Habitat use by shovelnose sturgeon in Pool 13, upper Mississippi River, Iowa

by

Gary L. Curtis

A Thesis Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

Department: Animal Ecology

Major: Fishery Biology

Iowa State University
Ames, Iowa
1990

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ABSTRACT

Habitat use and general movement patterns of adult shovelnose sturgeon in Pool 13 of the upper Mississippi River were monitored by radio-telemetry in April through August, 1988, to determine the response of this species to unusually low water conditions. A total of 217 telemetry contacts were made on 27 fish in Pool 13 during the study period. Shovelnose sturgeon only utilized about 25 percent of the available habitat in the pool. Most (94 percent) telemetry contacts were made in three habitat types; main channel (49 percent), main channel border where wing dams were present (30 percent), and tailwaters of Lock and Dam 12 (15 percent). Shovelnose sturgeon were found primarily in areas with a sand bottom, mean water depth of 5.8 m, and mean bottom current velocity of 0.23 m/sec. They tended to use areas of swifter current but were not always in the highest current velocities available. Current velocity was an important factor in determining sturgeon habitat use, although substrate type, depth, and water temperature were also important.

Tagged shovelnose sturgeon tended to remain in the upper, riverine portion of the pool, and no fish migrated into pools above or below Pool 13. Linear total range of movement of individual fish varied between 1.9 and 54.6 km.

Dispersal patterns away from the tagging site suggests that the sturgeon population in Pool 13 may consist of localized stocks.

INTRODUCTION

The shovelnose sturgeon (*Scaphirhynchus platorynchus*), smallest of the North American sturgeons (Bond 1979), is widely distributed in the Mississippi River Basin (Bailey and Cross 1954). The shovelnose sturgeon is the more abundant of the two sturgeon species in Iowa waters of the Mississippi River (Helms 1974), where the once abundant lake sturgeon (*Acipenser fulvescens*) is now rare.

Historically, shovelnose sturgeon were not regarded as a desirable commercial species but were frequently taken incidentally in fisheries for lake sturgeon, the latter sought for their eggs to be sold as caviar (Helms 1974). Today, sturgeon are in moderate demand as a commercial food fish, and are sold primarily as a whole smoked product in many towns along the river (Helms 1974). When lake sturgeon were abundant, shovelnose sturgeon were considered a nuisance and often destroyed (Coker 1930; Carlander 1954).

Commercial harvests of sturgeon in the upper Mississippi River have declined substantially since record keeping began in the late 1800s. Early harvest records did not distinguish between the two species. Combined harvests as high as 195,450 kg were recorded in the early 1890s, but had declined to less than 9100 kg by 1950 (Carlander 1954).

In 1953-1977 the harvest of shovelnose sturgeon alone averaged 21,900 kg per year with an average yearly value of approximately $11,000 (Kline and Golden 1979).

Recent lower harvests reflect a decline in shovelnose sturgeon abundance since the early 1900s (Pflieger 1975). The reasons for this decline are probably a combination of overfishing, habitat alteration, and pollution. Commercial fishing for lake sturgeon and the accompanying destruction of shovelnose sturgeon as "trash fish" may have initially reduced shovelnose sturgeon abundance. The impoundment of the upper Mississippi River in the 1930s (to permit maintenance of a navigable channel for commercial transportation) has reduced the amount of flowing water habitat. An influx of various pollutants from both point and non-point sources may have further reduced abundance. The distribution of the shovelnose sturgeon in the Missouri River system has been limited somewhat by the construction of six mainstem reservoirs (Held 1969) and impoundment of the upper Mississippi River may have also caused changes in the distribution of this species. Impoundment and manipulation of water levels in the Volga River in the U.S.S.R. is known to have adversely affected the abundance and reproduction of several species of Russian sturgeons (Yelizarov 1968; Khoroshko 1972).

Anticipated increases in barge traffic and tentative proposals to increase the minimum depth maintained in the navigation channel (Rasmussen 1979) have generated concern about the effects of navigation and channel modification and maintenance on the distribution, reproduction, and future abundance of shovelnose sturgeon. The physical habitat requirements and early life history of this species are not well known (Smith 1979). Previous studies indicate that shovelnose sturgeon prefer areas of current (Coker 1929), such as is found in the main channel and main channel border, and near wing dams (Pitlo 1981; Hurley et al. 1987). They also tend to be found in upstream, lotic areas rather than in lower reaches of the ponded river (Helms 1974).

At the present time the location and physical characteristics of spawning grounds and nursery areas used by shovelnose sturgeon in the upper Mississippi River are not known, despite preliminary efforts by Hurley and Nickum (1984). Information on habitat use in a variety of annual flow regimes is needed to document the response of this species to changes in river conditions. This would allow us to better predict the effects of increased navigation, possible future navigation projects, and variations in river flow regimes on shovelnose sturgeon habitat.

The objectives of this study were twofold: 1) determine the habitats used by adult shovelnose sturgeon in spring through early fall; and 2) describe in detail the physical parameters of habitats.

STUDY AREA

The Mississippi River extends from its headwaters at Lake Itasca, Minnesota to the Gulf of Mexico near New Orleans, Louisiana. The upper Mississippi River (UMR) has been defined by the Upper Mississippi River Conservation Committee (UMRCC) as that portion between Hastings, Minnesota and Caruthersville, Missouri, a distance of 1490 km (Rasmussen 1979). In its natural state the upper river consisted of a series of relatively deep pools separated by shallow bars and rapids and some stretches were nearly impossible to navigate at low water (Carlander 1954).

The upper Mississippi River has been subjected to significant modifications by man to improve navigation since the early 1800s. Initially these modifications were limited to removing debris from the main channel areas (Schnick et al. 1982). In 1878 the U.S. Congress authorized the development and maintenance of a 1.4 m-deep navigation channel in the upper river. To accomplish this, the U.S. Army Corps of Engineers constructed a series of wing and closing dams and bank revetments. Dredging was also done where necessary. The main channel project depth was increased to 1.8 m by Congressional authorization in 1907, and increased again in 1930 to the 2.7 m depth which is currently maintained by the Corps of Engineers

(Rasmussen 1979).

The present project depth of 2.7 m was achieved by the construction of a series of 29 large concrete dams in the 1930s to allow manipulation of river flow. The effect of these dams was to reduce the riverine nature of the upper Mississippi River to a series of large pools often referred to as "river lakes" (Rasmussen 1979; Eckblad 1986).

Pool 13 extends from Lock and Dam 12 at Bellevue to Lock and Dam 13 at Clinton, Iowa and is 55 km long, 0.5 to 6.4 km wide, and covers 11,379 hectares at normal pool (Figure 1). Mean annual flow at Lock and Dam 13 is 1,342 m^3/sec. The portion of the pool upstream from Sabula, Iowa is essentially riverine, while the lower portion is more lacustrine (Hurley et al. 1987).

A variety of aquatic habitats are found in the upper Mississippi River, and specifically in Pool 13: 1) tailwaters, a turbulent area defined as the 0.8 km long area directly below the dams; 2) main channel, where commercial navigation occurs, with a minimum depth of 2.7 m and minimum width of 122 m, usually delineated by marker buoys; 3) main channel border, the zone between the main channel and river bank; 4) side channel, departures from the main channel with current flow at normal river stage, often blocked off by diversion or closing dams; 5) river lakes and ponds, area of low flow in channel areas-usually

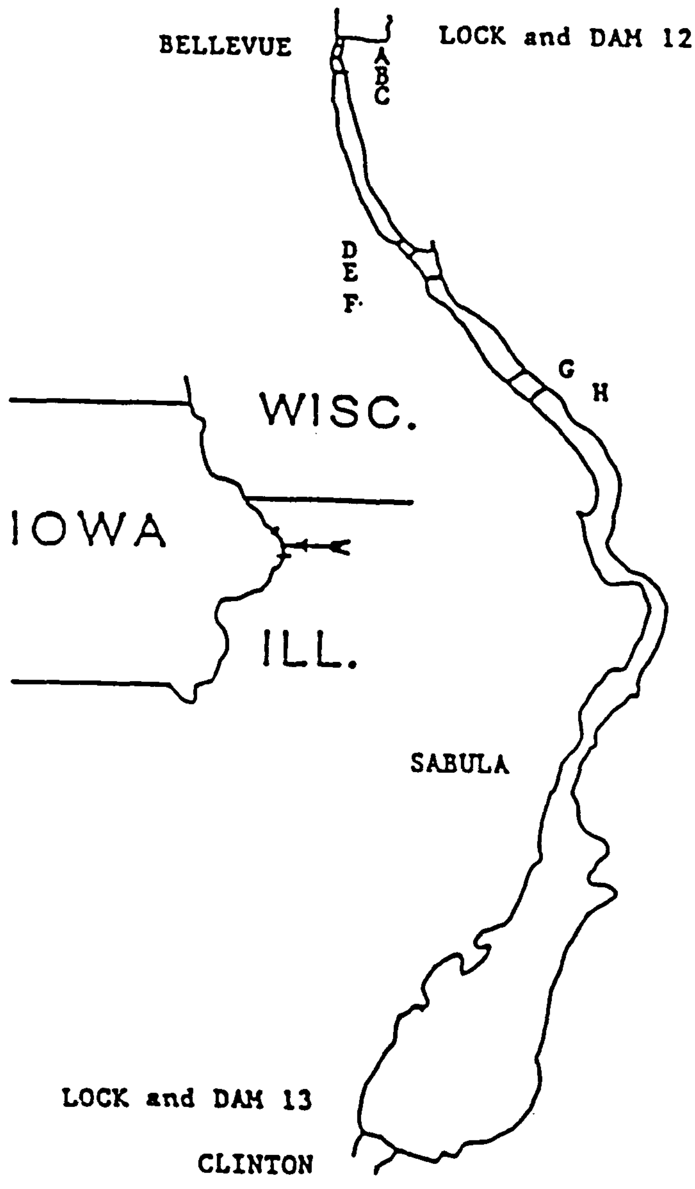

Figure 1. Location of study area and transect sampling sites, Pool 13, upper Mississippi River

directly above navigation dams; and 6) backwater lakes, areas of standing water located away from the channel area (Rasmussen 1979, Eckblad 1986). All of these general habitat types are found in Pool 13. The 0.8 km long area in Pool 13 defined by Rasmussen (1979) as tailwaters contains several distinct habitat types and was not a useful designation for this study, and I defined the tailwater as the area directly below Lock and Dam 12 to the first small wing dam on the Illinois side of the river. I also classified the main channel border as areas having or not having wing dams. At flat pool levels, available habitat in Pool 13 consists of about 0.3% tailwaters, 10.1% main channel, 4.8% main channel border with wing dams, 5.3% without wing dams, 4.7% side channel, 9.8% slough, and 64.5% lake and backwater (Hurley 1983). Extreme low flow conditions in 1988 may affect the accuracy of these estimates, but would most greatly affect the amount and accessibility of backwaters and affect the areas used by shovelnose sturgeon in this study to a lesser degree.

METHODS

Telemetry

Telemetry equipment used in this study was obtained from Advanced Telemetry Systems of Isanti, Minnesota. The antenna system consisted of a four-element Yagi antenna mounted horizontally on a collapsible three-meter conduit mast. Horizontal mounting of the antenna provided for directionality of signal reception. Receivers were compact, programmable scanning receivers powered by rechargeable batteries.

Transmitters used were of the external mounting type, powered by a high-energy lithium battery and fitted with a 25 cm antenna. Each transmitter broadcast on a unique frequency in the 48 or 49 Mhz range. Two sizes of transmitters were used: 23 small transmitters (mean weight 10 g) with an estimated transmitting life of 50-60 days, and six larger transmitters with an expected life of 300 days. Both sizes weighed less than two percent of fish body weight, the maximum transmitter weight recommended by the manufacturer. The smaller transmitters were pre-fitted with external mounting wires by the manufacturer. The six larger tags were wrapped three times with nylon-coated stainless steel wire and dipped in Plasti-Dip rubber coating compound (PDI Inc., St. Paul, Minnesota) prior to attachment.

Transmitters were attached by drilling small holes through the base of the carina of the fourth and sixth dorsal scutes. Attachment wires were threaded through and either knotted or crimped. This method of attachment has been successfully used on both shovelnose (Hurley et al. 1987) and shortnose sturgeon (*Acipenser brevirostrum*) (Buckley and Kynard 1985). Neither study reported any tag loss within a year of the initial tagging date.

Fish Capture and Tagging

Study fish were captured in stationary-set trammel nets fished overnight in the area just downstream from the tailwaters of Lock and Dam 12. Trammel nets used consisted of 10.2-11.4 cm inner mesh (stretch measure) and 76 cm mesh outer wall. Fish captured on 26 April were tagged at the point of capture. Fish tagged on 25 May were transported to a fish market holding facility in Savanna, Illinois, tagged, then hauled back to Lock and Dam 12 in a tank truck and released at the Bellevue city dock, directly across the river from where fish previously tagged were released. Fish selected for tagging were measured (fork length), weighed, and sex determined by external examination.

A total of twenty-seven shovelnose sturgeon were fitted with radio transmitters. Because of the relatively short life expectancy of the smaller transmitters and uncertainty as to the time and duration of the spawning season, tagging was done on two dates, one month apart to attempt to bracket the spawning season.

Fourteen fish were tagged on 26 April and 13 on 25 May to insure that some fish could be located through at least mid-August. Lengths of fish tagged ranged from 62.2 to 80.4 cm FL (mean= 71.5) and weights ranged from 0.91 to 2.5 kg (mean=1.65) (Table 1). Comparison of mean lengths of fish tagged on the two dates showed no significant differences (t=1.4, P=.18), so the data were pooled. One fish died immediately after tagging and was eliminated from all analyses.

To facilitate locating spawning areas, a larger proportion of mature, gravid females were tagged. Twenty two females 62.2-80.4 cm FL (mean= 71.9) and 0.91-2.49 kg (mean=1.74) and five males 70.1-74.0 cm FL (mean= 72.2) and 1.18-1.57 kg (mean=1.41) were tagged.

Sex determination was done by external examination only, and the sex of tagged fish should be viewed with caution--especially for males. Sexual dimorphism has not been documented in shovelnose sturgeon and there are no known external morphological features for sex determination. However, my sampling was conducted just prior to the spawning season and many of the larger fish

Table 2. Biological and tracking statistics of 27 shovelnose sturgeon fitted with radio transmitters, Pool 13, upper Mississippi River, 1988

Frequency (mhz)	Date Tagged	Fork length (cm)	Weight (kg)	Sex	Date of last obs.	No. obs.	Range (km)
48.540	26 April	67.3	1.59	F	29 June	15	11.8
48.561	26 April	65.5	1.43	F	18 May	8	10.8
48.580	26 April	66.2	1.40	F	29 June	14	15.4
48.620	26 April	62.7	1.23	F	26 May	12	12.1
48.681	26 April	62.2	1.35	F	9 June	13	9.7
48.719	26 April	71.1	1.87	F	12 July	14	10.5
48.800	26 April	68.7	1.58	F	14 July	16	18.2
48.820	26 April	77.2	2.31	F	7 May	4	10.2
48.841	26 April	72.4	1.57	M	18 June	14	17.1
49.028	26 April	71.8	2.27	F	5 November	24	12.8
49.139	26 April	80.4	2.38	F	5 November	20	20.0
49.438	26 April	76.8	2.13	F	23 June	13	23.6
49.639	26 April	77.8	2.49	F	5 November	24	1.9
49.778	26 April	74.8	1.97	F	5 November	17	11.8
48.460	25 May	70.1	1.41	M	1 June	2	33.5
48.489	25 May	72.5	1.55	M	1 July	4	25.6
48.521	25 May	73.0	1.59	F	26 July	6	26.3
48.530	25 May	73.3	1.82	F	1 June	3	23.2
48.612	25 May	76.8	2.27	F	22 July	6	27.8
48.631	25 May	74.0	1.18	M	2 August	6	26.4
48.659	25 May	69.3	0.91	F	2 August	7	9.4
48.710	25 May	73.1	1.41	F	24 July	7	18.1
48.739	25 May	74.2	1.59	F	1 June	3	2.5
48.870	25 May	72.1	1.36	M	9 July	4	9.0
48.932	25 May	74.6	1.50	F	18 July	6	35.1
48.951	25 May	69.0	1.36	F	12 June	4	54.6
49.522	25 May	75.5	1.82	F	5 November	11	22.5

caught in the trammel nets were very turgid in appearance, with black coloration visible through the abdominal wall. Internal gonadal examination of many other fish in the catch with this turgid appearance indicated that they contained large ovaries composed of all-black eggs of relatively large size, similar to those described by Moos (1978) for nearly ripe shovelnose sturgeon in the Missouri River. Moos (1978) stated that gravid female shovelnose sturgeon could be recognized by external inspection because the large mass of black eggs inflated the abdomen and produced an externally visible dark color. Sex determination of females based on these criteria should be reliable. Fish designated as males were usually much more slender in appearance and no darkening of the abdomen was observed. Some mature males were observed in the catch (determined by dissection) and fish designated as males in this study were very similar in appearance to these fish. Some of these fish could have been immature females, however.

Individual fish weights measured in the field were compared with weights calculated from the length-weight relation developed by Helms (1974) for shovelnose sturgeon in Pool 13: $\log_{10}$ weight= -4.292 + 3.307 ($\log_{10}$ FL), where weight was in pounds and FL was in inches. The measured weights of females tagged in the present study were significantly higher than their calculated weights ($t=4.31$, $p=.003$), while fish designated as males showed no difference between measured and calculated weights ($t=.79$, $p=.47$). Helm's length-weight relation was developed from fish sampled throughout the open-water season, thus the increased weight of the gravid ovaries in the study fish may account for the higher mean weight among females in this study.

Fish Monitoring

Sturgeon were tracked from a 6-meter boat. An effort was made to find each fish once before starting a new search cycle. Individual fish were located as often as possible (usually several times per week) but the elapsed time between telemetry contacts was an uncontrollable variable in this study. Searching was done primarily from the main channel while constantly rotating the directional antenna. When a signal was detected, gross location was determined by triangulation. More precise location was then obtained by reducing the receiver signal gain and attempting to pass directly over the fish, as determined by the consistency of the volume of the reduced signal. Each position fix was plotted on maps. Fixes in the tailwater and upper 0.8 km of the pool were plotted on 1:4800 scale hydrographic charts (U.S. Army Corps of Engineers), and all other fixes were plotted on Upper Mississippi River Wildlife and Fish Refuge maps obtained from the U.S. Fish and Wildlife Service. The time and general habitat type in which each fish was found were also recorded. An aircraft overflight of pools 12-16 was made on 11 August to attempt to locate fish suspected to have moved out of the study pool.

Habitat Sampling

Specific habitat variables were measured at systematically selected fish locations. Depth was measured with a Humminbird LCD depth finder. Current velocity was measured at 30.5 cm below the surface, at 0.6x the depth, and at 30.5 cm above the bottom with a Marsh-McBirney Model 2101 digital flowmeter. Substrate samples were collected with a Ponar dredge and substrate type classified visually as to the predominant material present. Surface water temperature was measured with a hand-held thermometer. Water temperature was recorded continuously by a Ryan recording thermograph placed just downstream from the tailwater area. Discharge data for Lock and Dam 12 was obtained from the U.S. Army Corps of Engineers, Rock Island District, Rock Island, Il. Habitat variables were measured at 72 fish locations: 15 in the tailwater area of Lock and Dam 12 and 57 in areas outside the tailwaters.

Habitat sampling for fish found in the tailwater area was done by establishing three index sites along a lateral transect that approximately bisected the defined tailwater area. The habitat variables described above were measured at each index site and collectively used to characterize the habitat for fish found in the tailwater area. These index sites were sampled throughout the study period when tagged sturgeon were found in the tailwater area. The three-site index transect was sampled eight times, five in June and three in July. To develop a composite summary of tailwater conditions, data from the three index sites along the transect were combined to characterize conditions that a sturgeon moving within the tailwaters would likely encounter. The tailwater habitat was found to be highly variable from day to day (sometimes from hour to hour) and data from fish locations there were summarized separately from other habitat types. Data from one observation in the lower tailwater area was included in summaries for the other habitat types because its location was more similar to the area just downstream from the tailwaters than the actual tailwaters. Since current velocities were extremely low and no spring flood occurred in 1988, habitat data from all areas (excluding the tailwaters) collected from 9 May to 3 August were pooled.

Habitat variables were also measured in areas adjacent to selected fish locations by sampling along across-river transects. Initially, three sites were sampled per transect, then later expanded to five sites (Figure 1). The three-site transects were done by sampling habitat variables at the actual fish location, then sampling at two additional locations, each equidistant between the fish location (marked with an anchored float) and the river bank. The five-site transects were done by sampling at the fish location, and then locating five equally-spaced locations along an across-river transect using a rangefinder (Ranging Inc., Rochester, New York). The actual fish location was substituted for the nearest of the five transect sites, and the other four sites were sampled as described. Sampling sites along transects were numbered 1-5, with the site closest to the Iowa shore designated as number 1. A total of eight across-river transects were sampled between 25 May and 3 August. Three transects (sampled on May 25 and June 27) consisted of three sample sites, and five of the transects (July 14,21,24 and August 2,3) consisted of five sites.

Data Analysis

Data were processed and analyzed using a Lotus spreadsheet (Lotus Development Corporation) on a microcomputer and the Statistical Analysis System (SAS

Institute Inc. 1985) operating on the Iowa State University NAS AS/9160 computer. A probability value of 0.05 was used as the level for rejection of the null hypothesis in all statistical tests, and actual probability values (P) are given in the text. Differences among means were tested using the PROC TTEST procedure in SAS. Measured and calculated fish weights were compared with the paired-comparison t-test using the PROC MEANS procedure. PROC REG or PROC GLM procedures were used for linear analyses.

RESULTS

River Conditions

Extreme drought conditions throughout most of the Mississippi River watershed resulted in very low flows in the river in 1988. The flow regime during 1988 was the lowest observed since the lock and dam system was completed. Mean monthly flows from March to August averaged 42% lower than the 1941-88 mean (personal communication, Clint Beckert, U.S. Army Corps of Engineers, Rock Island, Il.).

There was no spring flood in 1988 and the gates at Lock and Dam 12 remained closed throughout the open-water season. Monthly discharge rates, water temperatures (taken from thermograph readings), and river stage levels are given in Table 2. Maximum discharge levels occurred during the first week of April, and minimum flows occurred in the first week of August. Daily discharge and river stage measurements at Lock and Dam 12 are shown in Figure 2. Because of the low summer flow rates, many wing dam structures in the upper, riverine, portion of the study pool protruded above the water surface.

Movement

A total of 277 telemetry contacts on 27 fish were made between 26 April and 5 November. The number of contacts

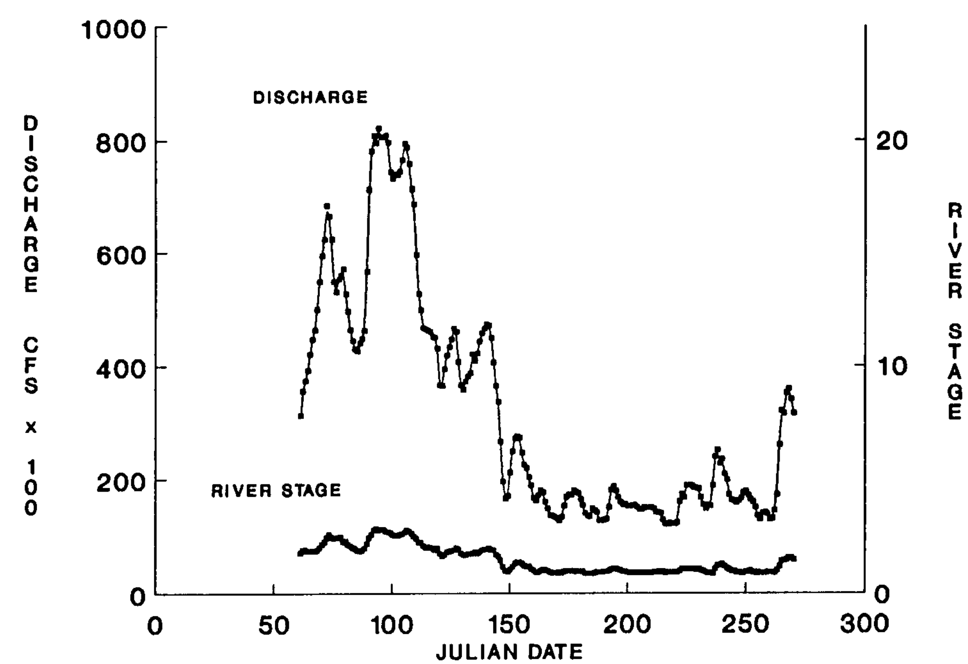

FIGURE 2. Discharge and river stage at Lock and Dam 12, upper Mississippi River, 1988

Table 2. Monthly means and ranges of discharge, water temperatures, and river stage at Lock and Dam 12, Pool 13, upper Mississippi River, April-August, 1988

Month	Discharge (CFS x 100)	Temperature (C)	Stage (m)
April	640 (364-820)	NA	2.41 (1.7-2.9)
May	372 (166-473)	18.4 (13.8-23.0)	1.68 (.98-2.0)
June	175 (128-275)	24.8 (23.7-26.1)	1.04 (.88-1.4)
July	150 (128-186)	25.6 (24.2-27.1)	0.94 (.85-1.1)
August	171 (122-151)	27.0[a] (26.4-27.9)	1.04 (.88-1.3)

[a]Mean and range for August 1-20 only.

per individual fish ranged from 2 to 24 (mean=10.3)(Table 1). There was considerable variation in movement patterns among individual fish. Rapid downstream movement of several fish (frequencies 48.460, 48.951) was observed and these fish (as well as others) may have left the study pool. However, no sturgeon were located during intermittent tracking in the pools immediately upstream and downstream from the study pool (Pools 12 and 14), or during the aircraft overflight. Detailed analyses of movement patterns in relation to river conditions were not done because of the relatively few contacts with individual tagged fish and the often large time gaps between contacts. Composite graphs depicting individual sturgeon movements in relation to discharge levels at Lock and Dam 12 are presented in the Appendix. Several sturgeon moved downstream between 26 May and 18 June, and several fish moved more than 10 km during the last week in June. These movements occurred during periods of generally declining discharge, but telemetry contacts were not made often enough with individual sturgeon to detect responses to short-term changes in flows.

Radio-tagged sturgeon showed no tendency to congregate in any area and no evidence of spawning activity was observed. No shovelnose sturgeon eggs were collected in a concomitant study to document actual reproduction by this species in Pool 13. Shovelnose sturgeon were found in areas near Lock and Dam 12 suggested by Hurley and Nickum (1984) as potential spawning areas, but it is not known if any spawning occurred.

The distance between the farthest upstream and downstream contact locations were used as a measure of the range of an individual fish. Total ranges varied between 1.9 and 54.6 km (mean=18.5)(Table 1). There were significant differences between the total ranges among fish tagged on different dates: sturgeon tagged on 26 April ranged from 1.9 to 23.6 km (mean=13.3) while those tagged on 25 May ranged from 2.5 to 54.6 km (mean= 24.1) ($t=2.83$, $P=.009$) Fish tagged on the 26 April tended to remain in areas well upstream from those tagged in late May, although some overlap was noted. There was no relation between range size and fish length ($r^2=.008$, $P=.65$) or differences between males and females ($t=.83$, $P=.41$).

General Habitat Use

Shovelnose sturgeon tagged in this study tended to remain in the upper, more riverine portion Pool 13. Only one fish (Frequency 48.951) moved to the lower, lacustrine area of the pool; its last known location was just above Lock and Dam 13 at Clinton, Iowa. Sturgeon were most often found in the main channel (49% of all contacts), but made extensive use of main channel border areas with wing dams (30%), and the tailwaters of Lock and Dam 12 (15%) (Table 3). Only limited use was made of main channel border areas without wing dams present or side channels. Sturgeon found associated with wing dam areas were often found between the outer end of the wing dam and the edge of the main channel, usually just downstream from the wing dam itself. Only rarely were they found in the area directly behind a wing dam.

Habitats were not used in proportion to their availability (Figure 3). Main channel, main channel border areas with wing dams, and tailwater areas were used in much larger proportions than they were available (Figure 3), whereas the most abundant habitat type, lake and backwater, were almost never used. Habitats used by shovelnose sturgeon in 1988 made up only 25% of all available habitat in Pool 13.

Habitat Parameters

Water depth

Sturgeon were found in a wide range of available water depths, from 2.7 to 8.2 m (mean=5.3 SE= 0.2)(Table 4). Sturgeon were found in depths ranging from 4.6 to 6.1 m more than 60% of the time (Figure 4).

Table 3. Habitat use by 27 shovelnose sturgeon fitted with radio transmitters, Pool 13, upper Mississippi River, 1988

Habitat Type	No. of Observations	Percent Available	Percent Used
Tailwater	33	0.3	15.2
Main channel	106	10.1	48.8
Main channel border with wing dam	65	4.8	30.0
Main channel border without wing dam	10	5.3	4.6
Slough	0	9.8	0.0
Side channel	2	4.7	1.0
Lake and backwater	1	64.5	0.5
TOTALS	217	100	100

Table 4. Water depth and current velocities measured at 58 shovelnose sturgeon locations in Pool 13, upper Mississippi River, May-August, 1988

Habitat variable	Mean	SE	Range
Depth (m)	5.3	0.15	2.7-8.2
Current velocity (m/sec)			
Surface	0.36	0.018	0.13-0.64
0.6x Depth	0.32	0.016	0.12-0.60
Bottom	0.23	0.014	0.0-0.52
MCV[a]	0.31	0.015	0.1-0.57

[a]Mean column velocity.

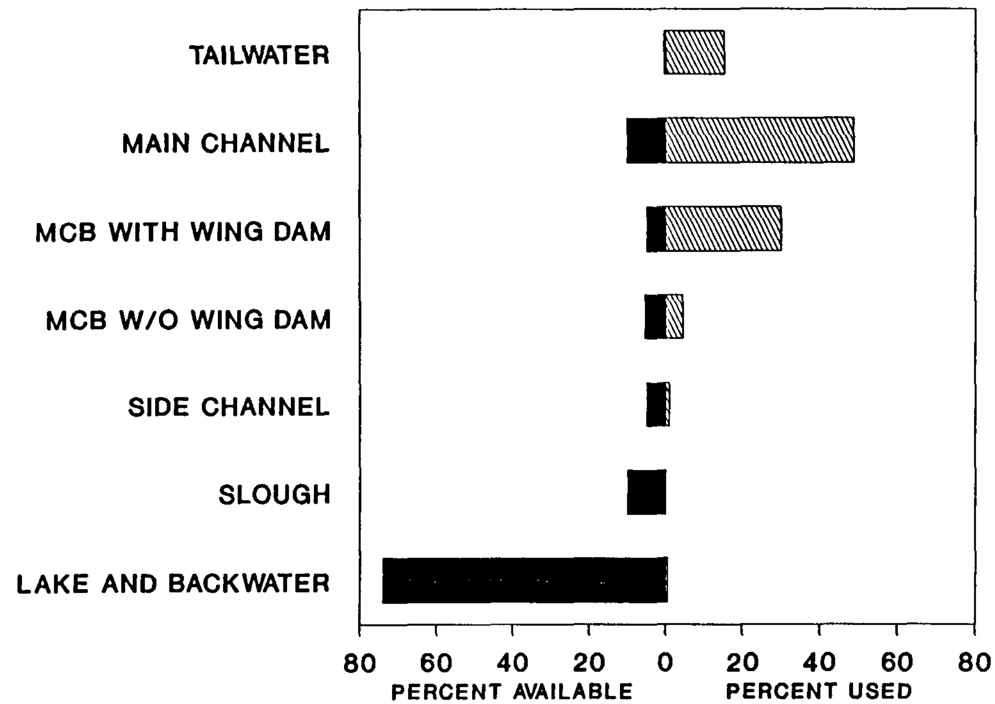

FIGURE 3. Habitat availability and use by shovelnose sturgeon in Pool 13, upper Mississippi River, May-July, 1988

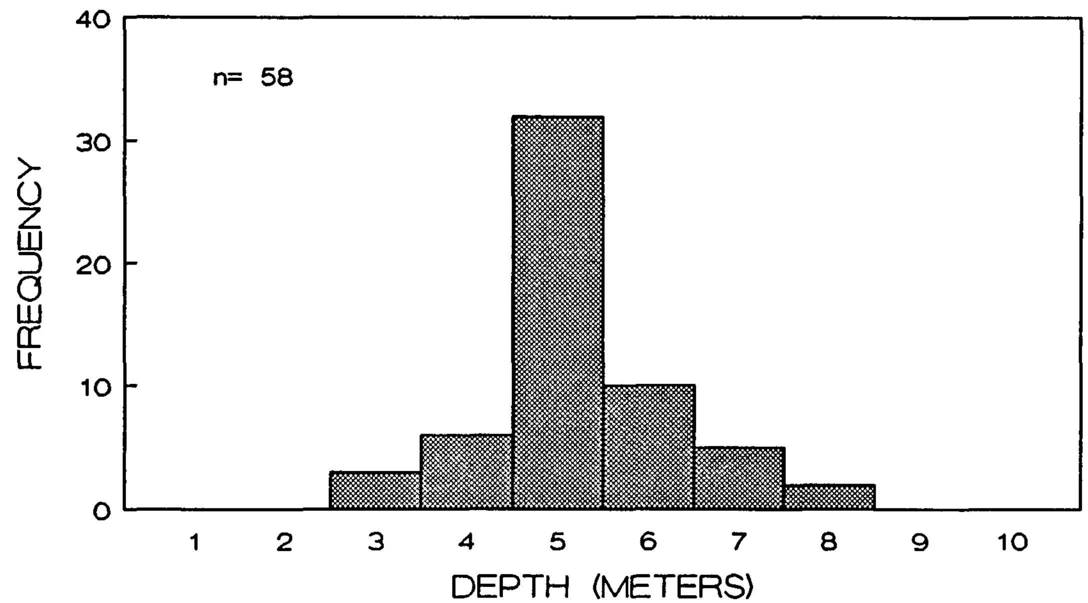

FIGURE 4. Frequency distribution of water depths used by shovelnose sturgeon in Pool 13, upper Mississippi River, May-July, 1988

Substrate type

Clean sand was the most common substrate type in areas where sturgeon were found, and 92% of all observations were made over sand bottom (Figure 5). Occasionally fish were found in areas with a mixed sand/silt substrate (3.4%) and one fish (Frequency 49.438) was sampled twice over rock and gravel substrates.

Current velocity

Surface current velocities at sturgeon locations ranged from 0.13 to 0.64 m/sec (mean=0.36 SE=0.17)(Table 4). Shovelnose sturgeon were most commonly found in areas with surface current velocities of 0.20-0.65 m/sec (Figure 6). Current velocities at 0.6x depth were slightly less than at the surface, ranging from 0.12 to 0.60 m/sec (mean=0.32 SE=.016)(Figure 7).

Bottom current velocities ranged from 0.0 to 0.52 m/sec (mean=0.23 SE=.016). Sturgeon were most commonly located at velocities of 0.20-0.45 (Figure 8). Measurements of bottom current velocities of zero or near-zero occurred at several fish locations. These measurements were likely taken behind a sand ridge (common in the main channel) or some other physical obstruction such as a sunken tree. Since it was not possible to determine the precise location of a radio-tagged fish, it was not known if an individual sturgeon was located behind

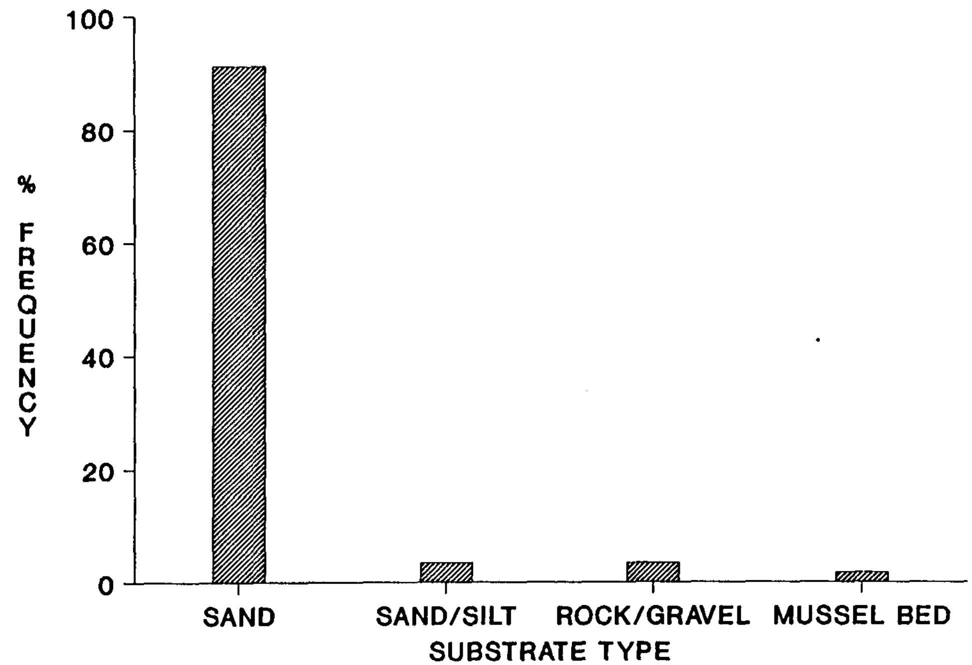

Figure 5. Frequency distribution of substrate types used by shovelnose sturgeon in Pool 13, upper Mississippi River, May-June, 1988

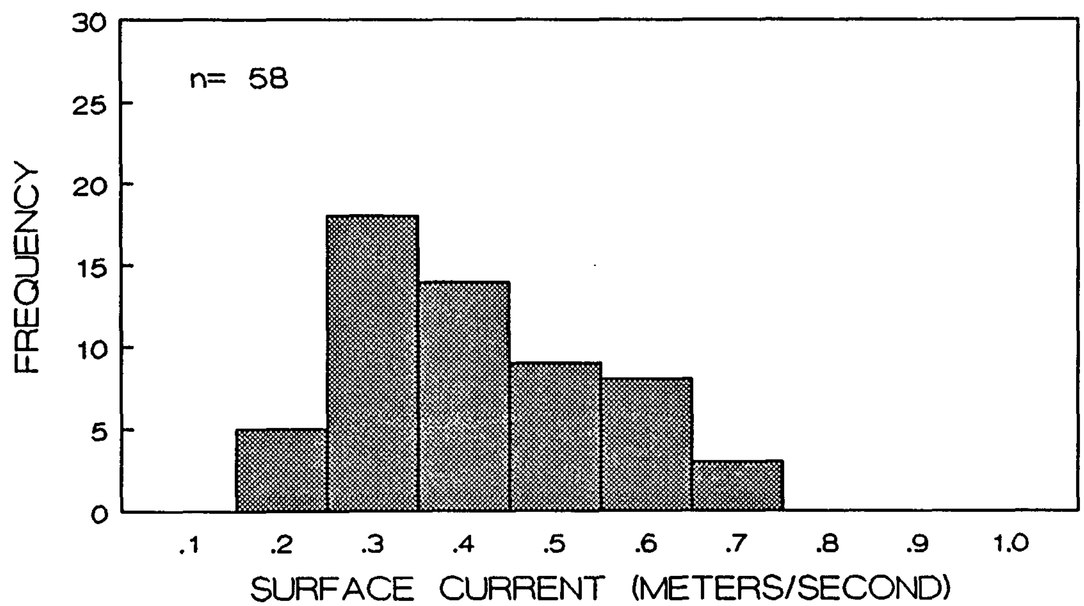

FIGURE 6. Frequency distribution of surface current velocities at sites used by shovelnose sturgeon in Pool 13, upper Mississippi River, May-July, 1988

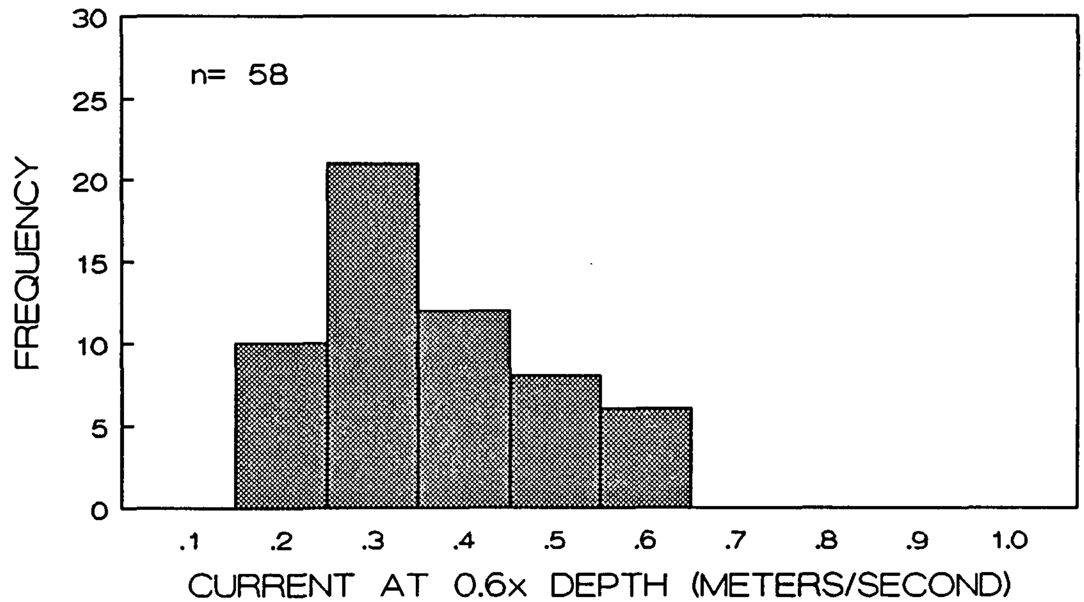

FIGURE 7. Frequency distribution of current velocities at 0.6x depth at sites used by shovelnose sturgeon in Pool 13, upper Mississippi River, May-July, 1988

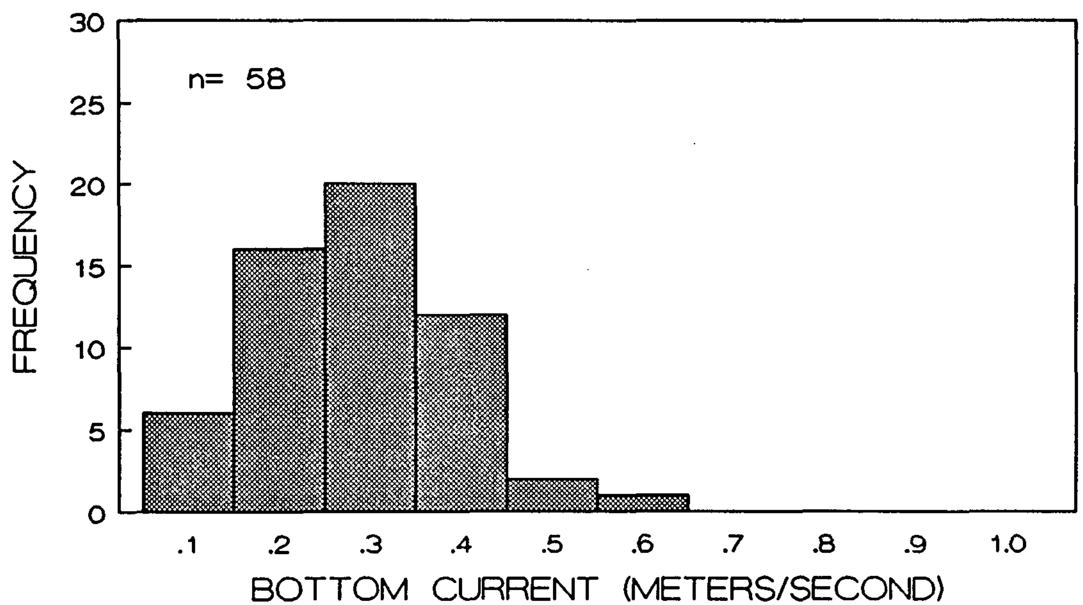

FIGURE 8. Frequency distribution of bottom current velocities at sites used by shovelnose sturgeon in Pool 13, upper Mississippi River, May-July, 1988

such an obstruction or merely adjacent to it. Bottom current velocities were positively related to surface current velocities (r^2=.43 P=.0001).

Mean column velocities (MCV) ranged from 0.10 to 0.57 m/sec (mean=.31 SE=.015) and represent a characterization of the general conditions that would be encountered by a shovelnose sturgeon if it were to make use of the entire water column. Sturgeon probably remain on or near the bottom, but some use of the upper water column likely does occur. Sturgeon were occasionally observed on the surface while tracking, but extensive use of the upper water column could not have been documented with the techniques used in this study. None of the study fish were observed on the surface.

<u>Water temperature</u>

Surface water temperatures at sturgeon locations ranged from 17.0 to 28.5 C. However, water temperatures were continually increasing during the study period and the range of observed temperatures probably reflected this trend rather than actual selection of temperatures by shovelnose sturgeon. There was no relation between surface water temperatures and depth used by fish (r^2=.026 P=.24), and there was no indication that sturgeon were moving into deeper, cooler water (if available) as water temperature increased.

Tailwater Conditions

Sturgeon were found in a variety of locations throughout the defined tailwater area. Determination of the precise microhabitat used was not possible because individual fish may not have been on or near the bottom. Shovelnose sturgeon were also occasionally observed at the surface in the tailwater area during the study period. Current velocities at the surface or at any given depth were highly variable and depended on the positioning of the roller gates of the dam and current patterns within the tailwater area.

Substrate in the tailwater consisted of hard bedrock and clean sand. Water depths at the sampling locations ranged from 13 to 23 m (Table 5). Variations in depths among sampling dates were due to difficulties encountered in positioning and anchoring the boat under constantly changing current conditions. Surface water temperatures in the tailwater ranged from 24.5 to 28.0 C during June and July (Table 5).

Current velocities were highly variable among index locations and depths on different sampling dates and were recorded as ranges only (Table 5). Occasionally current velocities and movement patterns would change within a matter of minutes while measurements were being made. To

Table 5. Temperatures, water depths, and current velocities measured in the tailwater area of Lock and Dam 12, upper Mississippi River, June-July, 1988. Current velocities are given as the maximum range observed at three index locations

Date	Mean Temp. (C)	Mean Depth (m)	Current Velocity Range (m/sec) (min.-max.)		
			Surface	0.6x depth	All depths
7 June	24.6	18.7	0.04-0.69	0.11-0.58	0.04-0.69
8 June	25.6	16.7	0.08-0.42	0.04-0.51	0.04-0.54
10 June	24.6	20.4	0.00-0.74	0.04-0.59	0.00-0.74
14 June	24.1	17.5	0.06-0.51	0.07-0.56	0.06-0.56
23 June	26.4	16.9	0.09-0.34	0.00-0.41	0.00-0.41
9 July	25.5	19.8	0.03-0.34	0.09-0.38	0.03-0.38
18 July	28.7	17.6	0.07-0.62	0.02-0.49	0.02-0.62
30 July	27.7	18.5	0.04-0.59	0.03-0.41	0.03-0.59

best represent current velocities in the tailwater area, the range of minimum and maximum velocities measured at the three index locations were used (Table 5). Surface current velocities ranged from 0.0 to 0.74 m/sec and velocities at 0.6x depth ranged from 0.04 to 0.59 m/sec. Sampling locations were generally too deep to permit measurement of bottom current velocities, although a few bottom measurements were made.

Transect Sampling

Sturgeon were found in three different habitat types among the eight transect locations: the main channel (4 locations), main channel border with wing dams (3 locations), and main channel border without wing dams (1 location), the same general habitat types used by sturgeon throughout this study.

Substrate type

Shovelnose sturgeon sampled along across-river transects were found over sand substrate in all areas except transect A, where the fish (Frequency 49.438) was found over gravel. This transect was sampled on 25 May, which is within the suspected spawning period of mid- to late May for shovelnose sturgeon in the upper Mississippi River (Hurley and Nickum 1984) and use of gravel substrate by this fish may have been related to spawning activity.

Sand was the predominate substrate type at nearly all sampling sites within a transect, particularly sites adjacent to the actual fish locations.

Water temperature

Surface water temperatures were fairly uniform among sampling sites within transects. The maximum variation within transects was 1.5 C (Transect B) and temperatures at six of the other transect locations varied less than one degree (Table 6). Temperature was likely not an important criterion in habitat selection by shovelnose sturgeon during the study period.

Water depth

A fairly wide range of water depths were available to sturgeon at most transect locations (Table 6). Depths used ranged 4.0-5.5 m (mean=4.5), while available depths ranged 1.1-6.1 m. Sturgeon were located in the deepest available depths at half the transect locations, but were never found in the shallowest depths available. The tendency to occupy depths greater than four meters might be a result of sturgeon seeking a suitable current velocity, substrate type, or other condition, rather than a preference for certain depths.

Current velocity

Sturgeon were found in fastest bottom current velocity available at five of the eight transect locations

Table 6. Temperature, water depth, and current velocity measured at eight transect locations, Pool 13, upper Mississippi River, May-June, 1988. "Fish" indicates position of radio-tagged sturgeon

Trans.	Site	Temp. (c)	Depth (m)	Current Velocity[a]			
				S	0.6x depth	B	MCV
A	1	21.5	6.1	0.57	0.51	0.40	0.49
	Fish	21.5	5.5	0.60	0.49	0.48	0.52
	3	21.5	4.0	0.39	0.38	0.26	0.34
B	1	30.0	3.4	0.02	0.00	0.00	0.01
	2	28.5	2.0	0.05	0.03	0.01	0.03
	3	28.5	4.0	0.17	0.21	0.15	0.18
	4	28.5	3.7	0.29	0.26	0.22	0.26
	Fish	28.0	4.6	0.27	0.23	0.20	0.23
C	1	26.8	2.7	0.36	0.33	0.31	0.33
	Fish	26.8	4.0	0.42	0.34	0.26	0.34
	3	26.8	3.7	0.38	0.35	0.25	0.33
D	1	27.0	2.7	0.06	0.00	0.02	0.03
	Fish	27.0	4.9	0.25	0.20	0.20	0.22
	3	27.0	5.2	0.34	0.29	0.09	0.24
	4	27.0	3.7	0.28	0.29	0.18	0.25
	5	27.0	2.6	0.30	0.27	0.23	0.27
E	1	27.8	1.7	0.05	0.09	0.02	0.05
	Fish	27.3	4.0	0.52	0.46	0.36	0.45
	3	27.2	4.3	0.35	0.33	0.08	0.25
F	1	29.0	4.0	0.23	0.19	0.07	0.16
	2	28.5	3.7	0.29	0.20	0.17	0.22
	Fish	28.5	4.3	0.26	0.20	0.12	0.19
	4	28.5	3.7	0.06	0.01	0.08	0.05
	5	28.5	1.5	0.12	0.07	0.09	0.09
G	1	26.2	3.0	0.19	0.10	0.05	0.11
	2	26.3	3.4	0.31	0.24	0.16	0.24
	Fish	25.6	4.0	0.32	0.27	0.27	0.29
	4	27.5	4.0	0.29	0.26	0.17	0.24
	5	27.0	4.0	0.29	0.30	0.19	0.26
H	1	27.5	1.1	0.17	--	0.13	0.15
	2	28.0	3.4	0.21	0.19	0.12	0.17
	3	27.0	5.5	0.31	0.24	0.13	0.23
	Fish	27.5	4.9	0.39	0.33	0.28	0.33
	5	28.0	3.2	0.15	0.18	0.10	0.14

[a]S=surface, B=bottom, MCV= mean column velocity.

(Table 6). At locations where fish were not in the fastest current they were in current velocities near the fastest found along the transect. Sturgeon were observed in bottom currents of 0.20-0.48 m/sec at seven of the transect locations, and at 0.12 m/sec at one location (Transect F). However, the maximum bottom current velocity available at this location was only 0.17 m/sec.

Shovelnose sturgeon tended to use the faster water areas at most transect locations, but were not consistently found within a narrow range of bottom current velocities, nor were they always found at the highest current velocities available.

DISCUSSION

Movement

Shovelnose sturgeon exhibited a wide variety of movement patterns during the study period, but generally remained in the upper, more riverine, portion of the study pool. This tendency to occupy only the upper part of the pool is likely related to the impoundment of the river. Held (1969) reported that the capture of sturgeon in Lewis and Clark Lake on the Missouri River is uncommon except in the upstream portion of the lake, and is restricted to lotic areas of the old river channel. Tagged shovelnose sturgeon occupied only one fourth of Pool 13 in 1988. It is not known how much suitable habitat may have existed prior to impoundment, but it is likely that shovelnose sturgeon were more widely distributed along the river. In addition, low flows in 1988 further reduced the amount of suitable habitat in the pool, particularly side channels.

Several sturgeon remained in one restricted area for considerable periods of time. These fish appeared not to move, although gaps between telemetry contacts would have prevented detection of short-term forays away from their regular location. Hurley (1983) reported use of two distinct types of home areas by shovelnose sturgeon: 1) restricted home areas less than 50 m in diameter, usually associated with wing and closing dams, and 2) extended home areas associated with channel habitats and less than 1 km in length. Sturgeon exhibiting little or no movement in the present study usually were found in the main channel border associated with wing dams. They were often found in or near the scour hole just outside and slightly downstream from the wing dam. These sturgeon may have been exhibiting behavior similar to the use of restricted home areas described by Hurley (1983). Moos (1978) and Christenson (1975) reported only limited movement by shovelnose sturgeon in the Missouri River and Red Cedar-Chippewa River system, and Helms (1974) found that tagged shovelnose sturgeon did not move great distances in Pool 13 of the upper Mississippi River. The small number of contacts with several tagged sturgeon may have resulted from a variety of reasons. There was an ongoing commercial fishery for a variety of species in Pool 13 and several tagged shovelnose sturgeon were caught and their transmitters returned. Other fish may have been caught and not reported. Shovelnose sturgeon fitted with the 90-day transmitters were often difficult to locate due to their relatively low signal strength, and their locations occasionally may not have been detected. Transmitter failure was also possible, but no evidence of failure was noted.

Shovelnose sturgeon are not normally found in the areas at and just below the tailwaters of Lock and Dam 12 until late April, when commercial fishermen begin to capture large numbers of fish moving upriver (Wayne Kress, Bellevue, Iowa, personal communication). It is not known if this migration is directly related to spawning.

Significant differences were observed in the total range size and general dispersal of shovelnose sturgeon tagged on the two sampling dates. Fish tagged on 26 April remained in the tailwater area considerably longer than those tagged in late May. The dispersal of the second group of fish much farther downstream than those tagged earlier may be a result of differential timing of the upstream spring migration--possibly by different localized stocks. Hurley (1983) reported no inter-pool movement among radio-tagged shovelnose sturgeon in the same pool in 1982, suggesting that fish living in Pool 13 probably spawn within the pool. Genetic analysis of shovelnose sturgeon throughout the study pool would be useful in determining if discrete spawning stocks exist. If discrete stocks do exist it seems unlikely that the spring congregation of shovelnose sturgeon near Lock and Dam 12 is directly related to spawning. Temporal segregation of spawning in the vicinity of the tailwaters is possible but no fish with extrudable sex products were observed on either tagging date. Additional sampling should be conducted in the lower pool to confirm the use, if any, of that area by shovelnose sturgeon. The contact with one fish just above Lock and Dam 13 suggests that this area contains at least some suitable habitat for shovelnose sturgeon.

A number of sturgeon moved downriver between 26 May and 18 June, with several fish moving long distances (more than 10 km) during the last week in June. The reason for this movement is unknown, although it occurred during a period of generally declining flow, They may have been returning to their downstream home areas, or the movement may have been a spawning or post-spawning migration.

Habitat Use

Shovelnose sturgeon made extensive use of the main channel, main channel border areas with wing dams, and to a lesser extent, tailwater areas throughout the spring and summer in 1988 (94% of all observations). Use of the main channel proper is unusual in the spring when the upper Mississippi River normally reaches peak flow levels and the gates of the dam are opened to allow a free-flowing river. Hurley (1983) found shovelnose sturgeon to be most abundant in areas outside the main channel, often behind wing and closing dams and in side channels during high spring flows in 1982.

Despite the low flow rates in 1988, current velocity was an extremely important factor affecting shovelnose sturgeon distribution. Sturgeon were consistently found in areas of relatively swift current, in several habitat types. This species is known to inhabit areas with a swift current (Pflieger 1975), often in main channel (Hubert and Schmitt 1982) or main channel border areas, often associated with wing dams (Pitlo 1981).

Hurley (1983) found that shovelnose sturgeon in Pool 13 utilized current velocities of 0.40-0.70 m/sec at the surface and 0.20-0.40 on the bottom. The mean bottom velocity used by sturgeon in the present study was 0.23 m/sec, at the lower end of this range. The generally lower velocities used by sturgeon in 1988 may be more a function of availability than preference, since river conditions in 1982 were characterized by high spring flows and near-normal summer flows. Water depth and substrate type are probably only secondary factors affecting shovelnose distribution. Sand substrate, although patchy, is found throughout the upper reaches of the study pool. Sturgeon were found at a variety of depths, but it is likely that the depth ranges used were related to availability in the areas where fish were located. The lack of a significant relation between depth and water temperature suggests that shovelnose sturgeon were not changing depths to find or avoid any specific temperature.

Shovelnose sturgeon made considerable use of the tailwater area of Lock and Dam 12 in 1988. This is the first documentation of tailwater use over an extended period in the upper Mississippi River. Sturgeon using the tailwater may have been attempting to move upstream into Pool 12 and were blocked by the dam, or they may use this type of habitat more than previously thought. The highest flows were normally found in the tailwater. Current velocities greater than 0.50 m/sec typically were found only in or just downstream from the tailwater in 1988, suggesting that sturgeon might have been seeking higher current velocities than were available downstream.

Tagged fish were not always found in the fastest current velocities available at transect locations which indicates that current velocities in 1988 were above the minimum required for survival, despite the record low flows. Tagged sturgeon exhibited a behavioral strategy in spring very similar to that described by Hurley (1983) as normal for mid-to late summer. It is not known if low flow levels affected spawning or reproductive success in 1988, and further research on spawning and early life history of this species and the effects of various flow regimes on reproduction is needed.

ACKNOWLEDGMENTS

This study was jointly funded by the Iowa Department of Natural resources (through a Fisheries Research and Development Act contract from the National Marine Fisheries Service, Project Nos. 2-399-R, 2-433-R, and 2-IJ-5), the Iowa Cooperative Fish and Wildlife Research Unit, and the Department of Animal Ecology at Iowa State University. I wish to thank Clark Moen for his assistance during the many long days on the river. My major professor Dr. John Ramsey and Dr. Dennis Scarnecchia both deserve recognition for their support and active participation in the field work. Special thanks are due to the staff of the Mississippi River Fisheries Station at Bellevue (Iowa Department of Natural Resources)--John Pitlo, Tom Boland, Maurice Anderson, and Dennis Weiss. Their willingness to lend advice and equipment, as well as assistance in the field, made completion of this project possible. Commercial fishermen Wayne and Rita Kress of Bellevue, Iowa, and Mark Flickinger of Savanna, Illinois, provided much insight into the ecology of shovelnose sturgeon and the Mississippi River, and helped obtain fish for this study.

Finally, I thank my officemates Teresa Naimo and Jim Gallagher, whose friendship helped me keep things in perspective. Special thanks to Mr. James H. Selgeby for his encouragement and support (as always), and to Dr. Jon

Stanley and Dave Walsh of the National Fisheries Research Center - Great Lakes for granting me time off to pursue my interest in river ecology.

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APPENDIX: COMPOSITE GRAPHS OF MEAN DAILY DISCHARGE AND INDIVIDUAL STURGEON MOVEMENT PATTERNS

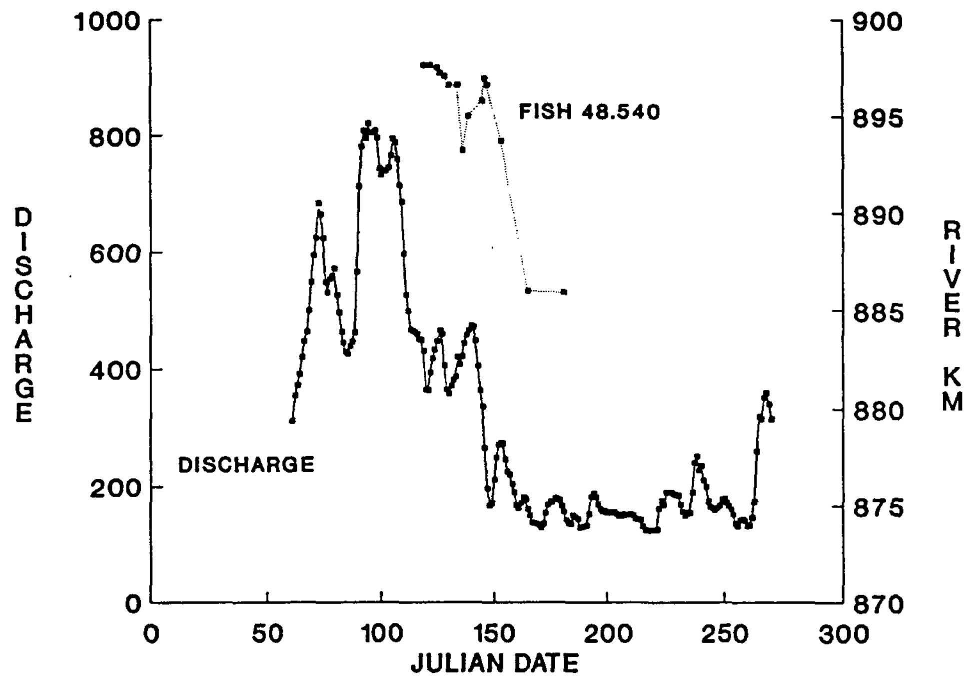

FIGURE A1. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.540

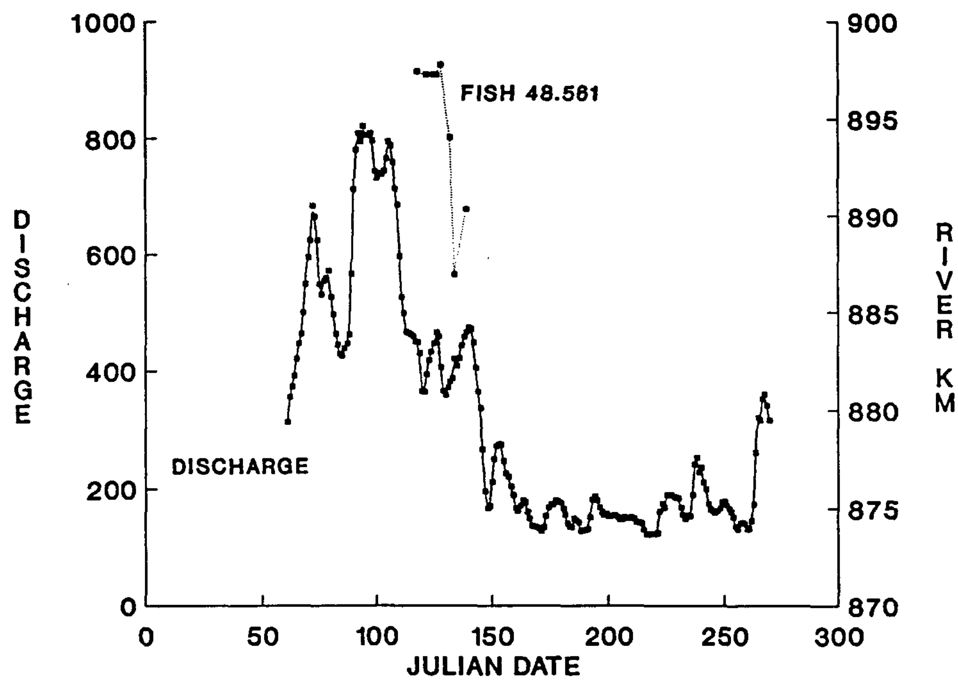

FIGURE A2. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.561

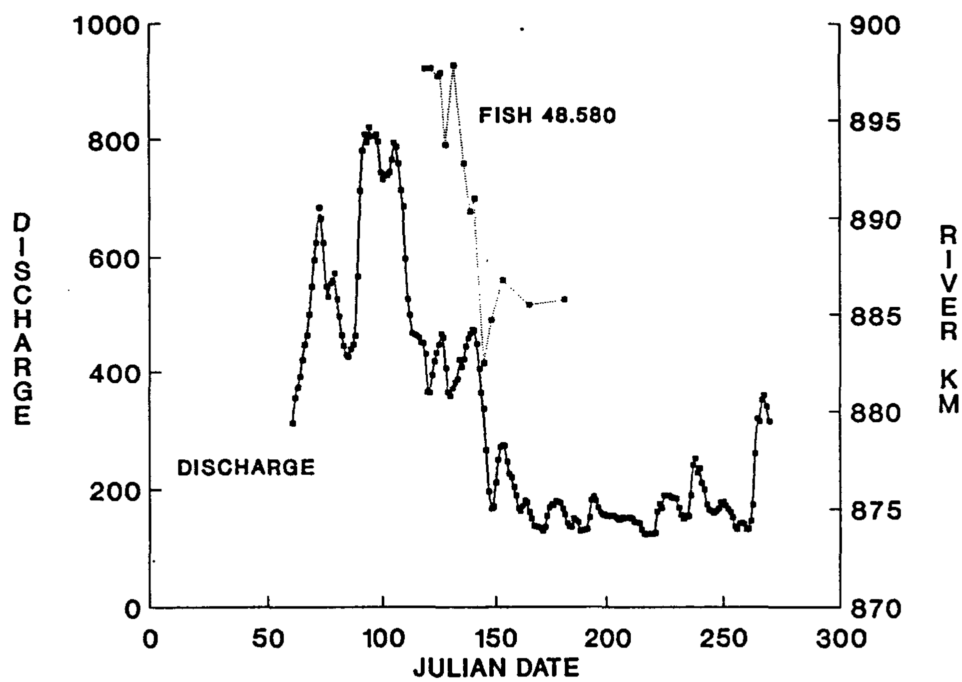

FIGURE A3. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.580

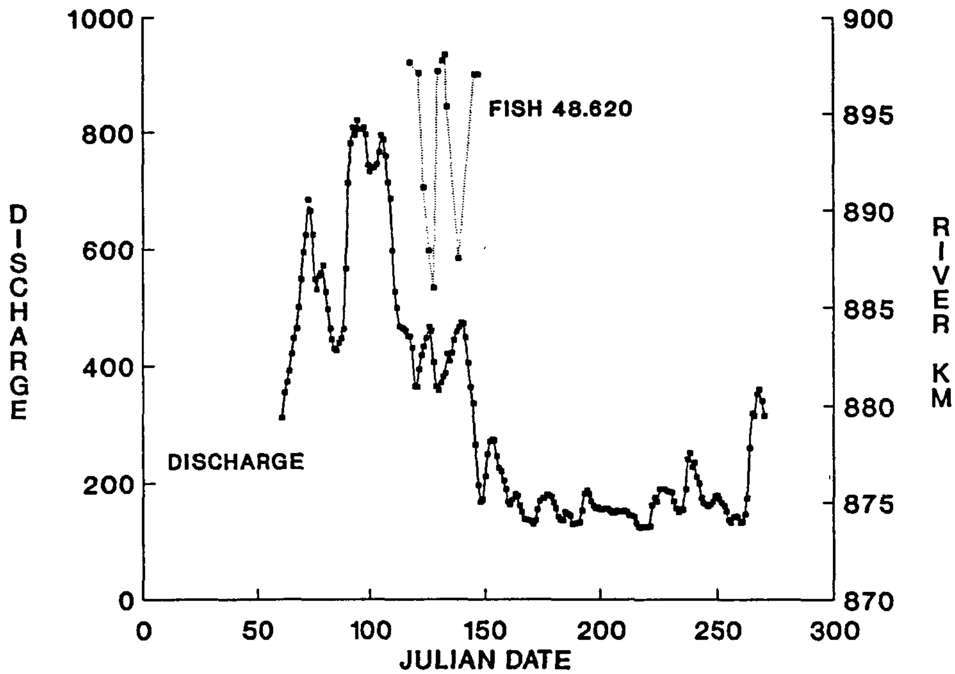

FIGURE A4. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.620

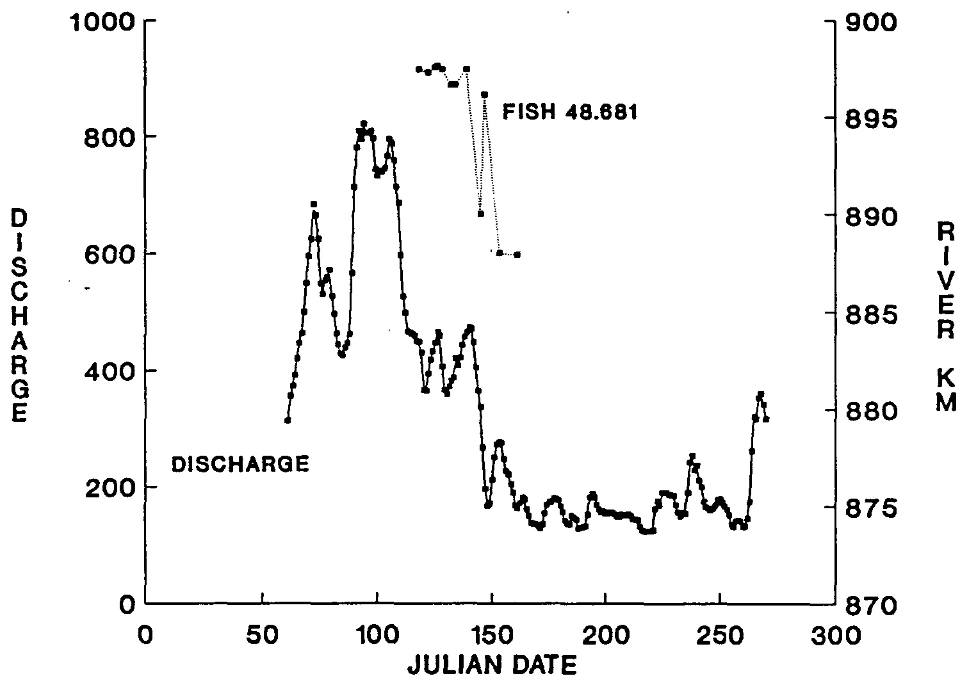

FIGURE A5. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.681

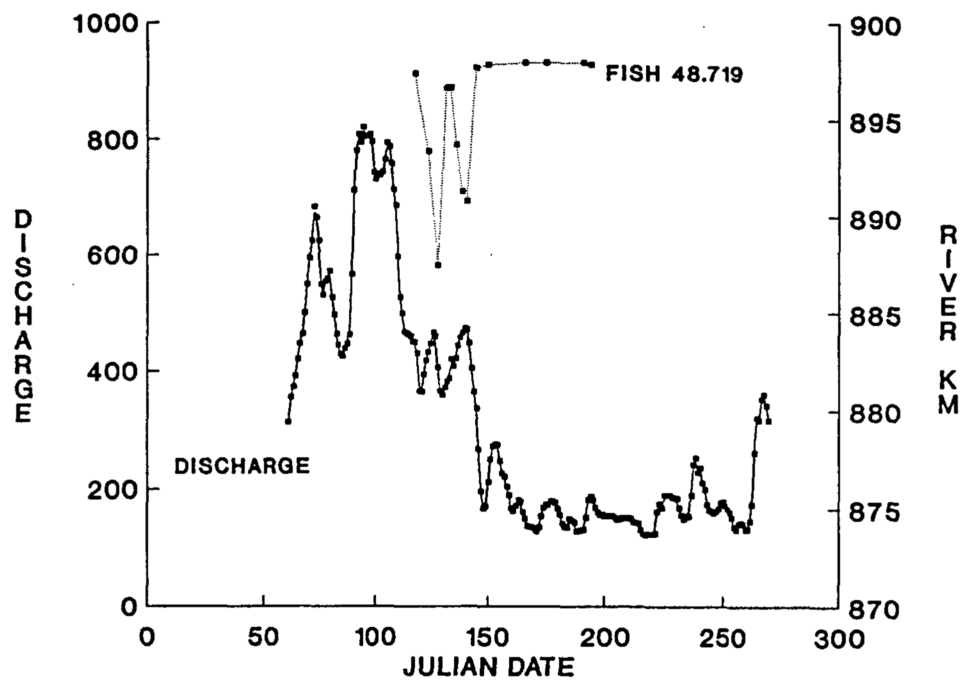

FIGURE A6. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.719

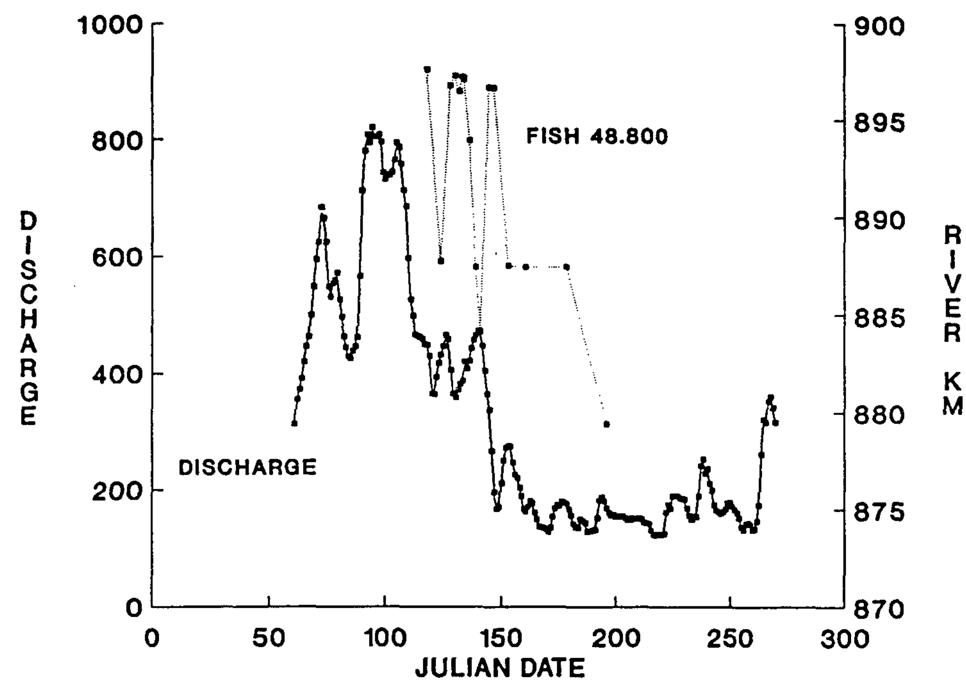

FIGURE A7. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.800

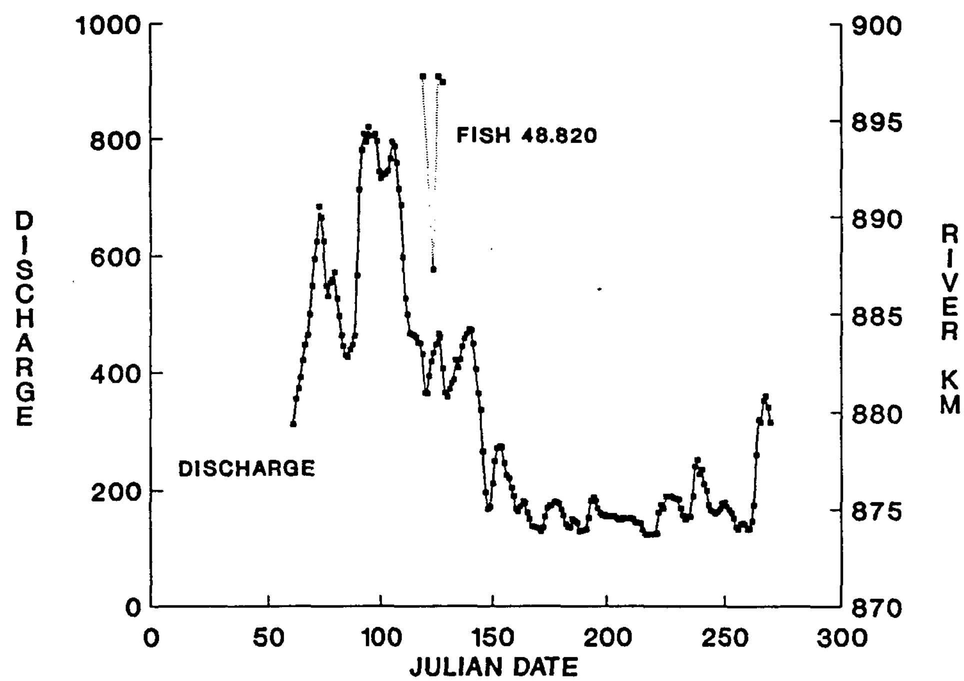

FIGURE A8. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.820

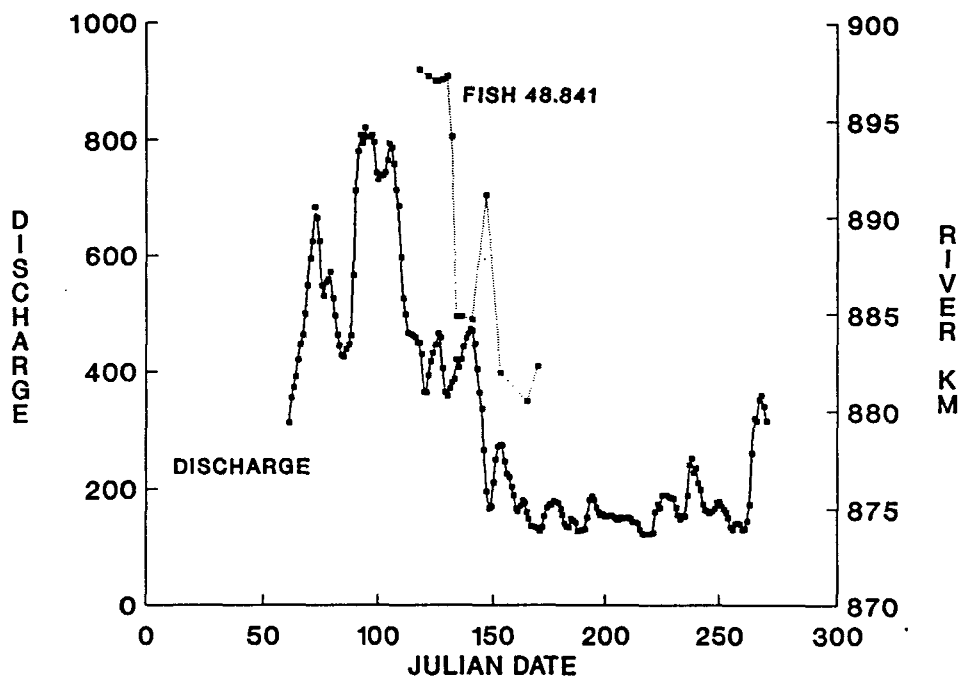

FIGURE A9. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.841

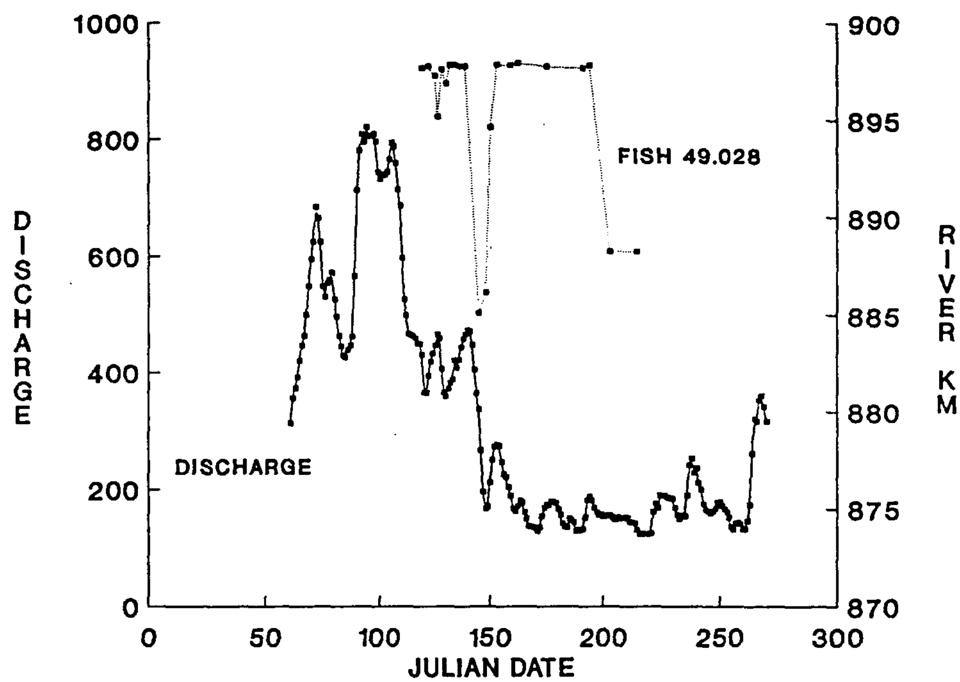

FIGURE A10. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 49.028

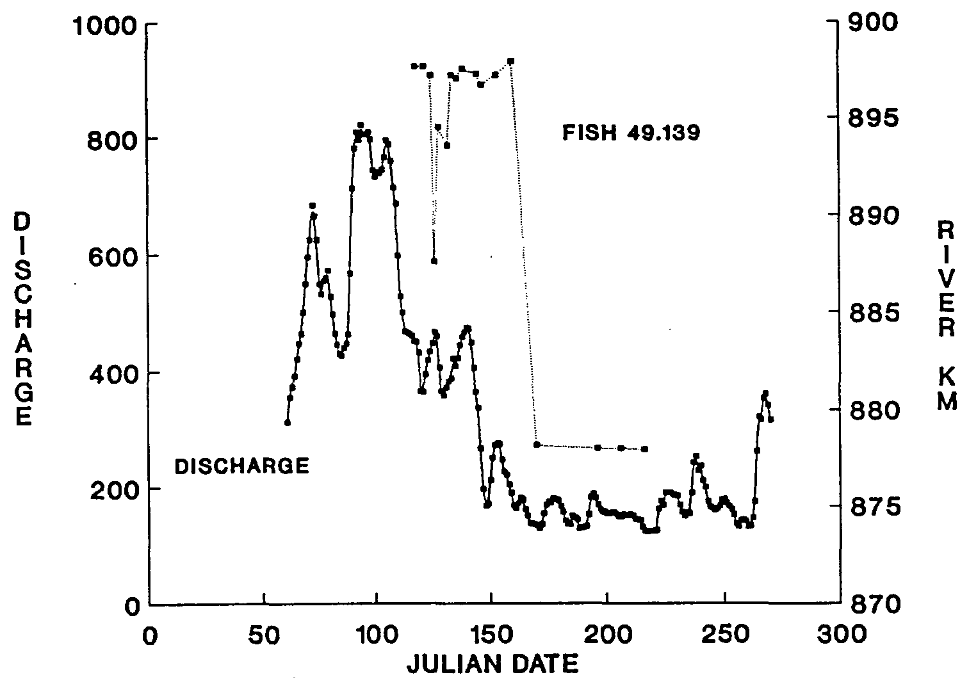

FIGURE A11. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 49.139

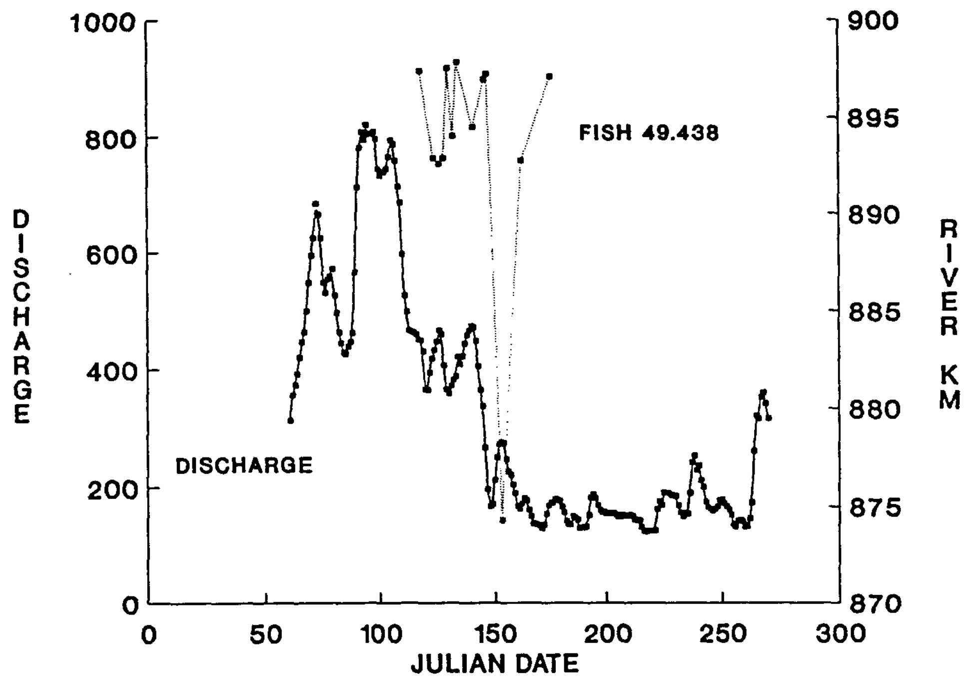

FIGURE A12. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 49.438

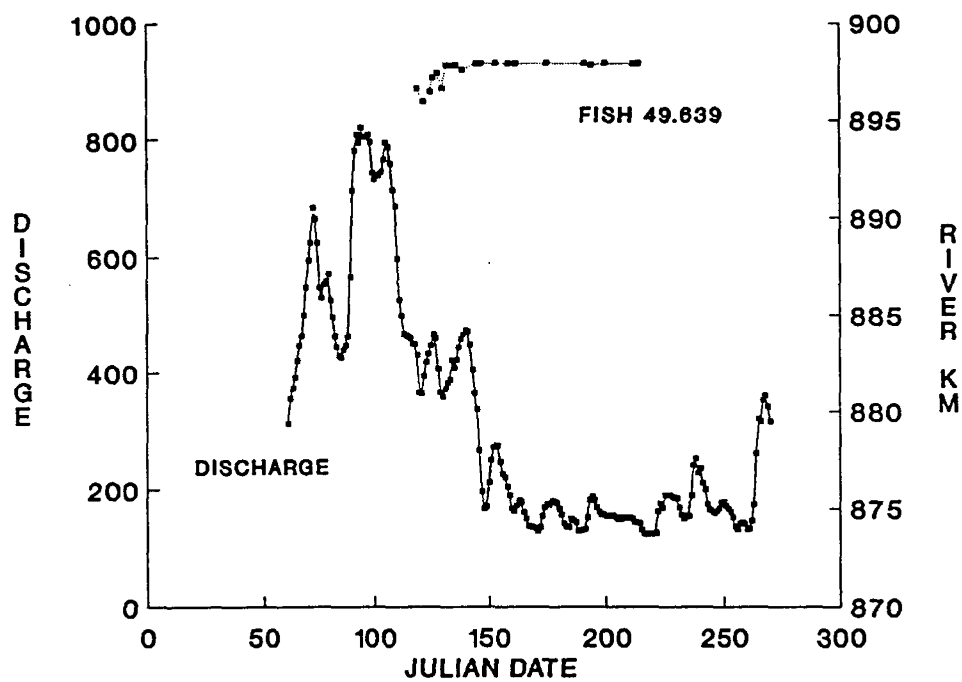

FIGURE A13. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 49.639

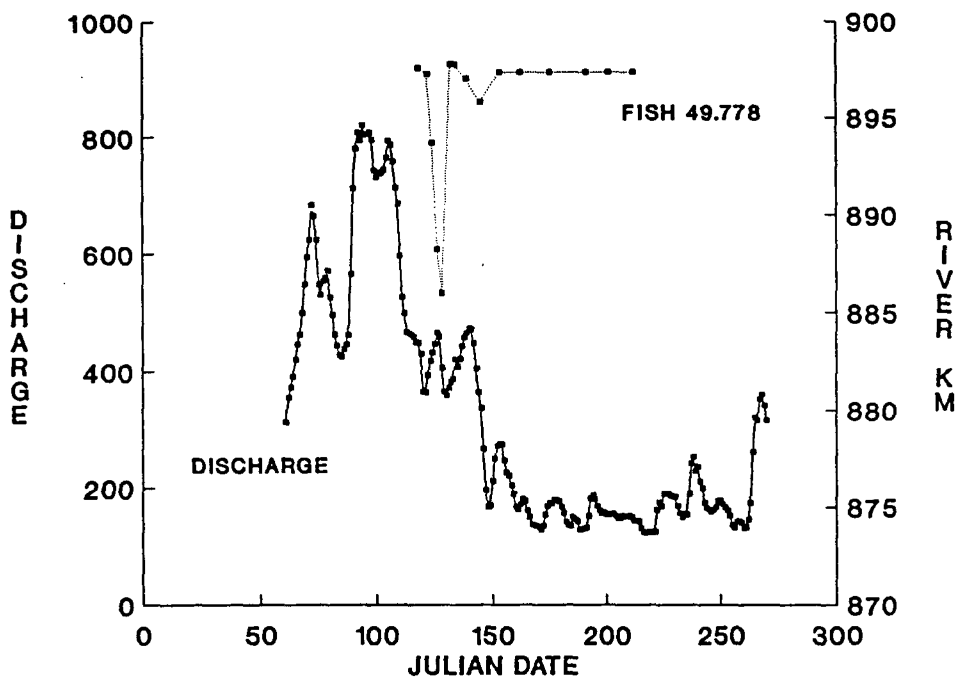

FIGURE A14. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 49.778

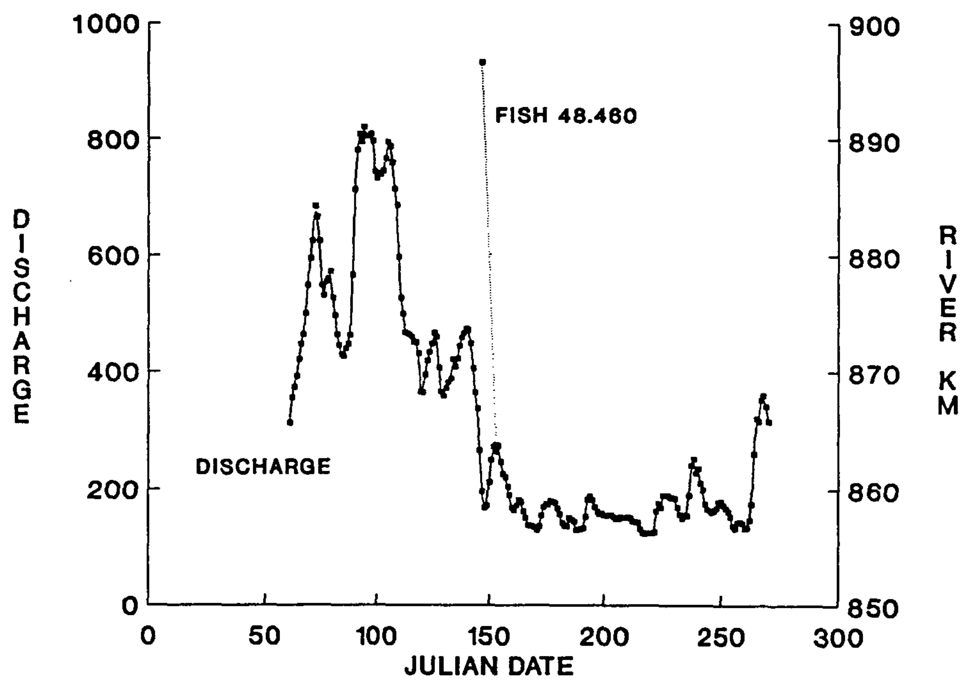

FIGURE A15. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.460

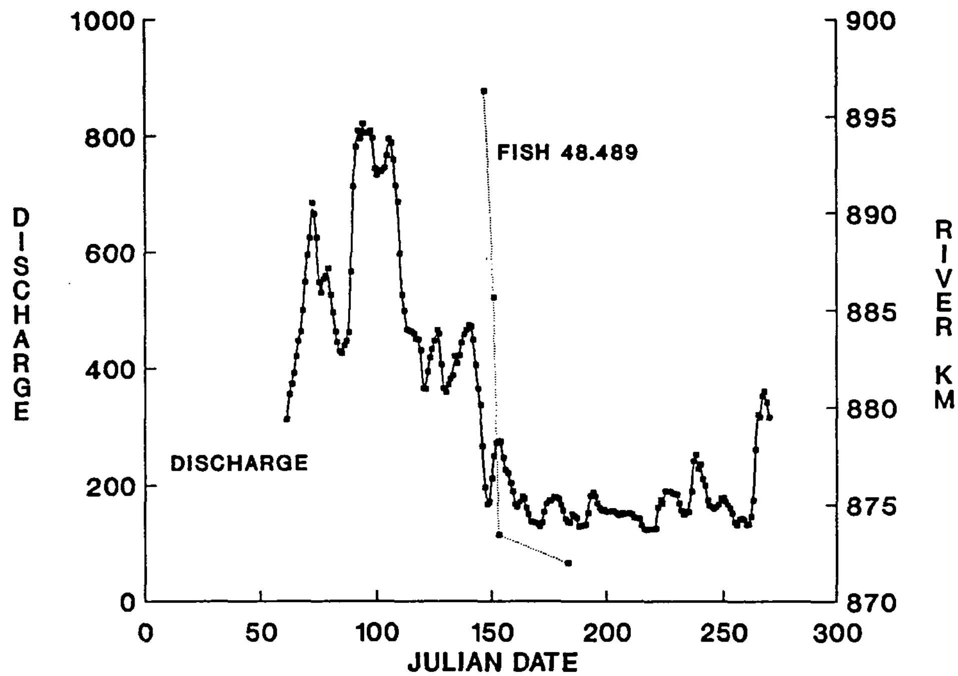

FIGURE A16. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.489

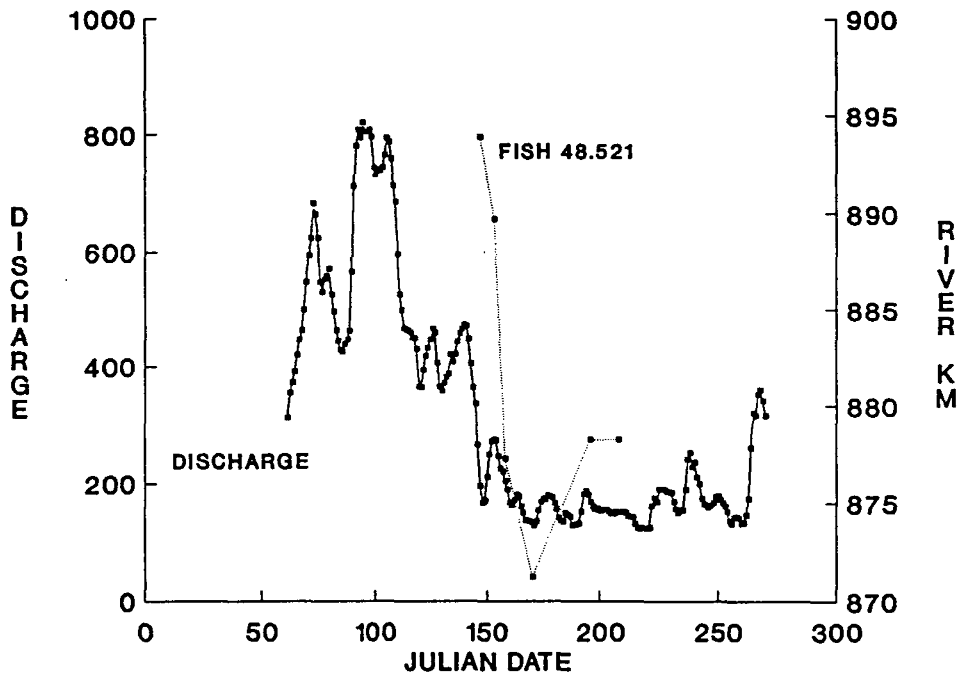

FIGURE A17. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.521

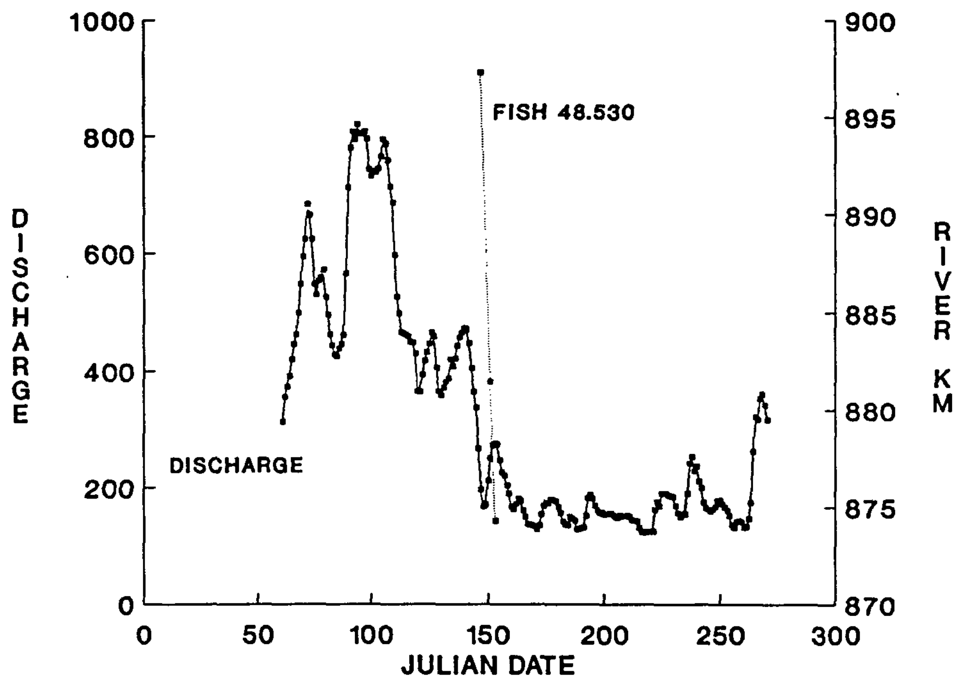

FIGURE A18. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.530

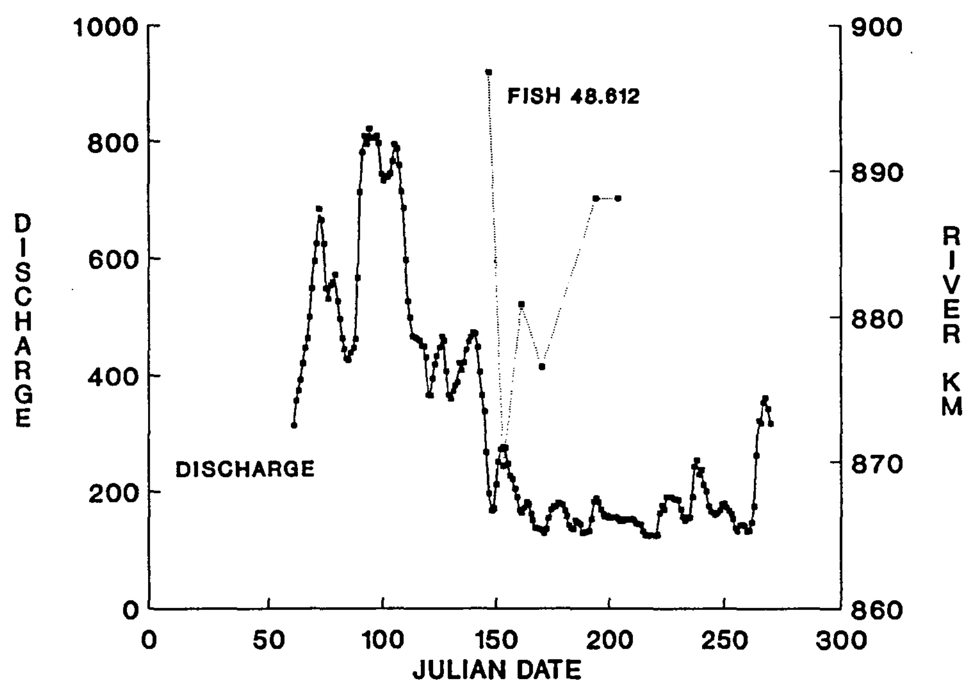

FIGURE A19. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.612

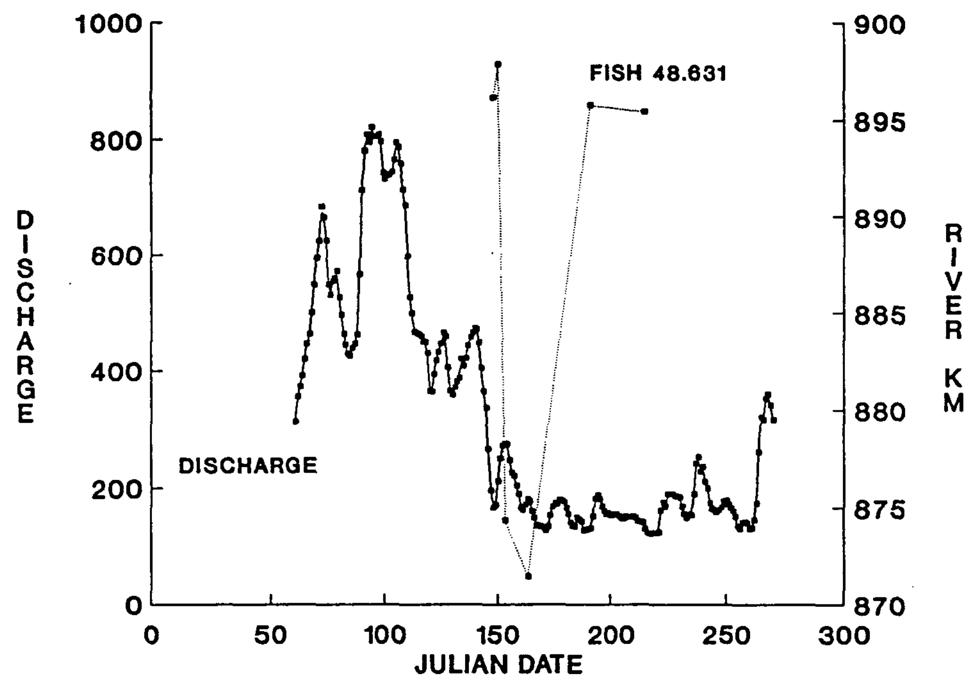

FIGURE A20. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.631

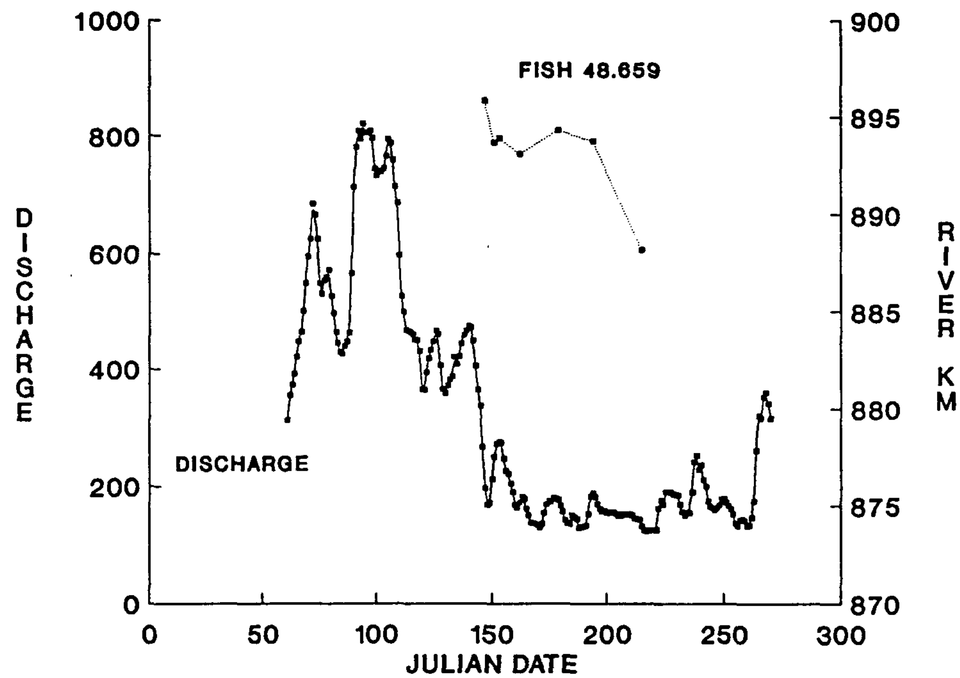

FIGURE A21. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.659

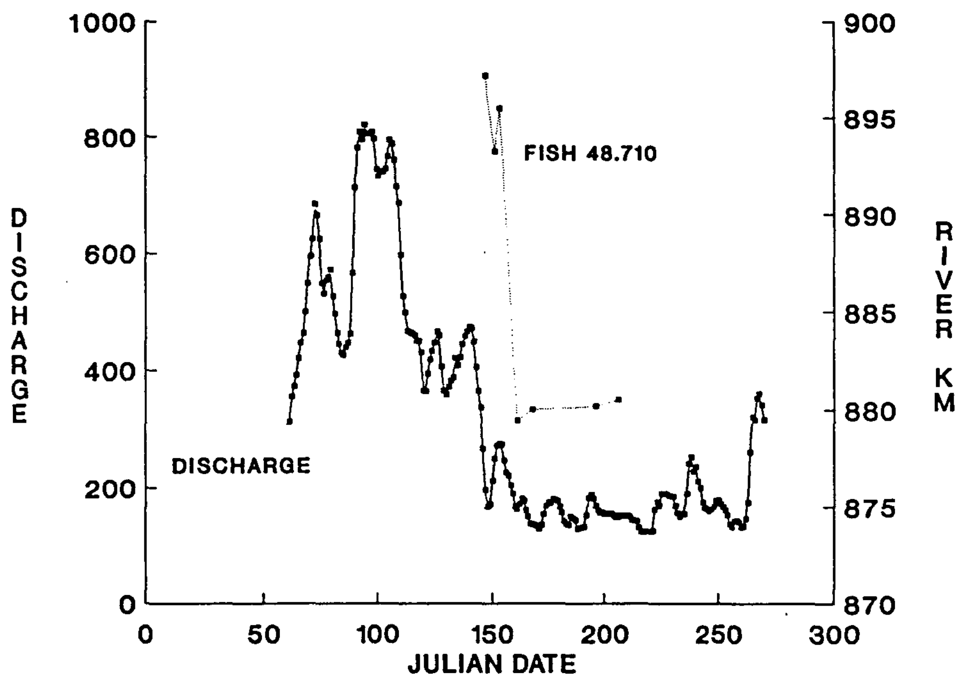

FIGURE A22. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.710

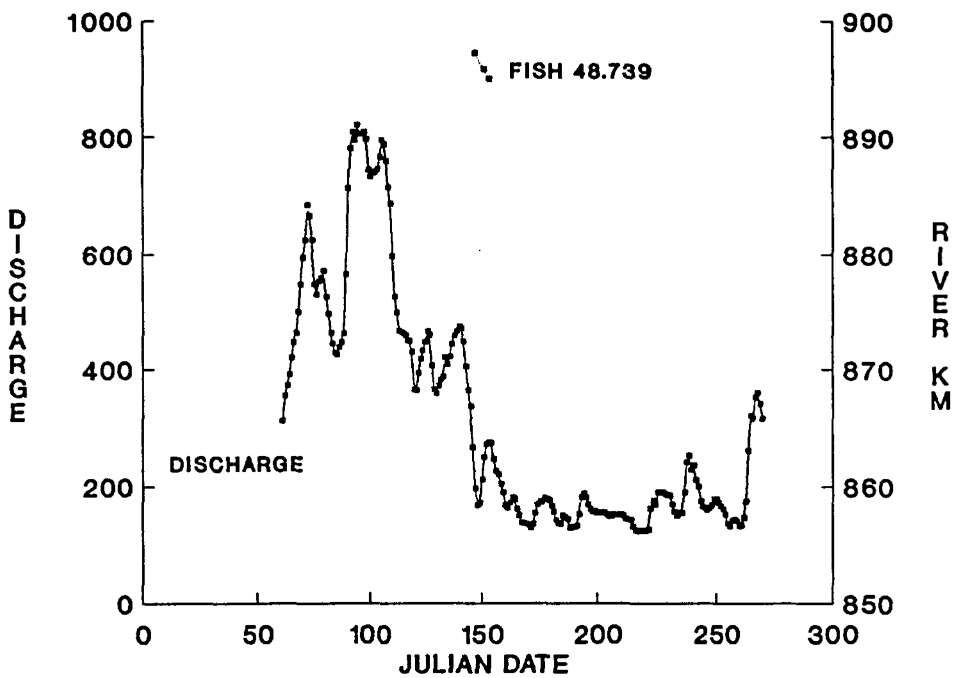

FIGURE A23. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.739

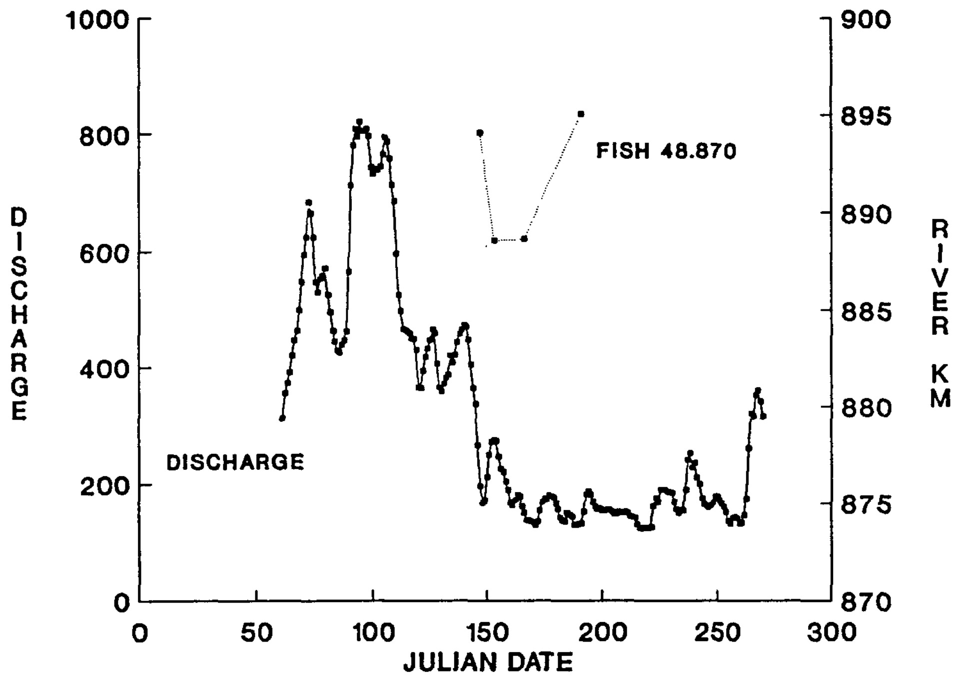

FIGURE A24. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.870

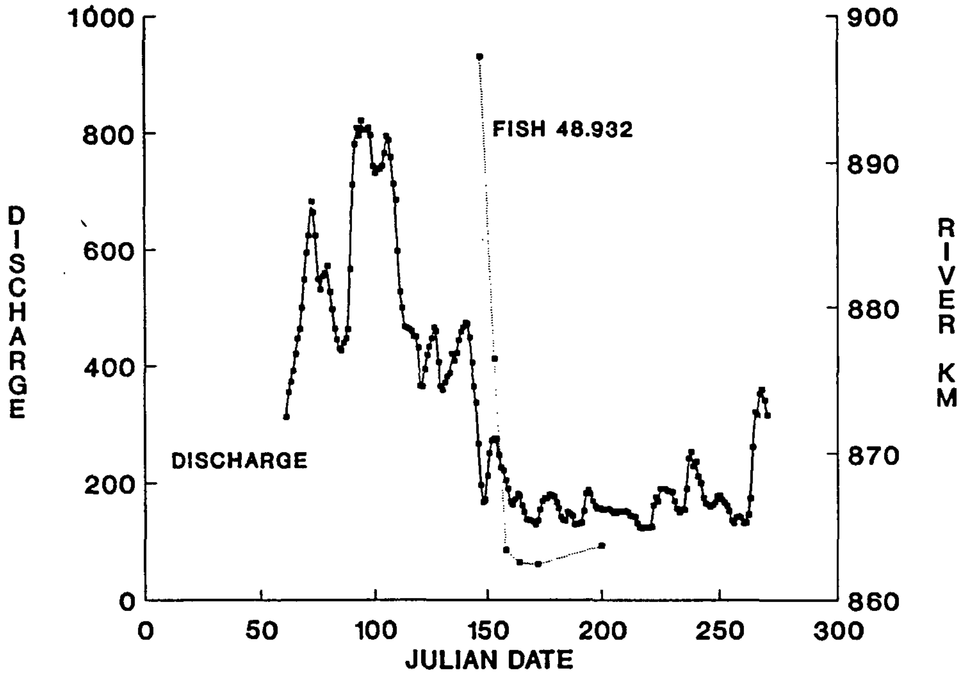

FIGURE A25. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.932

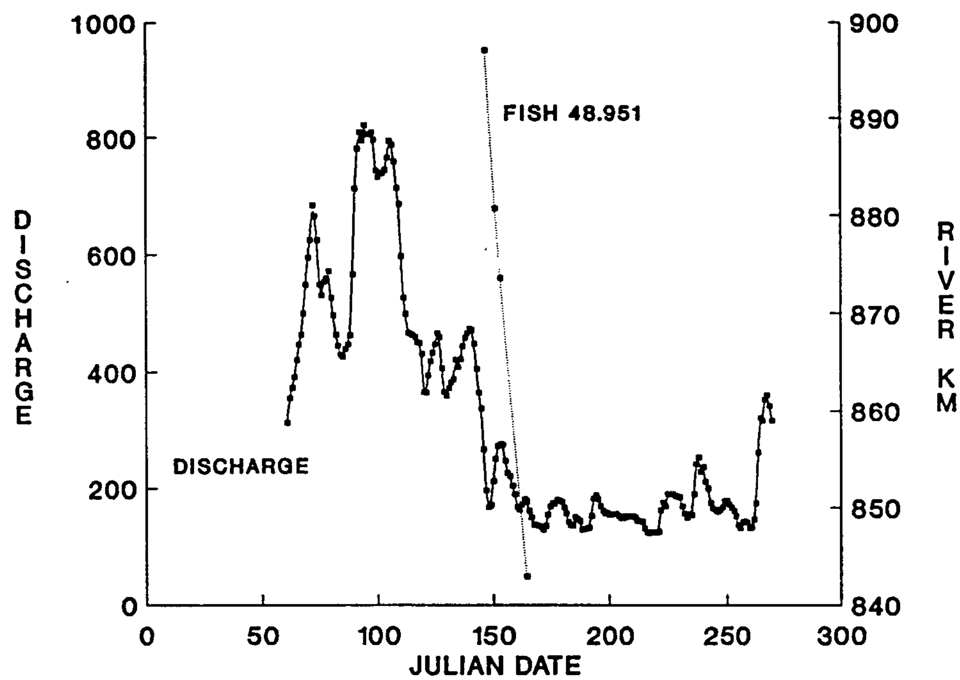

FIGURE A26. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 48.951

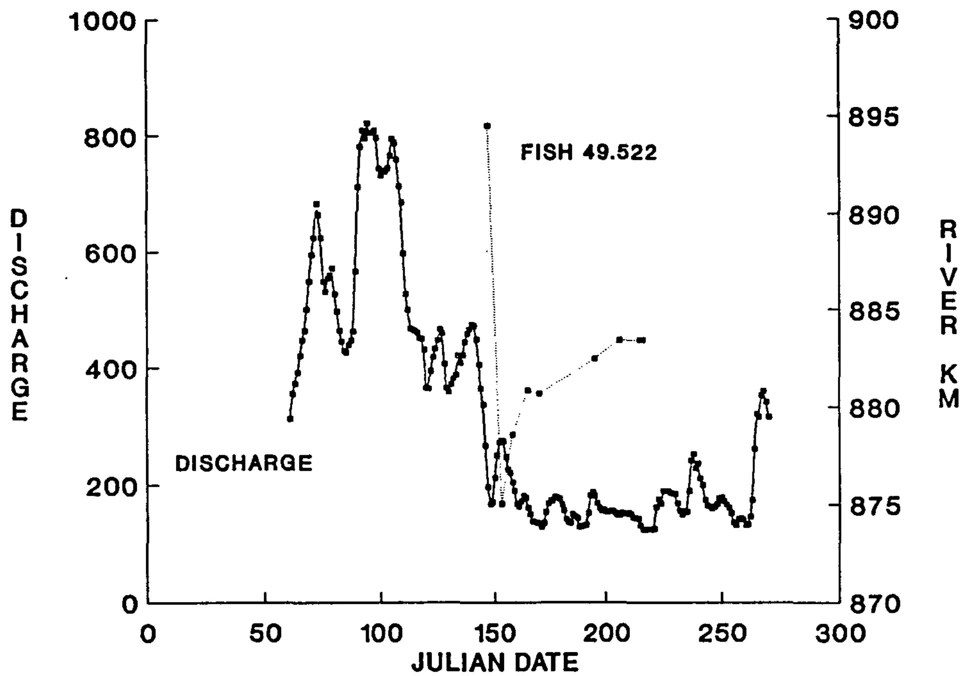

FIGURE A27. Composite graph of mean daily discharge (CFS) through Lock and Dam 12 and movement of shovelnose sturgeon frequency No. 49.522