the raw eggs brought $2.50 per lbs.

Sturgeon eggs are seldom taken in the modern era. In 1973, only a single market (Davenport Fish Co. of Davenport, Iowa) was known to buy eggs. They reported handling only about 50 lbs of new eggs annually ranging from 75¢ to $1.00 per lbs.

Egg processing follows a quite simple procedure. After washing in salt water and pressing through a 1/8 inch screen to remove fat and connective tissue the eggs are bagged in cheese cloth and held under refrigeration for resale to a New York firm at $4.39 per lbs. Finished caviar reportedly retails for about $15.00 per lbs. Davenport Fish Company did not buy eggs in 1973, apparently a market for this product no longer exists in Iowa.

COMMERCIAL HARVEST METHODS

Sturgeon are commercially captured with four basic types of commercial fishing gear. Helms (1970) reported the harvest in Iowa from 1960-69 was taken by 44.7% entrapment, 31.1% entanglement, 18.1% encircling, and 2.6% angling gear. Because of the numerous sharp spiny projections on the body, sturgeon are particularly vulnerable to capture by entanglement devices (Starrett and Barnicol, 1955). As a result, much commercial fishing effort for this species is with trammel nets.

A popular and effective fishing method during May and June is "dead setting" trammel nets below navigation dams. Nets are anchored with a heavy weight near the dam (900 ft is the minimum legal distance) and trailed downstream parallel with the current near the river bottom. The downstream end is usually bouyed with plastic jugs. Dimensions of nets fished for sturgeon in this manner are usually 6 ft deep and 100 yds long with the inner web of 2-2 1/2 inches bar measure, No. 178 or finer twine. Nets are tended each day with three or fewer fished simultaneously. Catches exceeding 300 lbs per net are rare with the average lift nearer 50-75 lbs.

Other methods of fishing trammel nets for sturgeon include setting the nets either parallel or perpendicular to the current in the main channel border during midsummer periods of low flow or by drifting. Nets used for drifting differ from stationary nets in that they are usually much shorter in length, depending largely on size of area to be fished.

Drifting requires current and the bottom cleared of all obstructions and debris. Fishermen using this technique usually choose gravel or sand bottom areas. Most are located in main channel or main channel border habitats and drifted repeatedly once they are cleared.

Drift nets are fished by laying the net perpendicular to the current at the upstream end. The nets are slightly demersal and drag lightly along the bottom as they float with the current. Sometimes nets are attached to a hydrofoil float at each end. The floats, termed "mules" by commercial fishermen, are designed to deflect the current in such a way that it pulls the net downstream

Shovelnose sturgeon are a highly valued food fish in the upper Mississippi River basin.

and keeps it stretched outward. This technique is used most often when stream velocity is insufficient to carry the net. Drifting nets are given constant attendance by fishermen and usually no more than two are fished at once. This method of fishing is currently popular with many commercial fishermen.

Fishing with hoop nets during the spawning season is productive in the upper pools, particularly Pool 9. During late May and early June, hoop nets of 1 1/2 to 2 inches bar measure are set in the deeper water of the navigation channel and baited with gravid females. The author on one occasion observed a catch of 58 fish from a single net fished in this manner.

Sturgeon harvested by other types of gear appear to be incidental to other species (Helms, 1970).

COLLECTION OF COMMERCIAL CATCH STATISTICS

The collection of reliable catch statistics is a chronic problem. Commercial fishermen are prone to be poor record keepers. In addition, some are hesitant to report true harvest and are secretive with catch records to protect fishing grounds from competition and various other personal reasons. Generally, misrepresentation of catch statistics are believed to be much below actual harvest. The exact magnitude of false reporting is unknown.

The five states bordering the upper Mississippi River have worked jointly through the auspecies of the UMRCC since the mid-1940's to standardize catch statistics and minimize reporting errors. Although methods of collection still differ somewhat, each state assembles comparable statistics. Illinois fishermen are contacted by department personnel at the end of each year and catch information recorded anonamously. This instills confidence to the fisherman that records won't be traced in a tax audit. Wisconsin enforces monthly reporting under penalty of fines.

Until 1972, Iowa required an annual report enforced by the rule of withholding licenses in ensuing years. Iowa changed in 1972 to a monthly postcard reporting system. Use of the simplified card forms and monthly reporting were expected to reduce error by forgetful fishermen who were negligent in record keeping. Deliberate misrepresentation of harvest, however, continues to be a major problem and is suspected to be in the magnitude of 10 to 25% lower than actual values. The best that can be hoped for in this system is that the inaccuracies are consistent from year to year and fishery trends can be determined.

COMMERCIAL CATCH STATISTICS

Harvest figures from the 1890's showed several hundred thousand pounds of shovelnose sturgeon taken annually in the upper Mississippi River. Catch declined steadily until the last few decades (Table 1). Cause of the decline was undoubtedly a direct result of habitat destruction. Manipulation of the river to enhance navigation through a chain of modifications including construction of 4, 6 and 9 foot channel depths by channel stabilization and impoundment of the pools restricted sturgeon habitat to small areas immediately downstream from navigation dams. Sturgeon harvest exceeded 100,000 lbs only two years (1956 and 1958) since construction of navigation dams.

Table 1. Shovelnose sturgeon harvest in pounds from the upper Mississippi River.

Year	Pounds harvested
1894	423,000
1899	383,000
1922	119,000
1931	57,000
1947-50	12,000-19,000
1950-59	9,000-120,000
1960-69	18,000-37,000
1970-73	36,000-48,000

Annual harvest for the past 15 years ranged from 18,385 to 48,096 lbs with a mean of 31,426. Nearly 75% was caught in the 313 mile section of river bordering Iowa and half (14,921 lbs) was reported by Iowa fishermen. Of the 11 pools bordering Iowa, Pools 9, 12 and 17 are generally the most productive, but harvest from individual pools fluctuates (Table 2).

VALUE OF THE STURGEON HARVEST

Sturgeon values have more than doubled in the past 20 years. Exvessel values for sturgeon in Iowa has risen from 15¢ in 1954 to 41¢ in 1973. Total value of the Iowa harvest ranged from $1,049 in 1962 to $9,960 in 1958. Harvest during the project was valued at $8,535 in 1971, $5,814 in 1972 and $6,241 in 1973. Value for other years are listed in Table 3.

DISTRIBUTION OF CATCH BY GEAR

The method of harvest was determined from 174 tagged sturgeon reported by commercial fishermen that specified the type of gear used for fishing. Three different types of gear were used with trammel nets used to catch 82% and hoop nets to catch 18%. Less than 1% was taken by seining (Table 4). These figures were heavily biased since greater numbers of tagged fish were available for capture in Pool 13 where fishing for sturgeon was primarily by trammel nets. Tagged sturgeon in Pool 9 were all reportedly captured by hoop net. With exception of Pools 17 and 19 where drifted trammel net was most popular, most fish taken by trammel net were by dead setting.

Only 7% were taken incidentally while fishing for other commercial food fish species, and all except one of these were caught in hoop nets. The author observed sturgeon being taken by setlines with one fisherman known to have caught tagged sturgeon while fishing for catfish near Bellevue. The sturgeon was not kept nor was the tag number reported.

Table 2. Shovelnose sturgeon harvest in pounds from Mississippi River pools bordering Iowa, 1960-73.

	Pool											
Year	9	10	11	12	13	14	15	16	17	18	19	Combined
1973	1,282	1,247	1,243	3,366	375	427	595	1,327	3,130	508	1,723	15,223
1972	1,846	782	1,882	5,728	238	46	1,033	868	2,182	1,369	638	16,612
1971	2,524	976	1,818	8,832	2,377	519	---	217	3,612	2,744	2,244	25,863
1970	1,009	881	48	5,048	3,696	1,715	51	2,479	2,167	1,884	508	19,486
1969	849	651	828	11,736	1,364	644	135	1,192	5,470	42	228	23,139
1968	872	416	145	5,497	563	2,140	28	2,021	1,985	1,056	353	15,076
1967	543	211	1,527	4,358	1,708	1,178	595	1,012	2,041	163	---	13,336
1966	2,070	275	1,090	3,411	634	468	68	238	1,305	1,883	314	11,756
1965	186	178	3,332	250	567	128	129	1,062	3,288	316	354	9,790
1964	221	1,280	540	1,536	636	33	42	857	206	1,115	2,611	9,077
1963	2,220	952	511	1,352	---	40	13	9	1,575	60	652	7,384
1962	1,916	497	115	436	140	680	96	106	440	500	323	5,249
1961	4,073	1,408	2,156	350	136	980	18	8	480	17	860	10,486
1960	6,559	2,455	2,554	850	175	3,048	310	252	3,672	749	153	20,777

Table 3. Exvessel values of shovelnose sturgeon harvested in Iowa, 1954-73.

Year	Pounds marketed	Value per pound	Total commercial value
1973	15,223	$ .41	$ 6,241
1972	16,612	.35	5,814
1971	25,863	.33	8,535
1970	19,876	.30	5,963
1969	23,139	.25	5,785
1968	15,076	.25	3,769
1967	13,336	.25	3,284
1966	11,756	.19	2,234
1965	9,790	.24	2,350
1964	9,077	.23	2,088
1963	7,384	.23	1,698
1962	5,249	.20	1,050
1961	10,486	.18	1,887
1960	20,777	.16	3,324
1959	13,919	.18	2,505
1958	58,591	.17	9,960
1957	30,194	.17	5,133
1956	29,939	.17	5,090
1955	21,214	.19	4,031
1954	25,342	.15	3,801

Table 4. Method of harvest by pool for 174 tagged sturgeon recaptured by commercial fishing.

	Pool											
Method of harvest	9	10	11	12	13	14	15	16	17	18	19	Combined
Sturgeon fishermen												
Trammel net drift												
Number			1		1			1	32		9	44
Percent			12.5		1.1			20.0	97.0		90.0	25.3
Trammel net set												
Number			5	6	83			4				98
			62.5	66.7	94.3			80.0				56.3
Hoop net												
Number	15	2		3								20
	88.2	100.0		33.3								11.5
Subtotal												
Number	15	2	6	9	84			5	32		9	162
	88.2	100.0	75.0	100.0	95.5			100.0	97.0		90.0	93.1
Other fishermen												
Hoop net												
Number	2		2		4	1			1		1	11
	11.8		25.0		4.5	50.0			3.0		10.0	6.3
Seine												
Number						1						1
						50.0						.6
Subtotal												
Number	2		2		4	2			1		1	12
	11.8		25.0		4.5	100.0			3.0		10.0	6.9
Total number	17	2	8	9	88	2		5	33		10	174

Sport fishing plays a minor roll in sturgeon harvest. Three tagged fish were reported from Pool 9 and two from Pool 11. All five were caught in tailwaters from sport fishing barges.

In a previous study by Helms (1970), catch of sturgeon by gear was tabulated from commercial harvest statistics. Catch by gear in Iowa from 1966-69 were as follows: entrapment, 45%; entanglement, 31%; encompassment, 18%; and setlines, 3%. Gear type was not specified for 4% of the catch.

SEASONAL DISTRIBUTION OF THE CATCH

Seasonal distribution of commercial harvest was calculated from 211 returned tags and results were similar to that determined from catch statistics for the period 1966-69 (Helms, 1970). The catch statistics showed peak harvest occurred in May and June with reduced harvest continuing through October. A preponderance of the tags were returned in June. Lower numbers of tags were returned in May which was attributed to high water conditions that month during the study. Few sturgeon were caught during winter. Table 5 lists the seasonal catch of sturgeon by fishermen and the monthly distribution of recaptured tagged fish.

Table 5. Monthly distribution of the commercial shovelnose sturgeon harvest in Iowa.

	Commercial catch distributed in percent	Catch of tagged sturgeon in percent
January	.1	.5
February	1.7	.5
March	3.6	1.0
April	10.3	
May	21.5	16.6
June	21.6	29.4
July	11.6	13.7
August	7.9	15.2
September	9.4	6.6
October	8.0	15.6
November	3.9	1.0
December	.4	

SIZE DISTRIBUTION OF THE COMMERCIAL CATCH

Samples totaling 5,204 commercially harvested shovelnose sturgeon from six pools were examined for length and weight distribution. All fish were measured to the nearest .5 inch and subsamples of fish were individually weighed.

Length frequency distributions differed somewhat between pools. Size of Pool 9 fish was affected by both size limits and method of take. Some fish examined at the Lansing Fisheries were taken by Wisconsin fishermen which were restricted by a 25 inch minimum size limit. The practice of taking spawning fish with hoop nets in this pool also increased the average size of fish caught.

Sturgeon examined from Pool 12 were also larger than average. Samples from this pool were wholly from one fisherman that dead set trammel nets in late summer adjacent to the navigation channel.

Fish measuring 20-24 inches FL and weighing 1-2 lbs dominated the catch contributing about 60% in both weight and number (Table 6). Few fish < 18 inches were kept and they contributed only 1.5% to the catch weight.

AGE DISTRIBUTION OF THE COMMERCIAL CATCH

Age distribution of 2,045 shovelnose sturgeon from six pools was determined as the product of the age ratio of subsamples within each length intervals and the total number of fish measured. Sample size ranged from 1,014 fish in Pool 9 to 72 fish in Pool 20. Age distribution was similar in all pools with the exception of Pool 9, where the youngest fish in the catch was age IV and all successive age groups through XIII were represented. Age groups II-VIII were represented in samples from all other pools, but two year old fish were proportionately more abundant in the samples from Pools 11 and 17 (Table 7).

Mortality and survival rate of shovelnose sturgeon was calculated according to Rounsefell and Everhart (1958). The age at which all fish in the population entered the fishery was 5 in Pool 9 and 4 in other pools. Annual mortality (r) was nearly 60% in all pools, with the compliment survival rate ($S = 1 - r$) estimated at 40%. Both values in addition to instantaneous mortality rate (Δ) are listed by pool in Table 8.

EXPLOITATION RATE OF THE COMMERCIAL FISHERY

Marked fish recovered by commercial fishermen were used to determine exploitation rate. During the study, 3,271 fish were marked by tagging and 183 or 5.6% were recovered. Since some fish measured 11 inches FL when tagged and those under 18 inches were not usually retained in the commercial catch, small fish were excluded. The total number of fish available to commercial harvest was 1,851 and of this number, 52 or 8.2% were recaptured by commercial fishermen.

Tag loss was a serious problem among fish tagged during the first year, and only 17 or 2.1% of the 777 fish were recovered (Table 9). In 1972 and 1973 loss of tags was reduced substantially. Most tagging was conducted during or slightly after the major fishing season for sturgeon and the recovery of tags during the first year does not represent full effort. Therefore, first year recoveries resulting from 1972 and 1973 tagging are comparable but do not

Table 6. Length and weight distribution of commercially harvested shovelnose sturgeon from six Mississippi River pools.

Length interval (FL)	$\overline{X}$ wgt (lbs)	Pool 9 N	Pool 9 Wgt	Pool 11 N	Pool 11 Wgt	Pool 12 N	Pool 12 Wgt	Pool 13 N	Pool 13 Wgt	Pool 17 N	Pool 17 Wgt	Pool 20 N	Pool 20 Wgt	Combined N	Combined Wgt
< 18				18.5	7.3	.6	.2	1.4	.6	3.4	1.6			3.9	1.5
18-19	.83	.4	.9	14.2	8.2	3.0	1.3	5.8	3.2	4.8	2.8	3.7	2.3	5.3	2.8
19-20	.97	3.2	1.7	4.3	2.9	7.7	4.0	16.9	11.1	19.6	13.6	14.6	10.5	11.0	6.9
20-21	1.16	12.5	8.0	6.8	5.5	8.0	4.9	21.5	16.8	18.9	15.7	30.5	26.3	16.4	12.2
21-22	1.38	18.6	14.2	16.0	15.4	7.7	5.9	18.5	17.2	17.4	17.2	24.4	25.0	17.1	15.1
22-23	1.62	20.4	18.2	9.3	10.5	16.3	14.1	13.0	14.2	16.3	18.9	14.6	17.6	15.0	15.6
23-24	1.88	16.5	17.1	9.9	13.0	19.9	19.9	9.5	12.0	10.4	14.0	7.3	10.2	12.2	14.8
24-25	2.18	13.5	16.2	7.4	11.2	14.8	17.2	5.1	7.5	4.4	6.9	3.7	6.0	8.1	11.4
25-26	2.51	6.1	8.5	8.0	14.0	12.2	16.3	2.6	4.4	2.6	4.7	1.2	2.2	5.5	8.8
26-27	2.87	4.2	6.7	3.1	6.2	6.2	9.5	2.4	4.6	1.9	3.9			3.0	5.5
27-28	3.27	2.5	4.5	1.2	2.7	2.1	3.7	1.4	3.1	.4	.9			1.3	2.7
28-29	3.71	1.1	2.3	1.2	3.1	.6	1.2	1.1	2.8					.7	1.6
29-30	4.19	.7	1.6			.9	2.0	.5	1.4					.4	.9
> 30		.3	.8					.3	1.0					.1	.3
Sample size		1,058		162		337		3,295		270		82		5,204	

Table 9. Annual rate of recovery by commercial fishing for 1,851 tagged shovelnose sturgeon in the Mississippi River during 1971-74.

Pool	Year	Number tagged > 18 inches	Recaptured 1971 N	1971 %	1972 N	1972 %	1973 N	1973 %	Combined N	Combined %
9	1971	93			2	2.2			2	2.2
	1972	24			4	16.7	3	12.5	7	29.2
	1973	49			7	14.3			7	14.3
10	1972	7								
11	1971	83	1	1.2					1	1.2
	1972	7			3	42.9			3	42.9
	1973	83	2	2.4	2	2.4			4	4.8
13	1971	281								
		207								
	1972	285	19	6.7	2	.7	1	.4	22	7.8
		148	10	6.8	25	16.9	9	6.1	44	29.8
	1973	219	6	2.7	8	3.7			14	6.4
14	1971	11			1	9.1			1	9.1
	1973	11								
16	1971	14			1	7.1			1	7.1
17	1971	25	8	32.0	1	4.0			8	32.0
	1972	65			13	20.0	1	1.5	14	21.5
	1973	60	10	16.7	2	3.3			12	20.0
18	1971	2								
19	1971	61	3	4.9	1	1.6			4	6.5
	1972	83	6	7.2	1	1.2	1	1.2	8	9.6
	1973	33								
Combined	1971	777	12	1.5	5	.6			17	2.1
	1972	619	35	5.7	48	7.8	15	2.4	98	15.8
	1973	455	18	4.0	19	4.2			37	8.1
Total		1,851	65	3.5	72	3.9	15	.8	152	8.2

represent a complete fishery. Second year recovery fish tagged in 1972 are more representative of true harvest. The percent recovered for that year was 16.7%, 0%, 42.9%, 17.6%, 20%, 0% and 1.2% for Pools 9, 10, 11, 13, 17 and 19. The extreme values of 0% in Pool 10 and 42.9% in Pool 11 can be explained by the small number of tagged fish in the population. The recovery of 1.2% of the tags in Pool 19 resulted from low fishing pressure and/or lack of cooperation in returning tags by fishermen. Fishermen and market contacts in this area of the river indicated fishing pressure for sturgeon was quite low and value was considered accurate. Overall mean exploitation rate was estimated at about 18% for pools with substantial fishing interest for sturgeon.

ECONOMIC ASPECTS OF PROCESSING FOR FOOD

Shovelnose sturgeon are very highly valued as a delicate food fish and the seasonal supply seldom meets demand. As a result, market values are among the highest for any commercial fish species in the upper Mississippi River basin. Processing by smoking adds considerable cost to the consumer product because of additional labor requirements. The process is also prone to large loss in tissue weight. A survey of processing steps was made to determine loss of weight and the change in market value.

Data from the incremental weight loss was collected from 189 specimen. Fish were individually marked by placing a number 3 monel wing band on the dorsal base of the caudal fin. Length, whole weight, dressed weight and smoked weight were obtained for each fish.

No relationship was discernable between body size and weight loss from dressing (Table 10). However, there was a significant change in the loss of weight due to smoking, particularly for smaller sized fish. Loss in body weight for sturgeon 1.25 lbs by smoking averaged 49.8% while the weight loss for larger fish averaged 42.6%. Presumably the difference resulted from higher evaporation due to greater surface area to body weight for smaller sized fish. The mean weight loss from whole fish to dressed fish was 32.9% and ranged from 26.2% to 37%. From dressed to smoked the average weight loss was 27.9% and varied from 20.4% to 40.4%. Mean weight loss for complete processing was 52.0%.

Flesh was stripped from 50 smoked sturgeon of various sizes to determine the edible fraction of the finished market product. The inedible waste included skin and cartilage and made up 39.4% of the smoked weight. For each pound of whole fish processed about .29 lbs of edible smoked flesh were marketed.

The average price paid to commercial fishermen ranged from 20-48¢ per lbs, while dressed price ranged from 45-85¢ per lbs. Smoked sturgeon ranged from 95¢-$2.25 per lbs. Most commercial fishermen dress sturgeon before selling. Experienced individuals dress up to 100 lbs of sturgeon in 15-30 minutes, increasing the market value by about 30%. At common market prices for whole, dressed and smoked sturgeon, the total values are $35, $65, and $155 per 100 lbs.

Shovelnose sturgeon are processed for human consumption by smoking.

Table 10. Changes in the body weight per 100 lbs of 189 shovelnose sturgeon during processing for food.

	Stage of process			
	Whole	Dressed	Smoked	Edible flesh[a]
Whole weight				
Initial weight in lbs	100	67.1	48.0	29.7
Percent loss		32.9	19.1	18.3
Cumulative percent loss		32.9	52.0	70.3
Dressed weight				
Initial weight in lbs		100	72.1	43.0
Percent loss			27.9	29.1
Cumulative percent loss				57.0
Smoked weight				
Initial weight in lbs			100	61.0
Percent not edible				39.4

[a]Edible portion was based on 50 fish sampled.

LIFE HISTORY INVESTIGATIONS

Life history studies of shovelnose sturgeon were conducted mostly in Pool 13 near Bellevue. Total number of fish used in the study was 5,204 commercially caught and 4,856 captured by experimental netting. A large portion of these fish were tagged and released for numerical population estimates, determination of intrastream movement and verification of tagging techniques. Data were also collected on the biology of early life stages, fecundity, age and size at maturity, length-weight relationship and other biological parameters.

EXPERIMENTAL NETTING OF SHOVELNOSE STURGEON

Trammel nets and bottom trawls were used for collecting sturgeon. The trammel nets were designed for drift fishing. Dimensions of the net were 100 ft x 6 ft and 1 and 1-1/2 inches (bar measure) inner web, No. 178 twine. Walling was 10 inches bar measure of No. 9 twine. Float lines contained standard sized plastic floats about 2 ft apart. Lead lines had 3 weights per float. Inner web of the net was hung relatively tight as a loosely hung inner web tended to drag on the bottom collecting debris, mussel shells and rocks. Methods of drifting were comparable to those previously described by commercial fishermen. Trammel nets were permitted to drift until they became "snagged" or approached known obstacles. Drifts were subjectively labeled short, medium or long. Short drifts were usually < 200 ft while long drifts were .5-1 mile lasting as long as 30 minutes. Fish samples were held in a live tank and processed after the nets were reset.

The bottom trawl was a standard 16 ft semi-balloon design modified by the attachment of a 6-ft extension of 1/8 inch Ace web. Towing was usually in an upstream direction. Downstream and cross current towing occurred only in areas known to be free of bottom obstructions. A standard trawl haul was 2 1/2 minutes pulled at full throttle by a 16 ft boat powered with a 40 hp outboard motor.

During many sampling periods two trammel nets were fished simultaneously, either one behind the other or side by side. While these nets were drifting, one or two trawl hauls could be made either beside or between the trammel nets. Using this technique, up to 20 drifts and 15 tows were accomplished in a work day.

CATCH SUCCESS AND STATISTICS OF EXPERIMENTAL NETTING

Catch effort (C/E) by drifting trammel nets and trawling was examined for 1972-73. Excluding young-of-year and minnow species, 4,043 fish were caught in 789 trammel net drifts and 503 in 313 trawl hauls. Success was slightly higher for both types of gear in the first year, but catch composition was similar.

Shovelnose sturgeon contributed 54% of the total catch by trammel net capturing fish at the rate of 2.8 per drift. Other major species captured included channel catfish, freshwater drum, pike perch and mooneye contributing 13%, 11%, 7% and 5% to the catch, respectively. Flathead catfish, carp, buffalo, carpsucker species, blue sucker, gizzard shad, redhorse species, northern pike, paddlefish, bullhead species, gar, white bass, and crappie contributed < 3% each (Table 11).

Mean catch per net drift was 5.1 for all species and ranged from 7.8 in Pool 17 to 3.7 in Pool 14. Pool 14 also had the lowest catch rate for sturgeon, .2 per drift. Low catch in this pool may have resulted in part from the small amount of effort expended. Some initial experimentation was usually necessary to locate productive areas. Disregarding the catch in Pool 14, catch rate for sturgeon was progressively higher downstream. Catch rates for individual pools were as follows: Pool 9, .6; Pool 10, 1.3; Pool 11, 2.0; Pool 13, 3.4; Pool 17, 4.3; and Pool 18, 5.3 per drift.

Sturgeon were generally caught in greater numbers than other fish species, being equalled or exceeded only by channel catfish, drum, pike perch and mooneye in Pool 9, drum in Pool 11, and channel catfish, drum and pike perch in Pool 14.

With the exception of tailwaters, sturgeon catch rates were similar for all types of river habitat. Tailwater C/E was 5.3 per drift compared to 2.9, 2.5 and 3.0 for main channel, main channel border and side channel (Table 12). Slack water habitats (i.e., slough, lake) could not be sampled by this method, but these habitats are generally considered unproductive for sturgeon by commercial fishermen.

Contribution of sturgeon to total catch was lowest in side channel (35%) which resulted primarily from higher catch rates of channel catfish, drum and pike perch. In contrast, sturgeon contributed 80% to the total catch in tailwater

Table 11. Species composition and catch effort (C/E) of shovelnose sturgeon by drifting trammel nets in Mississippi River pools.

Pool	Number of drifts	Number of fish		Shovelnose sturgeon	Catfish	Freshwater drum	Pike perch	Mooneye	Minnow
9	166	670	%	14	22	17	14	14	1
			C/E	.6	.9	.7	.6	.6	a
10	8	27	%	37	22	7	22		4
			C/E	1.3	.7	.2	.7		.1
11	70	418	%	33	16	36	3	2	2
			C/E	2.0	1.0	2.2	.2	.1	.1
13	440	2,251	%	67	10	5	6	4	2
			C/E	3.4	.5	.3	.3	.2	.1
14	16	59	%	5	58	22	10		2
			C/E	.2	2.1	.8	.4		.1
17	49	380	%	56	16	13	7	3	1
			C/E	4.3	1.2	1.0	.5	.2	.1
19	40	238	%	89	1	4		1	3
			C/E	5.3	.1	.2		.1	.2
Total	789	4,043	%	54	13	11	7	5	2
			C/E	2.8	.7	.6	.4	.3	.1

Table 11. (Continued).

Pool	Number of drifts	Number of fish		Carpsucker	Buffalo	Flathead catfish	Others	Combined
9	166	670	%	4	a	1	12	99
			C/E	.2	a	a	.5	4.0
10	8	27	%	4	4			100
			C/E	.1	.1			3.4
11	70	418	%	1	3	a	3	99
			C/E	.1	.2	a	.2	6.0
13	440	2,251	%	1	2	1	2	100
			C/E	.1	.1	.1	.1	5.1
14	16	59	%	2	2			101
			C/E	.1	.1			3.7
17	49	380	%	2	a	1	a	99
			C/E	.2	a	.1	a	7.8
19	40	238	%	1	1	a	a	100
			C/E	.1	.1	a	a	6.0
Total	789	4,043	%	2	1	2	3	100
			C/E	.1	.1	.1	.2	5.1

[a]Less than .5% and less than .05 C/E.

Table 12. Species composition and catch effort (C/E) of shovelnose sturgeon by drifting trammel nets in different Mississippi River habitats.

Habitat	Number of drifts	Number of fish		Shovelnose sturgeon	Catfish	Freshwater drum	Pike perch	Mooneye
Main channel	240	1,186	%	58	16	11	5	3
			C/E	2.9	.8	.5	.3	.2
Main channel border	484	2,365	%	52	12	10	8	7
			C/E	2.6	.6	.5	.4	.3
Side channel	33	282	%	35	20	24	10	
			C/E	3.0	1.7	2.1	.9	
Tailwater	32	210	%	80	1	6		1
			C/E	5.3	.1	.4		.1
Total	789	4,043	%	54	13	11	7	5
			C/E	2.8	.7	.6	.4	.3

Table 12. (Continued).

Habitat	Number of drifts	Number of fish		Minnow	Carpsucker	Buffalo	Flathead catfish	Others	Combined
Main channel	240	1,186	%	2	2	1	a	1	99
			C/E	.1	.1	.1	a	.1	4.9
Main channel border	484	2,365	%	2	2	1	1	3	98
			C/E	.1	.1	.1	.1	.2	4.9
Side channel	33	282	%	2	a	1	5	1	98
			C/E	.2	a	.1	.4	.1	8.6
Tailwater	32	210	%	1	2	4	2	3	100
			C/E	.1	.1	.3	.1	.2	6.6
Total	789	4,043	%	2	2	1	2	3	100
			C/E	.1	.1	.1	.1	.2	5.1

[a]Less than .5% and less than .05 C/E.

habitat while main channel and main channel border catches consisted of 58% and 52% sturgeon.

Trawling was generally less successful in capturing fish than trammel nets, but was especially useful for sampling young-of-year sturgeon in Pool 13. Consequently, sufficient effort was not expended to make valid catch comparisons between pools and habitats (Tables 13 and 14). Sturgeon were caught in greater numbers than any other fish species comprising 31% of the total catch with a mean catch rate of .5 fish per tow. Channel catfish, carp and mooneye each contributed 15% to the catch. Other species captured by trawling included drum, pike perch, flathead catfish, buffalo, carpsucker, redhorse, gar, white bass, crappie and bluegill.

STURGEON TAGGING STUDIES

Two methods were used to tag sturgeon in 1971. Both used serially numbered, Floy (FD-67) anchor tags colored international orange. Tags were initially anchored with a model FD-67 gun in the mid-section midway between the dorsal and lateral rows of bony plates. After marking 477 fish in this manner, it became apparent tag loss was quite high. An additional 890 fish were tagged in 1971 by anchoring tags between the bony plates along the lateral line. Although tag shedding was not as rapid by the later method, there was progressive erosion through the adjacent posterior plate until the tag fell out.

Methods of tagging was again altered in 1972. Schmulbach[1] (personal communication) indicated high success with monel tags attached to the pectoral fin. Number 3 monel wing band tags were placed over the anterior fin rays close to the body. This method was used in combination with a Floy tag anchored through the pectoral girdle dorsal to the fin. Cursory examination of the first 13 recaptured fish tagged by this method indicated little chance of either tag being lost. After 502 fish were combination tagged the monel tag was discontinued. An additional 613 were marked with Floy tags in the pectoral girdle in 1972 and 819 in 1973.

Most tagging effort was expended in Pool 13, but a goal of 100 marked fish was set in odd numbered pools each year to determine commercial fishing exploitation rates. This goal was not attained in Pool 15 because bottom topography precluded effective sampling. Neither goal was met in Pools 9 and 11 in 1972. In all, 3,271 shovelnose sturgeon were tagged and 326 (10%) were recaptured (Table 15).

TAG RETENTION

Tag loss from marked sturgeon was a major problem. Shedding began within a few weeks following side tagging above the lateral row of bony plates, and the longest interval between marking and recovery was 92 days.

Placement between lateral plates improved retention, but loss was still too rapid for long term study. Loss was observed to occur via erosion through the

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[1]Schmulbach, J. University of South Dakota, Vermillion. Letter dated 18 October, 1971 relating to tagging methods.

Table 13. Species composition and catch effort (C/E) of shovelnose sturgeon by trawling in Mississippi River pools.

Pool	Number of tows	Number of fish		Shovelnose sturgeon	Catfish	Mooneye	Minnow	Freshwater drum	Pike perch
9	22	23	%	4	39	13	21	4	9
			C/E	[a]	.4	.1	.2	[a]	.1
10	5	21	%	33	48			19	
			C/E	1.4	2.0			.8	
13	282	455	%	32	13	15	15	4	4
			C/E	.5	.2	.2	.2	.1	.1
17	1	0	%						
			C/E						
19	2	4	%	25	25				
			C/E	.5	.5				
Total	313	503	%	31	15	14	15	5	4
			C/E	.5	.2	.2	.2	.1	.1

Table 13. (Continued).

Pool	Number of tows	Number of fish		Carpsucker	Buffalo	Flathead catfish	Others	Combined
9	22	23	%	4			4	98
			C/E	[a]			[a]	1.0
10	5	21	%					100
			C/E					4.2
13	282	455	%	6	7	2	2	100
			C/E	.1	.1	[a]	[a]	1.6
17	1	0	%					0
			C/E					
19	2	4	%	25		25		100
			C/E	.5		.5		2.0
Total	313	503	%	6	6	2	2	100
			C/E	.1	.1	[a]	[a]	1.6

[a] Less than .05 C/E.

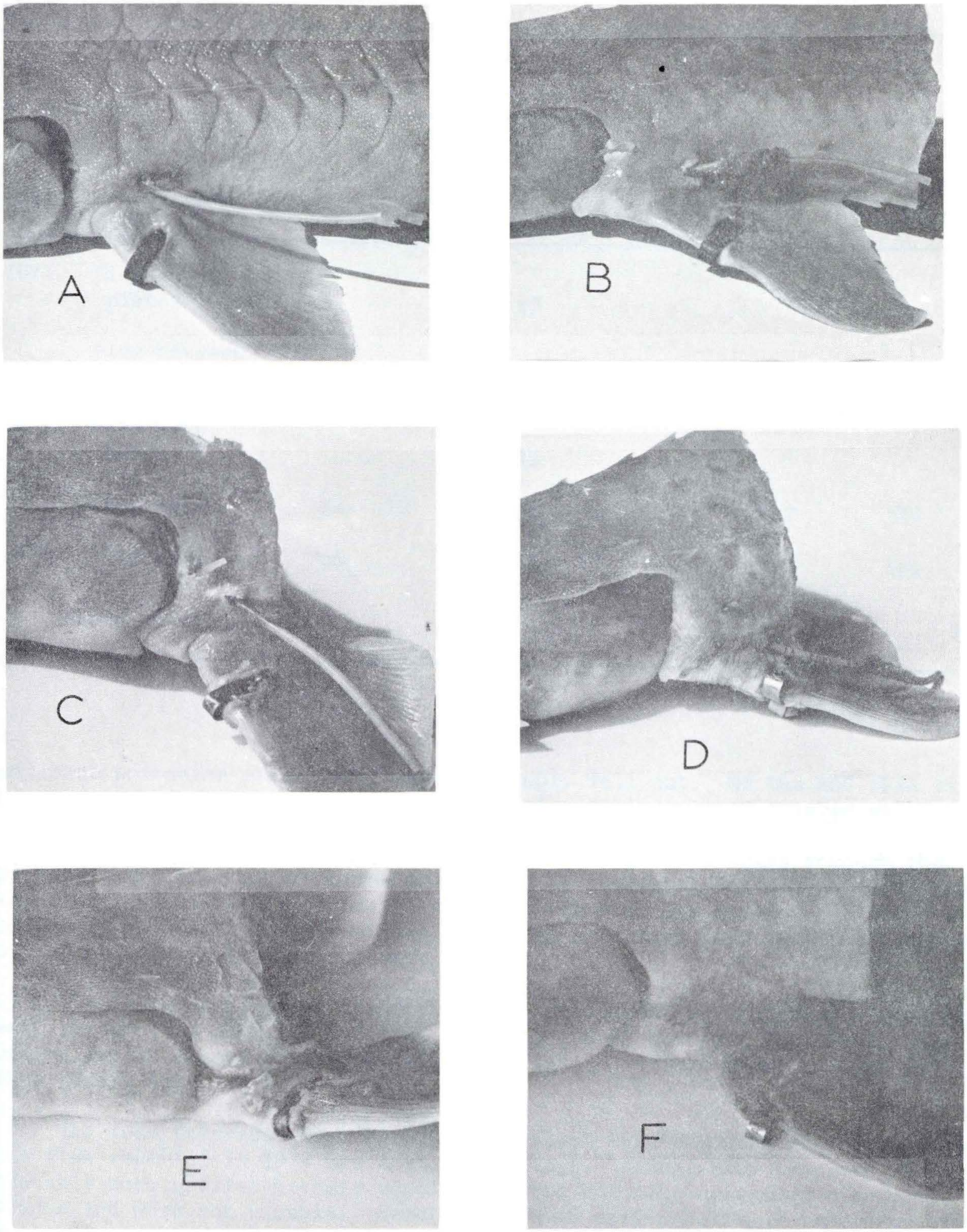
Table 14. Species composition and catch effort (C/E) of shovelnose sturgeon by trawling in various Mississippi River habitats.

Habitat	Number of tows	Number of fish		Shovelnose sturgeon	Channel catfish	Mooneye	Minnow	Freshwater drum	Pike perch
Main channel	107	174	%	45	21	7	6	6	1
			C/E	.7	.3	.1	.1	.1	a
Main channel border	203	325	%	24	13	18	19	4	5
			C/E	.4	.2	.3	.3	.1	.1
Side channel	3	4	%			25	50	25	25
			C/E			.3	.7	.3	.3
Total	313	503	%	31	15	14	15	5	4
			C/E	.5	.2	.2	.2	.1	.1

Table 14. (Continued).

Ha Habitat	Number of tows	Number of fish		Carpsucker	Buffalo	Flathead catfish	Others	Combined
Main channel	107	174	%	2	10	1	2	101
			C/E	a	.2	a	a	1.6
Main channel border	203	325	%	8	4	3	3	101
			C/E	.1	.1	a	a	1.6
Side channel	3	4	%					100
			C/E					1.3
Total	313	503	%	6	6	2	2	100
			C/E	.1	.1	a	a	1.6

[a]Less than .05 C/E.



Tag loss was a serious problem with shovelnose sturgeon. The photograph depicts various stages of tag retention. Photograph A is 72 days after tagging, B is 149 days, C is 378 days, D is 751 days, E is 693 days and F is 768 days.

Table 15. Summary of the number of shovelnose sturgeon tagged in Mississippi River pools.

		Pool										
Year	Tag placement	9	10	11	13	14	15	16	17	18	19	Total
1971	Floy above plates				447							447
	Floy between plates	108		108	388	27	1	37	97	3	121	890
1972	Floy plus monel				502							502
	Floy only	34	12	14	331				117		105	613
1973	Floy only	65		104	433	14			102		101	819
	Grand total											3,271

adjacent posterior plate until the tag simply fell out. Of the 890 fish tagged by this method, only 49 were recaptured. The maximum time at large was 322 days.

Tagging in 1972 was altered by inserting Floy anchor tags through the pectoral girdle. Tag retention was tested by placing a No. 3 monel wing band tag over the anterior rays of the pectoral fin near its base on the first 502 marked fish. Initial observations indicated both tags hold quite well and use of the monel tag was discontinued.

Eighty-three (17%) of these fish were subsequently recaptured. Both tags were retained by 81%; 12% had lost the Floy and 6% had lost the monel. Although others surely passed unnoticed, only one fish (< 1%) was known to have lost both tags (Table 16).

Tag loss increased rapidly after the first twelve months and nearly half the fish reported in 1974 had lost anchor tags. Actual Floy tag loss was probably much greater because monel tags were becoming overgrown with body tissue and were not visable. Hence, fish with only monel tags remaining were being missed by fishermen. The author examined one tagged fish on October, 1974 and obtained body measurements. Upon checking records, it was discovered the fish had also been tagged with a monel band. Further examination of the fish revealed the tag had become completely encased with skin tissue and appeared as a raised area on the fin.

Table 16. Rate of tag loss among 83 recaptured shovelnose sturgeon tagged with Floy anchor tags in combination with monel wing band tags during 9 May-12 July, 1972.

Time period	Number of recaptured fish	Tag status: Both present	Floy missing	Monel missing	Both missing
May-June, 1972	37	37 (100%)			
July-December, 1972	13	12 (92%)	1 (8%)		
January-June, 1973	7	6 (86%)		1 (14%)	
July-December, 1973	14	6 (43%)	4 (29%)	4 (29%)	
January-June, 1974	6	4 (67%)	2 (33%)		
July-December, 1974	6	2 (33%)	3 (50%)		1 (17%)
Total	83	67 (81%)	10 (12%)	5 (6%)	1 (1%)

The manner in which tags were shed from the pectoral girdle are depicted in photographs of preserved specimens. Observe the location of the T-anchor of the Floy tags as they drifted posteriorly. Scars from lost tags were readily identifiable. Caddis fly cases were often heavily encrusted on the tube and had to be removed to facilitate identification of the serial number. Overgrown flesh was also removed from monel tags. The last number digits were sometimes difficult to read and resulted in error by fishermen reporting tag numbers.

Both Floy and monel tags continue to be returned at this time. The greatest amount of time at large was 887 days for a speciman carrying both tags. Both were anchored securely.

Tagging by the Floy-pectoral girdle method was concluded to offer reliable data only during the first year. After that, loss was significant and may result in error exceeding 50%. Monel tags placed on the pectoral fin appear to hold well, but required close examination because of overgrown tissue after the first year.

MOVEMENT OF TAGGED FISH

Movement data were obtained from 279 recaptured shovelnose sturgeon. Experimental netting resulted in the recovery of 122 and the remainder were obtained from commercial fishermen. All fish except one were captured in the same pool where tagging occurred. Movements of tagged fish in upstream and downstream directions were nearly equal and 15.6% were recaptured at the site of original capture. Mean upstream and downstream distances were 1.6 and .5 miles (Table 17).

Movement of 155 sturgeon recovered by commercial fishermen differed considerably from those recovered by experimental netting. Sixty-six percent moved upstream, 25% moved downstream and 9% were taken at the tagging site. Mean upstream and downstream distances were 9.5 and 1.2 miles (Table 18). Movement calculated from the commercial fishermen recovered tags were biased by the high proportion of returns from Pool 13 where the major commercial fishing grounds are located a substantial distance upstream from the primary marking and release site.

Distance did not increase significantly with time at large for either source of recapture, but movement patterns differed during the final year of study. During the first two years, all fish were recaptured in the pool in which they were tagged, but from 1 July, 1973 through 30 June, 1974, 25 were recaptured in pools other than where they were tagged. One was by experimental netting and two were by sport fishermen. The remaining 22 resulted from commercial fishing. In every instance, inter-pool movement was in an upstream direction. Greatest distance traveled was 120 miles by 4 fish moving from Pool 13 to Pool 9. They were recaptured 265-724 days after tagging. Movement between pools from commercial recovered fish are presented in Table 19.

Upstream movement between pools may be explained by habitat distribution within pools. Upstream portions are generally more lotic, particularly in the tailwater. Since sturgeon apparently prefer stream to lake conditions, they tend to congregate in these areas. During high water years, such as 1973, the dam control gates are out of operation much of the time and are not barriers to upstream movement. Once in the lentic environment above dams, sturgeon probably continue to wander seeking the upstream lotic waters.

POPULATION ESTIMATES

Two population estimates based on the Schnabel method (Rounsefell and Everhart, 1958) were conducted in Pool 13 near Bellevue. The first was based on 43 recaptured fish of 835 tagged in 1971 by the two tagging methods previously described. Estimates initially stabilized between 6,000 and 7,000, but increased to 13,000 by the end of the 1971 fishing season (Table 20).

Recruitment, emigration of tagged fish, tag loss and mortality are possible explanations for the increase. Since recruitment was minimized by adjusting for growth, and tag returns initially indicated little movement, the increasing estimate was attributed mostly to tag loss and mortality of tagged fish. Seven sturgeon were recaptured with identifiable scars or lesions where tags had been

Table 17. Movement of tagged shovelnose sturgeon recaptured by commercial fishing.

		Time at large in days								Number returned in year			
		1	2	4	8	16	32	64	128	1st year	2nd year	3rd year	Combined
Upstream	Number	1	5	7	5	7	2	12	36	74	26	2	102
	Mean distance (miles)	1.0	1.5	1.7	3.0	3.8	12.2	3.2	15.6	7.9	14.8	1.5	9.5
	Percent	33.3	71.4	77.8	100.0	46.7	13.3	100.0	63.2	60.7	83.9	100.0	65.8
Downstream	Number					4	13		20	37	2		39
	Mean distance (miles)					3.1	.3		1.7	1.1	3.2		1.2
	Percent					26.7	86.7		35.1	30.3	6.5		25.2
No movement	Number	2	2	2		4			1	11	3		14
	Percent	66.7	28.6	22.2		26.7			1.8	9.0	9.7		9.0
	Total	3	7	9	5	15	15	12	57	122	31	2	155

Table 18. Movement of tagged shovelnose sturgeon recaptured by experimental netting.

		Time at large in days								Number returned in year		
		1	2	4	8	16	32	64	128	1st year	2nd year	Combined
Upstream	Number	6		1	9	8	4	3	16	47	3	50
	Mean distance (miles)	.2		.2	.2	.6	.2	.4	.7	.4	20.7	1.6
	Percent	22.2		25.0	50.0	57.1	33.3	33.3	55.2	41.2	37.5	41.0
Downstream	Number	17		2	4	3	7	6	10	49	4	53
	Mean distance (miles)	.2		.3	.3	1.1	.3	.5	.5	.5	.2	.5
	Percent	63.0		50.0	22.2	21.4	58.3	66.7	34.5	43.0	50.0	43.4
No movement	Number	4	1	1	5	3	1		3	18	1	19
	Percent	14.8	100.0	25.0	27.8	21.4	8.3		10.3	15.8	12.5	15.6
	Total	27	1	4	18	14	12	9	29	114	8	122

Table 19. Interpool distribution of tagged shovelnose sturgeon recaptured by commercial fishing.

Pool	Total number tagged	Total number recaptured	Percent recaptured	Number recaptured in pool										
				9	10	11	12	13	14	15	16	17	18	19
9	207	16	7.7	16										
10	12	0	0											
11	226	10	4.4		1	9								
13	2,101	102	5.0	2	1	2	9	88						
14	41	2	4.9						2					
15	1	0	0											
16	37	1	2.7								1			
17	316	49	15.5								3	46		
18	3	0	0											
19	327	15	4.6								1	2	1	11
Sum	3,271	195		18	2	11	9	88	2		5	48	1	11

Table 20. Population estimates of shovelnose sturgeon based on tagged fish recovered within a four mile segment of river in Pool 13 near Bellevue, 1971.

Date	Number captured	Number marked	Number recaptured	Population estimate	95% Confidence interval Lower limit	Upper limit
June						
24	16	13	2	672	282	∞
28	47	47	0	2,951	1,237	∞
29	117	115	2	5,688	2,872	284,387
July						
6	16	15	1	5,379	2,867	43,519
7	1	1	0	5,433	2,896	43,962
8	5	5	0	5,709	3,042	46,187
9	7	7	0	6,100	3,251	49,359
12	3	3	0	6,273	3,343	50,752
13	58	50	6	4,380	2,753	10,705
14	152	98	8	5,256	3,626	9,548
15	53	45	4	5,351	3,799	9,048
16	55	53	2	5,986	4,300	9,845
19	8	7	1	5,920	4,277	9,617
30	14	14	0	6,212	4,488	10,092
August						
2	15	14	1	6,292	4,569	10,103
10	5	5	0	6,398	4,645	10,272
11	67	61	3	7,044	5,188	10,969
16	3	2	1	6,878	5,088	10,615
27	11	1	1	6,883	5,112	10,532
September						
8	34	34	0	7,561	5,616	11,569
20	45	44	1	8,248	6,150	12,520
28	86	0	2	9,537	7,163	14,261
October						
14	112	109	4	10,615	8,079	15,469
15	27	2	1	10,906	8,326	15,803
29	94	0	3	11,953	9,203	17,048
November						
4	41	0	0	12,741	9,809	18,172

lost. Some were difficult to recognize by mid-August and probably some were overlooked.

The second estimate was based on 22 recaptured fish from the 502 double tagged fish in 1972. No tag loss was noted the first year from using this method and population estimates ranged as high as 19,622 with a final estimate of 16,870. Confidence limits (α = .05) were 11,899 and 28,978 (Table 21).

The higher 1972 estimate resulted largely from expanding the fishing grounds. Tagging during 1971 was conducted throughout a 4-mile stretch of river downstream from the Bellevue lock and dam, while fishing effort in 1972 extended 10 miles downstream from the dam.

GROWTH OF TAGGED FISH

Growth of recaptured sturgeon was difficult to evaluate because growth rate in length varied considerably by body size and season. All sizes were tagged and recaptured throughout the year.

Growth data were obtained from 107 sturgeon recaptured by experimental netting and commercial fishermen. Most were recovered in Pool 13. Results were tabulated by body length at time of tagging and weeks at large (Table 22). Calculated weekly growth increments between time of tagging and recapture were .23, .13, .17, .08, .06, .05 and .08 inches for fish at 2 inch intervals ranging 10-24 inches FL. Fish at large over the winter months were excluded from calculations. Small sample size precluded interpretation of seasonal growth.

AGE AND GROWTH OF SHOVELNOSE STURGEON IN POOL 13

Aging technique. Age structure of shovelnose sturgeon populations were vital to several biological parameters. Although aging techniques using sectioned bony structures have been widely used for other species of sturgeon (Cuerrier, 1951; Cuerrier and Roussow, 1951; Probst and Cooper, 1955), their reliability for shovelnose sturgeon has never been evaluated. Anterior pectoral fin rays are most often used in aging lake sturgeon. The validity of age marks in fin rays of this species was reported by Probst and Cooper (1955).

Zweiacker (1967) used anterior pectoral fin rays to determine the age of 288 shovelnose sturgeon from the Missouri River. Ages ranged from 8 to 27 years and fork length (FL) ranged from 48 to 55 cm (18-22 inches).

Fogle (1963) used sectioned pectoral rays to age and calculate prior growth of 35 shovelnose sturgeon from Oahe Reservoir, South Dakota. Sturgeon in this study ranged from 3 to 10 years of age and ranged in size from 18 to 23 inches total length (16-20.5 FL).

The studies of Zweiacker (1967) and Fogle (1963) did not contain young fish and both lacked means of verifying age.

Specimens for computation of age and growth statistics were collected from 29 October-5 November, 1971 from Pool 13. Anterior fin rays were removed and body measurements recorded from 110 fish. Fin rays were air dried in coin envelopes and sectioned with an electric sectioning saw. Sections measuring < .5 mm in thickness were cut approximately 12 mm from the basal joint and were mounted between microscope slides and moistened with alcohol for examination.

Table 21. Population estimates of shovelnose sturgeon based on double tagged fish recovered within a 10 mile segment of river in Pool 13 near Bellevue, 1972.

Date	Number captured	Number marked	Number recaptured	Population estimate	95% Confidence interval Lower limit	Upper limit
June						
5	64	50	1	8,256	2,789	∞
6	109	93	2	9,256	4,342	∞
12	39	27	0	12,791	6,002	∞
13	47	28	1	13,107	6,619	655,350
14	39	25	1	13,036	6,947	105,470
16	120	82	1	17,903	9,946	89,517
21	25	19	1	16,896	9,707	65,127
27	37	15	3	13,503	8,337	35,507
29	7	0	0	13,830	8,539	36,368
July						
7	49	33	2	13,437	8,582	30,942
12	27	0	1	13,443	8,710	29,446
28	24	0	1	13,342	8,756	28,013
August						
9	14	0	2	12,112	8,129	23,750
17	29	0	0	13,020	8,739	25,531
22	33	0	0	14,054	9,432	27,557
September						
15	52	0	0	15,682	10,525	30,749
11	17	0	0	16,214	10,882	31,793
19	80	0	0	18,719	12,563	36,705
22	18	0	1	18,149	12,301	34,592
October						
5	24	0	0	18,856	12,780	35,941
12	26	0	0	19,622	13,300	37,401
19	12	0	1	18,866	12,905	35,060
November						
2	30	0	4	16,119	11,369	27,688
15	16	0	0	16,483	11,626	28,313
30	17	0	0	16,870	11,899	28,978

Table 22. Mean growth increments of shovelnose sturgeon between the time of tagging and recapture by size structure and time at large. Sample size is listed in parenthesis.

Weeks at large	Number of fish	Fork length in inches at tagging 11	13	15	17	19	21	23	25 & over
1	33	.2 (5)		.3 (2)	.1 (3)	.1 (7)	.1 (11)	.2 (5)	
3	28			.3 (3)	.2 (1)	.1 (11)	.0 (8)	.2 (5)	
5	7				.4 (2)		.1 (3)	.1 (2)	
7	2					.4 (1)	.6 (1)		
9	3		1.2 (1)	1.1 (1)				.5 (1)	
11	3						.3 (3)		
13	1				1.0 (1)				
15	1	3.8 (1)							
17	1					.8 (1)			
19	1						.1 (1)		
21	3					.8 (1)	.2 (1)	.1 (1)	
23	0								
25	2						.5 (2)		
27	0								
29	0								
31	1		1.2 (1)						
33	2						.5 (2)		
35	5					1.1 (1)	.9 (2)	.6 (2)	
37	2						.9 (1)		.2 (1)
39	3						.5 (3)		
41	0								

Table 22. (Continued).

Weeks at large	Number of fish	Fork length in inches at tagging 11	13	15	17	19	21	23	25 & over
43	4		2.9 (1)		1.2 (2)				.1 (1)
45	4		3.6 (1)			1.4 (2)		.6 (1)	
47	1					.9 (1)			
Mean increment per week[a]		.23	.13	.17	.08	.06	.05	.08	

[a]Fish at large over the winter months were excluded from calculations.

Criteria used in assigning ages were similar to those described by Cuerrier (1951). Fin sections were examined and aged with a 10X dissecting microscope by one person then aged by a second person with a microprojector. Values were subsequently compared and a common age determined. Back calculation of FL at the end of each year of life was accomplished with a direct proportion nomograph with the intercept set at 0, 0.

Validity of annuli at true year marks. Validity of annuli as true year marks was established by comparing assessed age of individual fish with the sample length frequency distribution (Table 23). Samples not fitting into the length frequency distribution were re-examined. Although false annuli caused some initial error, with experience most year marks were easily identified and no samples were eliminated because they could not be interpreted.

Biweekly length frequency distributions of earlier 1971 catches (Table 24) supported validity of annuli. Growth of the smallest group could be traced from the first fish measuring 2.2 inches captured 24 June through the last biweekly sample when the range was 7.4-9.9 inches. These were identified as age 0 by the spine sectioning technique. Distribution of this group did not overlap with the next in any of the biweekly samples. Ages I and II, however, were superimposed toward the end of the season, and subsequent age groups became progressively more difficult to separate by the length frequency distribution.

Growth in body length and weight. Fork length of the sample ranged from 7.4 to 23.7 inches and weight ranged from .06 to 2.02 lbs. Sexes were combined because only two mature fish were included in the sample. Both were males and measured 22.0 inches. Mean fork lengths at the time of capture were 8.9, 13.7, 18.9 and 22.0 inches for ages 0, I, II, and III (Table 25). Calculated annual growth increments were 8.2, 5.8 and 4.7 inches.

Table 23. Length frequency distribution of 110 aged shovelnose sturgeon collected from Pool 13, 29 October-5 November, 1971.

Class mark (FL)	Age group 0	I	II	III	Combined
7.5	1				1
8.5	2				2
9.5	6				6
10.5					
11.5		2			2
12.5		12			12
13.5		20			20
14.5		16			16
15.5		8			8
16.5			1		1
17.5		1	4		5
18.5			9		9
19.5			3		3
20.5			4	4	8
21.5			1	5	6
22.5				8	8
23.5				3	3
Total	9	59	22	20	110

Table 24. Length frequency distributions of shovelnose sturgeon from Pool 13, 1971.

Class mark (FL)	Date of sample 4/18	5/2	5/16	5/30	6/13	6/27	7/11	7/25	8/8	8/22	9/5	9/19	10/3	10/17	10/31
1.5							1								
2.5					1										
3.5							13								
4.5							3	1							
5.5									4						
6.5												2			
7.5												5	4		2
8.5	1											7	4		2
9.5					2		1					2	1		5
10.5					10	6	16					2	1		
11.5				2	4	3	17	1	6			3	4		1
12.5					2	1	20	2	7		6	29	9		17
13.5		1				1	1		1		4	40	15		23
14.5					1	1	3					18	18		18
15.5	3	3		2	2	5	6	1	1		1	4	5		6
16.5	1	2		13	4	14	26	3	5		3	2	2		2
17.5	1			7	10	14	34	1	11		2	10	6		3
18.5	4	5		16	11	14	35	2	5		2	17	11		13
19.5	12	11		30	21	44	64	3	13		6	6	7		6
20.5	11	3		23	11	56	63	7	13		3	10	8		7
21.5	5	6		14	10	17	25	6	6		4	18	13		5
22.5	1	5		3	4	8	4		3		2	7	2		11
23.5	2	5		2	1	2	2					3	4		3
24.5	3	6		3	2	2	1		2			1			
25.5		3		1		1									
26.5	1	2		1		1						2			
27.5	1	1					1						1		
28.5	1	2													
29.5		1			1								1		
30.5		1										1			
31.5		1													
Total	47	58	0	117	96	190	336	27	77	0	33	189	116	0	124

Table 25. Calculated fork lengths (FL) and increments for each year of life for 110 shovelnose sturgeon from Pool 13.

Year class	Age group	Number	Year of life 1	2	3	4
			Growth			
1971	0	9	(8.9)[a]			
1970	I	59	7.8	(13.7)		
1969	II	22	8.4	14.4	(18.9)	
1968	III	20	8.5	14.0	18.7	(22.0)
Mean estimated FL			8.2	14.2	18.7	
			Increment			
1971	0	9	(8.9)[b]			
1970	I	59	7.8	(5.9)		
1969	II	22	8.4	6.0	(4.5)	
1968	III	20	8.5	5.5	4.7	(3.3)
Mean increments			8.2	5.8	4.7	
Sum of increments			8.2	14.0	18.7	

[a]Observed FL at time of capture.

[b]Calculated growth increment during current growing season.

The length-weight relationship for sturgeon in Pool 13 was computed from the logarithmic transformation of the exponential function $W = CL^n$, where W was weight in lbs and L was fork length in inches. The equation $\log_{10}W = -4.292 + 3.307 \log_{10}FL$ best described the relationship. Standard deviations of the coefficients were ± .046 and ± .038, respectively. Correlation coefficient for this regression was .986. Condition factors (C) averaged 11.6 and ranged from 9 to 17.

Eighteen biweekly samples of fin rays from 1,160 fish were examined from Pool 13 during 1972. Back calculation of FL at the end of each year of life for ages I through XI from subsmaples of 461 fish was 8.3, 12.4, 16.1, 19.1, 21.3, 23.6, 25.4, 26.2, 27.6, 28.5 and 28.8 inches. Subsamples of fin rays were also examined to determine seasonal growth. No discernable growth occurred until mid-May with greatest growth occurring in June, July and early August. After this time sampling error masked true growth rate (Table 26).

Table 26. Cumulative growth increments for shovelnose sturgeon of ages I-V at biweekly samples in Pool 13. Figures in parenthesis represent sample size.

	Age									
Date	I		II		III		IV		V	
4/5			0	(1)	0	(3)	0	(9)		
4/19			0	(2)	0	(2)	0	(7)		
5/3	0	(1)			0	(2)	0	(18)		
5/17	.9	(2)	0	(7)	0	(2)	0	(8)	0	(1)
5/31	1.5	(9)	0	(1)	0	(5)	0	(4)		
6/14	2.2	(11)	1.7	(5)	1.1	(4)	.4	(4)		
6/28	3.2	(15)	1.8	(4)	1.5	(4)	1.4	(5)		
7/12	3.5	(6)	3.5	(4)	1.8	(3)	2.8	(3)		
7/26	3.6	(2)	2.5	(10)	2.1	(4)	2.0	(2)		
8/9			3.4	(3)	2.5	(4)	2.2	(3)		
8/23			4.2	(10)	3.5	(14)	2.6	(13)	1.9	(1)
9/6			4.3	(7)	3.1	(22)	3.0	(33)	2.4	(3)
9/20	5.6	(9)	4.4	(36)	4.0	(18)	2.5	(14)	2.3	(2)
10/4	4.2	(1)	3.9	(12)	4.4	(2)	2.8	(2)	3.4	(2)
10/18	5.4	(1)	4.1	(5)	2.8	(4)	3.3	(5)		
11/1	5.8	(2)	4.2	(11)	3.1	(5)	2.8	(4)	3.4	(1)
11/15	5.3	(1)	3.4	(5)	3.0	(5)	3.6	(4)		
11/29	3.3	(1)	4.6	(6)	2.7	(4)	2.8	(4)	2.4	(2)
Mean FL at last annulus	8.9	(61)	12.4	(139)	16.9	(107)	20.4	(142)	23.1	(12)

Age and growth in other pools. Age and growth was also determined for Pools 9, 10, 11, 17 and 19 from samples collected during 1972.

Pool 9 Pool 9 samples of stugeon were principally from commercial harvested fish examined at markets. Smaller fish captured for tagging studies were used for supplemental age and growth data. As a result, size distribution was disproportionately influenced to include a high percentage of fish > 20 inches FL.

The largest fish measured was 30.5 inches FL, but was not weighed. Age I-XII grand average calculated lengths at each year of life were: 8.4, 12.5, 16.1, 18.8, 20.7, 22.5, 23.8, 25.0, 25.9, 26.7, 27.1, and 27.4 inches.

Pool 10 Seventeen fish were captured in July at Pool 10. Twelve were tagged and released. Five were preserved and fin rays collected for age determination. Ages I-IV and VI were represented in the sample. Grand average calculated lengths at each year of life were 8.6, 12.9, 16.9, 19.7, 21.8 and 23.0.

Pool 11 Fin rays were taken from 17 of the 30 fish collected for tagging during September in Pool 11. Ages I-IV and VI were represented in the sample. Grand average calculated lengths at each year of life were 7.8, 12.9, 16.9, 19.5, 21.8 and 22.7 inches.

Pool 17 A sample of 117 sturgeon were captured by drifting a trammel net in Pool 17 on 28-29 September, 1972. All fish captured were weighed, measured, tagged, and the anterior pectoral fin ray removed. Two fish had tail damage from unknown causes and one was a young-of-year. Growth was computed from the remaining 114 specimens.

Length frequency by age are presented in Table 27. Although length distribution within age groups was normal, overlap between ages was sufficient to prevent verification of age from the distribution.

Table 27. Length frequency distribution by age for 115 shovelnose sturgeon collected 28-29 September, 1972 in Pool 17.

Length group	Age						
	0	I	II	III	IV	V	Combined
9-10	1						1
12-13		1					1
13-14		4					4
14-15		8					8
15-16		9	5				14
16-17			11				11
17-18			14				14
18-19			14	4			18
19-20			3	7			10
20-21			1	13	2		16
21-22				7			7
22-23				1	3		4
23-24					4	1	5
24-25						1	1
25-26					1		1
Total	1	22	48	32	10	2	115

Body condition (C) range was 9-19 and increased with body size (Table 28). Length-weight relationship was

$$\log_{10}W = -4.560 + 3.526 \log_{10}FL.$$

Standard deviations for the regression coefficients were ± .083 and ± .066. Correlation coefficient for this fit was .981.

Grand average calculated fork lengths at the end of each year of life were 8.2, 13.2, 16.9, 19.6 and 22.6 inches.

Table 28. Body condition (C) of 114 shovelnose sturgeon from Pool 17.

Length group	Number in group	Fork length (inches)	Weight (lbs)	Condition (C)
12-13	1	12.5	.18	9
12-14	4	13.7	.30	11
14-15	8	14.6	.36	11
15-16	14	15.5	.43	11
16-17	11	16.7	.58	12
17-18	14	17.6	.69	12
18-19	18	18.6	.79	12
19-20	10	19.4	.97	13
20-21	16	20.6	1.20	13
21-22	7	21.5	1.36	13
22-23	4	22.4	1.64	14
23-24	5	23.5	1.93	14
24-25	1	24.8	2.98	19
25-26	1	25.7	3.02	18

Pool 19 One hundred ten shovelnose sturgeon were captured on 26-27 September, 1972. The fish were weighed, measured, tagged, released and the right anterior pectoral fin ray removed for aging. Five fish were young-of-year. The remaining 105 were used for computation of growth.

Length frequency distribution showed considerable overlap between ages (Table 29). Condition factors (C) ranged from 10 to 18 (Table 30). Fish of similar sizes in Pools 17 and 19 had similar condition factors.

The length-weight relationship of sturgeon from Pool 19 was

$$\log_{10}W = -3.988 + 3.083 \log_{10}FL$$

Table 29. Length frequency distribution by age for 110 shovelnose sturgeon collected 26-27 September, 1972 in Pool 19.

Length group	Age 0	I	II	III	IV	V	VI	Combined
7- 8	1							1
9-10	4							4
12-13		1						1
13-14		1						1
14-15		5	3					8
15-16		1	3					4
16-17		1	4					5
17-18			3					3
18-19			7	2				9
19-20			11	16				27
20-21			2	20	1			23
21-22			1	14	1			16
22-23				3	3			6
25-26					1			1
26-27							1	1
Total	5	9	34	55	6	0	1	110

Table 30. Body condition (C) of 105 shovelnose sturgeon from Pool 19.

Length group	Number in group	Fork length (inches)	Weight (lbs)	Condition (C)
12-13	1	12.7	.23	11
13-14	1	13.5	.27	10
14-15	8	14.5	.35	11
15-16	4	15.6	.41	10
16-17	5	16.5	.62	13
17-18	3	17.8	.79	13
18-19	9	18.5	.85	13
19-20	27	19.7	1.06	13
20-21	23	20.5	1.19	13
21-22	16	21.5	1.34	13
22-23	6	22.4	1.60	14
25-26	1	26.0	3.23	18
26-27	1	26.2	3.33	18

with standard deviation for the regression coefficient of ± .167 and ± .130, respectively. Correlation coefficient for this fit was .920.

Grand average calculated fork lengths at the end of each year of life were 8.5, 13.5, 17.3, 20.2, 22.6 and 25.0.

Conversion of body length. Measurements of fork, standard and total lengths were taken from 635 fish. Fork length (FL) was measured from tip of snout to the fork in caudal fin. Standard length (SL) was measured to the tip of upper lobe of the caudal fin. Total length (TL) included the caudal filament or whip located on the dorsal lobe of the caudal fin.

The ratio SL:FL was 1.12 and did not change significantly with increased body size (Table 31). The ratio TL:FL changed as fish size increased. Small fish (FL < 8 inches) had a ratio of 1.5 while the ratio for large fish averaged 1.15 (Table 32) resulting mainly from disproportionately slower growth of the filament. The filament is highly subject to loss by injury and caused extreme variation in TL:FL ratios. As a result, TL for small fish varied ± 3 inches ($P < .05$), and large fish varied ± 2 inches.

Summary of age and growth. Total sample size of sturgeon examined for growth in all pools was 857. Grand average body length (FL) at each year of life was 8.3, 12.9, 16.7, 19.5, 21.8, 23.4, 24.6, 25.6, 26.7, 27.5, 28.0 and 27.4 inches for the first 12 years of life. Downstream pools generally tended to show slightly faster growth rates, but the difference between pools was not significant (Table 33).

SEXUAL DEVELOPMENT

Biweekly samples of 188 shovelnose sturgeon from Pool 13 were collected from 5 April-29 November, 1972, to determine the age and size at maturity and seasonal sexual development. Each fish was measured, weighed, and aged. Gonads were removed, measured volumetrically and visually examined for sexual development.

Testes were separated from gonadal fat, and volumes were determined both with and without the attached fat tissue. Separating the ovaries from fatty tissues was not practical, so it was included in the ovary weight.

Gonads of immature males appeared as dark yellow longitudinal bands, 1-3 mm wide on the dorsal surface of the gonadal fat and comprised 5% of the whole organ. Developing male gondads made up 15-30% of the organ, while fully developed gonads exceeded 10 mm in diameter and were equal to or greater in volume than the attached fat. Mature testes were grey color and appeared as a homogeneous mass.

In contrast, ovaries had a laminated appearance. Very small specimens were white or grey along the dorsal surface but, being laminated, were easily distinguished from testes. Eggs in developing ovaries first appeared as minute yellow specks, graded to combinations of yellow and white, white, white and black, and all black eggs. The presence of yellow or white with black eggs was commonly referred to as "salt and pepper".

Percent of body weight contributed by gonads (fat included) for the 88 males and 100 females were examined by age and period. Contribution of testes to body

Table 31. Conversion of fork length to standard length.

Length group	Number	Mean fork length	Mean standard length	Standard length/ fork length	Standard deviation of ratio (SL/FL)	95% Confidence limits
7.0- 7.9	1	7.6	8.6	1.13		
8.0- 8.9	1	8.7	9.9	1.14		
11.0-11.9	3	11.7	12.9	1.10		
12.0-12.9	5	12.3	14.1	1.15	.015	± .4
13.0-13.9	14	13.4	15.1	1.13	.019	± .5
14.0-14.9	10	14.5	16.5	1.14	.009	± .3
15.0-15.9	20	15.6	17.8	1.14	.029	± .9
16.0-16.9	20	16.5	18.8	1.14	.011	± .4
17.0-17.9	39	17.5	19.6	1.12	.027	± .9
18.0-18.9	41	18.5	20.9	1.13	.019	± .7
19.0-19.9	53	19.5	22.2	1.14	.020	± .8
20.0-20.9	56	20.5	23.4	1.14	.020	± .8
21.0-21.9	66	21.5	24.3	1.13	.024	±1.0
22.0-22.9	72	22.4	25.1	1.12	.019	± .9
23.0-23.9	61	23.4	26.2	1.12	.018	± .8
24.0-24.9	51	24.4	27.1	1.11	.023	±1.1
25.0-25.9	39	25.4	28.2	1.11	.027	±1.3
26.0-26.9	42	26.4	29.6	1.12	.018	± .9
27.0-27.9	20	27.3	30.6	1.12	.019	±1.0
28.0-28.9	14	28.4	31.5	1.11	.018	±1.0
29.0-29.9	4	29.5	33.0	1.12	.015	± .9
30.0-30.9	1	30.5	33.7	1.10		
31.1-31.9	1	31.0	34.5	1.11		
33.0-33.9	1	33.6	37.3	1.11		

Table 32. Conversion of fork length (FL) to total length (TL).

Length group	Number	Mean fork length	Mean total length	Total length/ fork length	Standard deviation of ratio (TL/FL)	95% Confidence limits
7.0- 7.9	1	7.6	10.8	1.42		
8.0- 8.9	1	8.7	13.1	1.51		
11.0-11.9	3	11.7	17.0	1.45	.193	±4.4
12.0-12.9	5	12.3	18.1	1.47	.113	±2.7
13.0-13.9	14	13.4	19.7	1.47	.126	±3.3
14.0-14.9	10	14.5	20.6	1.42	.153	±4.3
15.0-15.9	20	15.6	20.9	1.34	.102	±3.1
16.0-16.9	20	16.5	21.8	1.32	.084	±2.7
17.0-17.9	39	17.5	22.8	1.30	.076	±2.6
18.0-18.9	41	18.5	23.3	1.26	.072	±2.6
19.0-19.9	53	19.5	24.0	1.23	.055	±2.1
20.0-20.9	56	20.5	24.2	1.18	.049	±2.0
21.0-21.9	66	21.5	26.0	1.21	.049	±2.1
22.0-22.9	72	22.4	26.4	1.18	.045	±2.0
23.0-23.9	61	23.4	27.4	1.17	.038	±1.8
24.0-24.9	51	24.4	28.1	1.15	.041	±2.0
25.0-25.9	39	25.4	29.0	1.14	.049	±2.5
26.0-26.9	42	26.4	30.1	1.15	.039	±2.0
27.0-27.9	20	27.3	31.1	1.14	.027	±1.4
28.0-28.9	14	28.4	32.4	1.14	.029	±1.6
29.0-29.9	4	29.5	33.9	1.15	.033	±1.9
30.0-30.9	1	30.5	34.3	1.12		
31.0-31.9	1	31.0	34.5	1.11		
33.0-33.9	1	37.3	39.8	1.18		

Table 33. Grand average calculated fork lengths of shovelnose sturgeon at each year of life from Mississippi River pools.

Pool	Number of fish	Year of life 1	2	3	4	5	6	7	8	9	10	11	12
9	137	8.4	12.5	16.1	18.8	20.7	22.5	23.8	25.0	25.9	26.7	27.1	27.4
10	17	8.6	12.9	16.9	19.7	21.8	23.0						
11	17	7.8	12.9	16.9	19.5	21.8	22.7						
13	461	8.3	12.4	16.1	19.1	21.3	23.6	25.4	26.2	27.6	28.5	28.8	
17	115	8.2	13.2	16.9	19.6	22.6							
19	110	8.5	13.5	17.3	20.2	22.6	25.0						
Average length		8.3	12.9	16.7	19.5	21.8	23.3	24.6	25.6	26.7	27.6	27.9	27.4

weight increased with age in males through age IV and stabilized in older fish at about 6%. All age II and III males were immature. Forty percent of age IV were mature or developing. The preponderance of mature and developing fish of this age appeared after the 1972 spawning season. Only 5 age V fish were included in the samples, and 3 were immature. Three males from age VI and older were mature (Table 34).

Table 34. Size of testes expressed as percent of body weight by period and age for 88 shovelnose sturgeon from Pool 13, 1972. Sample size is in parenthesis.

	Age											
Date	II		III		IV		V		VI		VI+	
4/19			2.5	(3)	5.3	(2)						
5/3			3.6	(1)	4.7	(13)			5.8	(1)		
5/17					6.0	(6)						
5/31			2.9	(5)							5.5	(1)
6/14	1.3	(2)	5.0	(2)	4.9	(2)						
6/28			6.6	(1)	7.1	(1)						
7/12	2.6	(1)	3.8	(1)	3.4	(1)						
7/26			3.2	(2)	5.8	(1)			6.7	(1)		
8/9			3.2	(2)	3.6	(1)						
8/23			2.5	(1)	6.9	(2)						
9/6	2.3	(1)	3.3	(1)	4.2	(1)						
9/20			2.3	(1)	11.3	(1)	8.0	(1)				
10/4	2.6	(1)	2.1	(1)	6.0	(1)	9.4	(1)				
10/18	1.4	(1)	2.8	(1)	5.3	(1)						
11/1	.6	(1)	4.1	(6)								
11/15	1.9	(3)	2.2	(2)	4.8	(3)						
11/29			3.4	(5)	4.9	(1)	2.1	(1)				
Mean	1.8		3.3		6.0		5.8		6.3		5.5	
Number of fish	10		35		35		5		2		1	
Percent mature or developing	0		0		40		40		100		100	

Contribution of ovaries to body weight for ages II, III and IV was comparable to the testes. However, contrary to testes the size of female gonads continued to increase after age IV. Overall contribution to body weight was 2%, 3.3%, 6.6%, 7.5%, 11.6%, 12.5% and 15% for ages I-VII and VII+ (Table 35). The seasonal change in the ratio of ovary weight to body weight resulted from spawning.

Table 35. Size of ovaries expressed as percent of body weight by period and age for 100 shovelnose sturgeon from Pool 13, 1972. Sample size is in parenthesis.

Date	II	III	IV	V	VI	VII	VIII+
4/19	.8 (1)		3.5 (3)				
5/19		3.2 (1)	4.7 (5)				16.5 (1)
5/17		4.8 (1)	7.1 (1)			16.1 (1)	
5/31	2.5 (1)		3.7 (3)			19.9 (1)	15.0 (2)
6/14		3.0 (2)	5.1 (2)			7.3 (1)	19.8 (3)
6/28	1.4 (1)	2.9 (3)	5.4 (4)				
7/12	1.4 (2)	4.6 (2)	6.5 (2)				
7/26	1.2 (3)	4.5 (1)	8.5 (1)			6.7 (1)	
8/9	3.0 (1)	1.6 (2)	7.9 (3)		17.9 (1)		
8/23	4.0 (3)	1.8 (1)	5.6 (2)	3.4 (1)			
9/6	2.4 (1)	2.3 (2)	7.6 (4)				8.6 (1)
9/20	2.2 (2)	4.1 (2)	5.3 (2)	9.3 (1)			
10/4	2.0 (1)	3.4 (2)	8.0 (1)	5.8 (1)	7.3 (1)		
10/18	2.0 (1)	2.3 (2)	9.8 (4)				
11/1			6.0 (2)	9.5 (1)			
11/15		4.0 (1)	10.0 (1)		9.7 (1)		
11/29	1.1 (1)		8.3 (1)	9.5 (2)			
Mean	2.0	3.3	6.6	7.5	11.6	12.5	15.0
Number of fish	17	22	41	6	3	4	7
Percent mature or developing	0	0	0	17	100	100	100

All females younger than age V were immature, and only one age V fish was found with developing ova. Age VI fish contained developing ova, while ages VII and older displayed various stages of egg development. Black eggs were observed in ages VII or older from 30 May-14 June. The first spawned sturgeon was captured on 24 May (Table 36).

Table 36. Ovarian development of 20 shovelnose sturgeon of age V and older from Pool 13, 1972.

Age	Date of capture	Fork length (inches)	Weight (lbs)	Gonad weight/ body weight (%)	Development
5	8/23	25.6	2.34	3.4	Immature
5	9/20	26.6	3.36	9.3	Immature
5	10/4	26.6	2.80	5.8	Immature
5	11/1	25.7	3.39	9.5	Immature
5	11/29	26.9	3.02	11.2	White eggs
5	11/29	25.3	2.45	7.8	Immature
6	8/9	26.5	3.56	17.9	Salt & pepper
6	10/4	27.2	3.29	7.3	Salt & pepper
6	11/15	28.0	3.23	9.7	Yellow eggs
7	5/17	26.2	3.32	16.1	Black eggs
7	5/24	27.2	3.49	19.9	Black eggs
7	6/6	28.8	3.77	7.3	Spawned out
7	7/26	28.8	3.84	6.7	Spawned out
8	6/14	26.9	3.19	21.9	Black eggs
8	9/6	29.5	4.47	8.6	Salt & pepper
9	5/31	28.0	3.72	19.5	Black eggs
9	6/7	28.8	4.61	25.9	Black eggs
10	5/24	30.7	5.25	10.5	Spawned out
10	6/14	27.8	4.17	11.5	Salt & pepper
11	5/3	28.8	4.32	16.5	Black eggs

Based on these observations, it appeared initial spawning commenced for female sturgeon at age VII, while most males spawn at age V. Monson and Greenbank (1946) also examined shovelnose sturgeon size and maturity in the upper Mississippi River. They sampled 503 females and 374 males during May-September, 1946. Although age was not determined, results of their study were similar and males matured at a smaller size than females. Frequency of spawning could not be clearly determined. However, the presence of varied stages of ovarian development strongly suggest females do not spawn every year.

SIZE COMPARISONS OF GONADS

In examining gonads, it appeared in most instances the left gonad of both sexes was slightly larger than the right. As a result, size data were separated. Observations were made on 84 males and 95 females (Table 37). Comparison by a Student's t test indicated the size difference between left and right was not significant ($.10 < P < .20$). In males, the left gonad averaged 55.5% of the total volume while in females, the left gonad averaged 54.2%.

Table 37. Preponderance of size differences between left and right gonads of shovelnose stugeon.

	Male	Female
Number of fish	84	95
Left > right	76	82
Right > left	3	6
Left = right	5	7

FECUNDITY

Fecundity data were collected at commercial fish landings in Pools 9 and 13 during May and June each year. Absolute fecundity was determined from 25 ml sample counts of 24 gravid females ranging in body size from 24.2 inches FL (2.36 lbs) to 33.6 inches (6.20 lbs). Ovaries averaged 18.1% of the body weight with a range of 12.2-27.1%, and while fat was virtually absent in some, the maximum fat content was 45%.

Ova measured 87-178 per ml and total counts ranged from 13,908 to 51,217 averaging 27,592 with a standard deviation of $\pm$ 9,474 (Table 38). Ova counts increased with body size and 50% of the variation was attributable to body length. Weight accounted for 54% of the variation, slightly better than length.

The linear regression equations for fork length on ova (Figure 1) and weight on ova (Figure 2) based on the functions

$$Y = a + b\ FL$$

and

Table 38. Total egg count and ovarian-body weight ratio of 24 shovelnose sturgeon from Mississippi River Pools 9 and 13.

Date	Fork length (inches)	Body weight (lbs)	Ovary wt/ body wt (%)	Fat in gonad (%)	Number of eggs/ml	Estimated number of eggs/female
1972						
3 May	28.8	4.32	16.4	4.9	87	25,000
17 May	26.2	3.32	15.9	18.5	112	21,807
24 May	27.2	3.49	19.7	16.3	140	36,624
29 May	28.0	3.72	19.4	20.8	139	36,063
7 June	28.8	4.61	25.7	17.7	97	43,814
1973						
28 May	25.2	2.21	15.2	19.7	114	13,908
31 May	25.8	2.58	14.3	10.1	109	16,384
31 May	25.9	2.65	18.5	20.0	104	18,635
31 May	26.0	2.56	15.8	2.2	132	23,760
31 May	27.1	3.32	17.3	20.0	95	19,718
31 May	28.2	4.26	17.2	5.0	96	30,288
31 May	33.6	6.20	20.8	5.0	92	51,217
11 June	24.2	2.36	27.1	35.2	143	26,922
11 June	24.8	2.71	16.7	4.9	120	23,400
11 June	25.0	2.62	12.2	4.8	105	14,531
11 June	25.4	2.57	14.4	5.1	110	17,513
11 June	25.8	2.69	18.8	5.0	123	26,876
11 June	25.9	2.65	20.8	10.0	134	30,128
11 June	27.0	3.12	17.6	24.6	120	22,601
11 June	27.8	3.99	17.7	15.0	95	25,949
11 June	30.5	4.76	20.8	45.0	111	27,374
1974						
7 June	29.1	4.20	17.8	20.0	129	35,088
7 June	30.9	5.50	14.8	20.0	122	36,112
9 June	26.6	3.16	19.2	20.0	175	38,500
Mean	27.2	3.48	18.1	15.4	117	27,592
Standard deviation	2.22	1.05	3.4	10.5	20	9,474

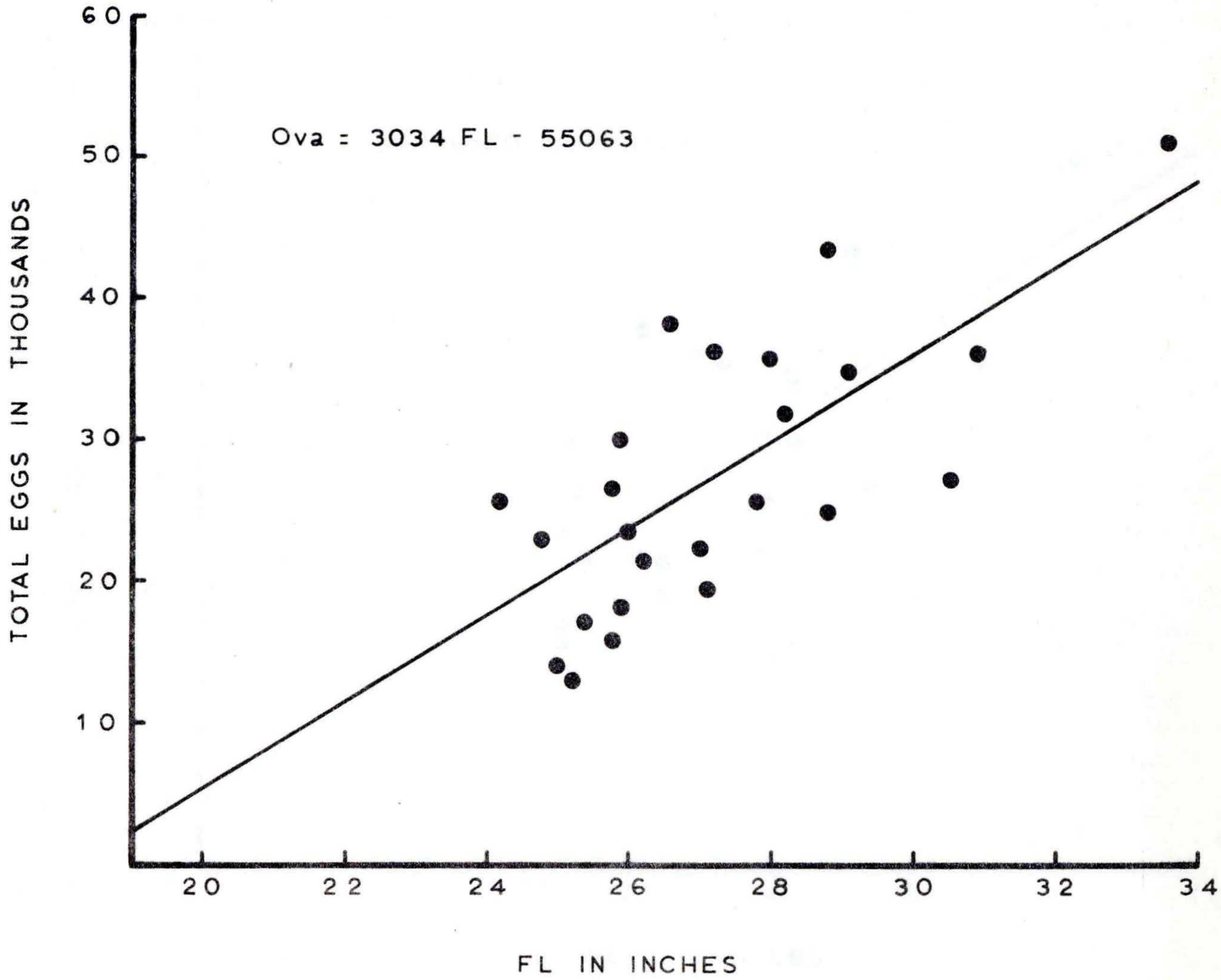


Figure 1. Regression of number of ova on fork length of shovelnose sturgeon.

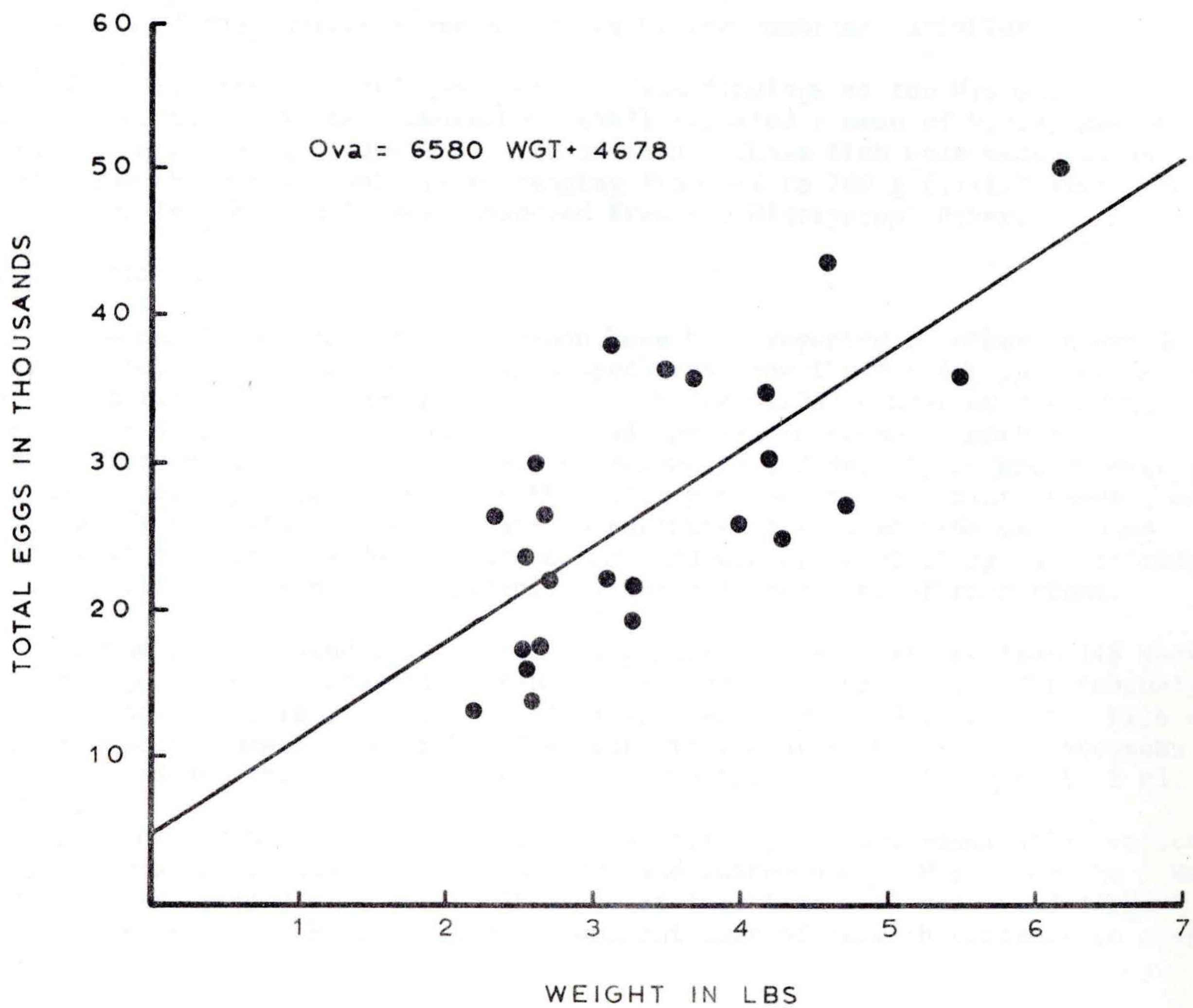


Figure 2. Regression of number of ova on body weight of shovelnose sturgeon.

$Y = a + b\ Wgt$

where Y = ova counts, FL = body fork length and Wgt = body weight were:

$\text{Ova} = 3{,}034\ FL - 55{,}063$

$\text{Ova} = 6{,}580\ Wgt + 4{,}678.$

Multiple regression of length and weight on ova ($Y = a + b_1FL + b_2Wgt$) was

$\text{Ova} = 5{,}624 - 47\ FL + 6{,}676\ Wgt.$

Again, 54% of the variation was explained by the combined variables.

These results differed considerably from findings at the Missouri River near Vermillion, South Dakota. Zweiacker (1967) reported a mean of 9,210 eggs per fish with a range of 6,709-15,637 for 30 fish. These fish were much smaller than those from the Mississippi River, ranging from 312 to 780 g (.7-1.7 lbs). No mature females this small were observed from the Mississippi River.

FOOD HABITS

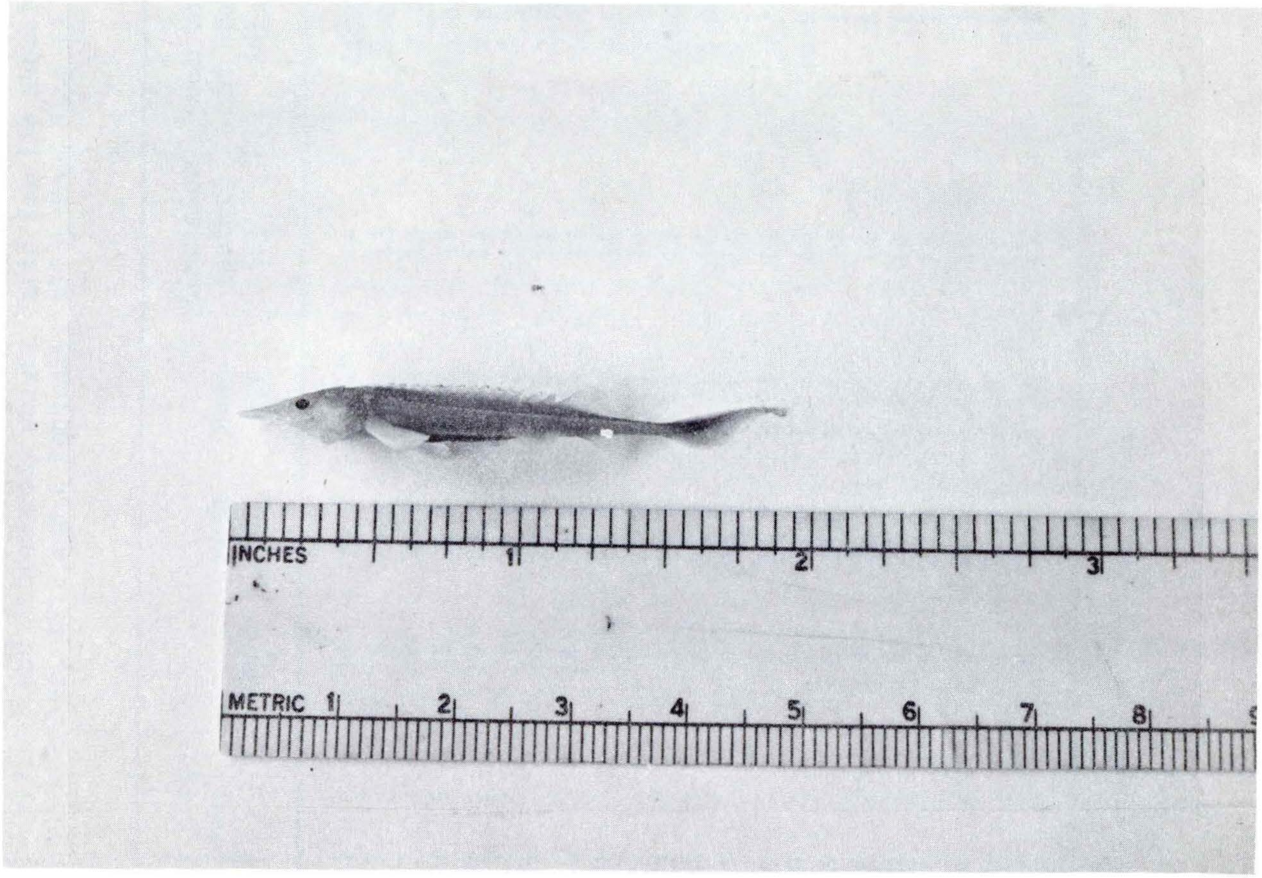
Food habits of shovelnose sturgeon have been reported by other investigators. Hoops (1960) and Held (1969) examined specimens from the Mississippi and Missouri Rivers captured during summer and autumn. Modde (1973) conducted a complete year food habit study in the Missouri River and correlated stomach contents with availability of food organisms. While chironomids, caddis flies and burrowing mayflies were reported to comprise the major portion of their diet, Modde found sturgeon to be mostly indiscriminate, opportunistic feeders. He also found highest stomach biomass during late autumn and winter attributing this to reduced water levels increasing the availability and vulnerability of food items.

In the current study, data on feeding habits were collected from 118 shovelnose sturgeon sampled biweekly during 5 April-30 November, 1972 and 6 February, 1973. Sample size ranged from 2 to 11 fish measuring 19-24 inches FL. Fish were measured to the nearest .1 inch and weighed to the nearest .01 lbs. Stomachs were removed and their contents measured volumetrcially to the nearest .1 ml.

Although stomach contents were not identified, cursory examination indicated a preponderance of caddis flies, mayflies and chironomids. Fish from the 3 May sampling were gorged with eggs. Stomachs at this time also confirmed large quantities of sand. Sand was not a prominent part of stomach contents in other samples.

Food consumption had a direct relationship to body condition. The ponderal index (C) increased from 13 to 15 in the spring. During May and early June, moderately low food consumption resulted in a drop in the C value to 12. Increased volume of stomach contents was accompanied by an increase in C to a peak value of 16 on 6 September. Beginning 22 September, food intake was markedly reduced. C decreased to 13 by 30 November and remained until 6 February, 1973 (Table 39).

Food consumption appeared to be unrelated to temperature. The first samples were taken from 11 fish captured 5 April at water temperature 36°F and averaged



The smallest shovelnose sturgeon speciman measured 1.7 inches (FL) and was collected from wing dam in Mississippi River Pool 13 by trawling 5 July, 1974.

Table 39. Volumes of stomach content (ration) and ration-body weight ratio for 118 shovelnose sturgeon sampled biweekly (5 April-30 November, 1972 and 6 February, 1973) from Pool 13.

Date	Water temperature (°F)	Tailwater stage at Bellevue TW (ft)	Number	Mean FL	Mean wgt	Condition factor (C)	Mean volume of stomach (ml)	Content/ lbs
4/5	36	12.41	11	20.7	----[a]	--	11.2	---
4/19	51	11.07	5	21.2	1.25	13	6.0	4.8
4/26	48	14.47	2	20.9	1.19	13	4.3	3.6
5/3	53	14.99	11	21.6	1.48	15	13.6	15.1
5/16	65	11.52	10	21.7	1.42	14	2.8	2.0
5/17	66	11.22	1	19.2	.82	12	1.3	1.6
5/30	74	8.27	9	20.5	1.11	13	2.3	2.1
6/13	71	7.41	4	21.3	1.29	13	1.4	1.1
6/14	74	7.69	2	21.3	1.33	14	3.5	2.7
6/27	74	6.91	7	21.9	1.44	14	4.2	3.0
7/12	74	5.52	5	21.6	1.41	14	4.4	3.1
7/28	76	7.65	6	20.7	1.21	14	4.0	3.3
8/9	70	12.57	4	22.8	1.81	15	3.5	1.9
8/22	83	8.36	5	21.9	1.53	15	6.7	4.5
9/6	71	9.10	5	22.9	1.94	16	10.9	5.7
9/22	70	6.03	6	20.6	1.24	14	.1	.1
10/5	59	12.37	4	21.2	1.36	14	.8	.6
10/19	47	7.60	5	22.1	1.55	14	.1	.1
11/2	45	9.27	5	22.1	1.55	14	.1	.1
11/15	39	11.53	3	21.9	1.49	14	.3	.2
11/30	33	6.76	6	22.1	1.40	13	.1	.1
2/6	32	8.20	2	20.9	1.21	13	.1	.8

[a] Weight was not recorded for fish sampled on 5 April, 1972.

11.2 ml per stomach. Ration varied during the summer months ranging from 1.3 to 13.6 ml through 6 September. Beginning 22 September, at a water temperature of 70° and continuing through 30 November when water temperature had dropped to 33°, food consumption was greatly lowered. Samples collected during this period contained a high proportion of fish with empty or with only trace amounts of residual material in their stomachs.

Neither was there a relationship between river discharge and food intake. High and low gage height readings were not associated with high or low volumes of stomach contents. Rather, the amount of the ratio was speculated to be controlled by availability as concluded by Modde (1973) in Missouri River populations. In the Mississippi River, food availability is probably controlled by a combination of seasonal abundance and vulnerability, competition and changing water levels.

EARLY LIFE HISTORY

Attempts were made to collect larval sturgeon each year from 1971-73 for the purpose of locating spawning grounds. Sampling in 1971 was conducted by towing a cone shaped net measuring one meter in diameter near the surface at a speed of 5 knots. Mesh size on the tow net was 12.6 meshes per cm.

Three, 5 minute upstream tows were made at each of two sites, three times a week for 10 weeks (5 May-12 July). Station M1 was located in the tailwater of Lock and Dam 12 and Station M2 was located seven miles downstream in main channel border habitat at the lower end of a one-mile long gravel bar known locally as Sand Prairie.

Meter net sampling was continued in 1972 during a 20 week period (6 April-17 August). Stations M1 and M2 were identical to those sampled in 1971. Number of samples differed as collections were made weekly rather than three times a week.

Efforts were expanded in 1972 to include bottom drift net collecting. Cone shaped drift nets 1.2 m in length with aperatures .61 x .46 m were anchored on the bottom for 10 minute periods. Mesh size of drift nets was also 12.6 meshes per cm. Three drift net stations were sampled. Stations D1 and D3 were adjacent to meter net Stations M1 and M2. Station D2 was located at the junction of main channel and main channel border habitats at the end of a submergent rock wing dike. Triplicate samples were taken weekly for 12 weeks (13 April-29 June) in conjunction with meter net sampling.

Only drift net samples were taken in 1973. Two sites at each station were sampled three times a week for six weeks (30 April-8 June). Sites D1a, D2a and D3a corresponded to Stations D1, D2 and D3 in 1972. Sites D1b, D2b and D3b were located adjacent to the sites designated as "a" but were nearer to shore. D1b and D2b were at submerged rock wing dikes.

During the three year period, 300 meter net samples and 216 drift net samples captured 88,375 larval fish (Table 40). Included were 15 identifiable genera, a composite group of unidentified minnows and suckers and an unknown group of fish. Identifiable genera were: *Aplodinotus*, (freshwater drum); *Cyprinus*, (carp); *Dorosoma*, (gizzard shad); *Esox*, (northern pike); *Hiodon*, (mooneye); *Ictalurus*, (channel catfish); *Lepomis*, (bluegill and sunfish species); *Lepisosteus*, (gar);

Table 40. Summary of meter and drift net sampling and total fish collected during 1971-73.

Sample period	Year	Number of sampling site	Type of sample	Total samples	Total fish
5 May-12 July	1971	2	Meter net	180	63,525
6 April-17 August	1972	2	Meter net	120	15,278
13 April-29 June	1972	3	Drift net	108	6,279
30 April-8 June	1973	6	Drift net	108	3,293
Grand total				516	88,375

Micropterus, (black bass); *Noturus*, (stone cat and/or madtoms); *Percina*, (log perch and darters); *Polyodon*, (paddlefish); *Pomoxis*, (black and white crappie; *Morone*, (white bass); and *Stizostedion*, (walleye and sauger).

Although no larval sturgeon were taken by either sampling techniques, 0-age sturgeon measuring as small as 1.7 inches FL were taken each year during late June near Station D2 by trawling. All successful trawl tows were rather far from shore and usually located in main channel or main channel border habitat. The most successful hauls were those associated with submerged rock wing dams and either crossed or paralleled immediately above or below.

Wing dams were also highly productive fishing grounds for adults. Their rocky consistancy apparently provided excellent habitat not only for protective cover and current diversion structure, but a suitable substrate for primary food organisms. Wing dams may also function as spawning grounds.

DISCUSSION AND RECOMMENDATIONS

Populations of shovelnose sturgeon are undoubtedly much lower today than when the Mississippi River was a natural unimpounded water course. Further indications are that in this stream sturgeon populations have probably attained an equilibrium state with the environment and seem capable of supporting a moderate commercial harvest for food fish. Numerical catch restrictions are currently unwarranted for the sole purpose of protecting populations from over exploitation by the fishery. Total annual mortality was estimated from the age structure at about 60%, but mortality from fishing ranged from 5-25% and did not affect total mortality. From these data the conclusion must be drawn that present levels of commercial harvest have no affect on sturgeon populations. According to the estimated total mortality, exploitation could be increased from two to twelvefold before changes in numerical abundance would be expected. The only indication of extraordinarily heavy harvest affecting stock in the past two decades was in the 1956-58 period when the harvest may have been a contributing factor for low catches in the early 1960's by reducing the number of mature sturgeon in certain pools to the level where year class strength was lowered.

Currently few restrictions on the harvest of shovelnose sturgeon exist in the Iowa section of the upper Mississippi River. Wisconsin maintains a 25 inch (TL) minimum length limit while Iowa and Illinois have no limits. There are no closed seasons or catch limits. Gear restrictions, although not specifically designed for sturgeon, never the less, control sturgeon harvest to some degree. Gill nets cannot be used because the large minimum mesh size renders them ineffective. Trammel nets, however, are often used as gill nets. Minimum mesh size for this gear is 2 inches (bar measure) in Iowa and Illinois and unrestricted in Wisconsin. Sturgeon fishermen generally use 2 1/2 inch mesh which allows easier fish removal.

Trammel nets used in Illinois requires immediate attendance during daylight hours. Wisconsin allows trammel net drifting only and nets can be fished only from one hour before sunrise to 30 minutes after sunset. Iowa does not restrict the method nor time for trammel net fishing. All three states have a restricted zone extending 900 ft below navigation dams, an area where sturgeon often congregate.

Though not immediately necessary as a harvest control measure, length limits have merit and would fit well into the biological aspects of the species and economics of the fishery. Age and growth studies show sturgeon grow quite rapidly until maturity. Permitting fish to approach maturity before harvest might increase both adult population level and permit the period of maximum growth rate to be completed.

Greatest market demand is for large fish. Supply, however, is nearly always insufficient to satisfy total demand and small fish are accepted. Some markets grade sturgeon and pay less for dressed fish under one pound. There is also less profit for smaller fish. Small fish may loose up to 40% during smoking compared to 25% for larger fish.

A length limit suitable for meeting these criteria is 22 inches (FL). Fish of this minimum length weight about 1.5 lbs, dressed weight about 1.05 lbs and smoked weight about .75 lbs. Male fish of this size would be approaching maturity and within two years females would mature. Both attain maximum growth rate near the end of this age.

Under present harvest conditions fish < 22 inches contribute about 54% by number but only 38% of the total harvest weight. Harvest in Pool 9 consisted of larger fish and the percentages of fish < 22 inches in that pool would be even smaller.

Vital statistics of shovelnose sturgeon at other theoretical length limits ranging from 18-24 inch FL are presented in Table 41. The percent change in the catch by number would be 3.9% at a minimum length limit of 18 inches to nearly 81% at 24 inches. By weight, the harvest would be reduced by 1.5% at 18 inches and nearly 69% at 24 inches.

Table 41. Vital statistics of shovelnose sturgeon at theoretical minimum size limits of 18-24 inches FL. Figures in parenthesis indicate confidence limits at the 95% level.

	Fork length (FL) in inches			
	18	20	22	24
Standard length (SL)	20.3 (± .7)	22.8 (± .8)	24.6 (± .9)	26.6 (±1.1)
Total length (TL)	22.0 (±2.6)	24.0 (±2.0)	26.4 (±2.0)	27.8 (±2.0)
Live weight (lbs)	.75	1.00	1.50	2.00
Dressed weight	.53	.70	1.05	1.40
Smoked weight	.33	.42	.75	.98
Age range	III-IV	III-V	IV-VI	IV-VII
Years to maturity	1-4	1-3	0-2	0-1
Percent of smaller fish contributing to harvest by number	3.9	20.2	53.7	80.9
Percent of smaller fish contributing to harvest by weight	1.5	11.2	38.5	68.9

Length limits would be more meaningful for this species if fork length or standard lengths were used rather than total lengths. Since total length includes the fragile caudal filament and is a source of considerable variation. A 22 inch (FL) fish might vary ± 2 inches in total length (24.4-28.4). The caudal filament of small fish is also longer in proportion to body length and 18 inch FL fish may measure as much as 24.6 inches (TL), overlapping in TL with a fish 22 inches (FL) having lost the filament.

Some sort of standardization of the rules governing the sturgeon fishery is most warranted at this time. By and large, Wisconsin imposes the most severe restriction on harvest by a minimum size limit. In comparison, Illinois and Iowa have few rules which actually restrict numerical harvest. Standardization would require general agreement and some changes in legal statutes and departmental rules. It appears only a strong effort by an interstate cooperating committee, such as the UMRCC, would solve the problem, and should command high priority.

Improvement of the commercial fishery reporting system remains a chronic problem despite personal encouragement to fishermen contacted during the study. Under reporting of the catch is particularly serious because it could result in overharvest while the reports show lower catch values. Most commercial fishermen are concerned about protection of fishing grounds and income tax audits. The monthly report card system initiated in the middle of this study improved accuracy considerably because a fisherman no longer must rely upon his memory for nearly a one year period. Evaluation of the improvement by use of the card system is vital for reliable catch statistics.

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Shovelnose sturgeon have in the past and perhaps shall continue to be overshadowed by larger and more spectacular sturgeon species. As a result, little research has heretofore been conducted on this species, and few references are available. A selected list of publications pertaining to the species and related subjects are therefore included with literature cited in order to help future studies of this interesting but neglected remnant.

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