Graham

Idaho Water Resources Research Institute

ABUNDANCE, GROWTH, DISTRIBUTION AND MOVEMENTS OF WHITE STURGEON IN THE MID-SNAKE RIVER

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ABUNDANCE, GROWTH, DISTRIBUTION AND MOVEMENTS of WHITE STURGEON IN THE MID-SNAKE RIVER

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ABSTRACT

During the years 1972-75, we captured 876 sturgeon from the Snake River between Lower Granite and Hells Canyon dams. We marked or tagged the sturgeon so that we could assess their abundance, growth, distribution and movements. We recaptured 204 of the sturgeon, some up to eight times.

Some of the large pools in the Snake River contained more than 200 sturgeon, according to our estimates. By expanding the population estimates we made for several pools in the river, we believe 8,000-12,000 sturgeon resided in the study area during the period 1973-1975. Small sturgeon (less than 3 feet) were the most abundant (86%) of the fish caught. Sturgeon 3-6 feet in length were least abundant (4%) and large fish (over 6 feet in length) comprised 10% of the fish we caught.

There was some tendency for the small 2 to 3 foot sturgeon to move downstream, whereas the larger sturgeon did not move far from the original site of capture. Growth of sturgeon produced since dams were constructed in Hells Canyon was less than for sturgeon produced prior to damming of the river.

Sturgeon are reproducing successfully in the middle section of the Snake River but the population may not thrive as in past years if the growth rate has indeed slowed and if critical habitat for the rearing of 3-6 foot sturgeon has been eliminated by dams in the lower Snake River.

INTRODUCTION

Construction of dams and creation of reservoirs has reduced the habitat for white sturgeon (*Acipenser transmontanus)* to the few free flowing sections of the Columbia and Snake rivers. In this report, we present information on the abundance, age and growth, distribution, and movements of the white sturgeon population in the Hells Canyon sections of the Snake River.

The studies of sturgeon reported herein were undertaken in 1972 when applications to construct dams in the remaining sections of the Hells Canyon portion of the Snake River were pending before the Federal Power Commission. Our objective was to collect ecological information regarding the white sturgeon to aid in management of the fish populations, especially if additional dam construction were approved for the middle Snake River. At the present time, a portion of the Hells Canyon section of the Snake River has been included in the wild and scenic rivers system which will preclude additional dam construction unless specifically approved by Congress.

Prior to this study, little was known about the white sturgeon inhabiting the Snake River in Idaho. Sturgeon were found throughout the length of the Columbia and Snake rivers upstream as far as Shoshone Falls. Sturgeon were harvested by local fishermen with extra large specimens noted in local newspapers. From 1960 to 1970, only those fish 3 to 6 feet (92-183 cm) in length could be kept by anglers. Fish smaller or larger had to be returned to the river. Prior to 1960, the fish had to be larger than 40 inches (1 m) to be kept. In 1970, the no-kill, catch-and-release regulation was put into effect.

Prior to the construction of dams in the Snake and Columbia rivers, sturgeon had free access up and down the rivers and to the ocean. Bajkov (1951) found sturgeon moving as much as 100 miles upstream in the fall and downstream in the spring to the mouth of the Columbia River. The extent of movements by sturgeon before the construction of dams was not determined and sturgeon are rarely seen in the fishways of the dams. Extensive up and downstream movements in the Snake and Columbia rivers were apparently not obligatory for survival of the sturgeon populations. Most sturgeon caught from the Columbia and Snake rivers at the present time are being caught from the free flowing sections or in the sections immediately downstream from the dams which have significant currents, but they may also inhabit the reservoirs.

The white sturgeon is one of the four genera and approximately 24 species of the family Acipenseridae. This ancient family of fishes has been widely distributed throughout the northern hemisphere since the upper Cretaceous, 75 to 100 million years ago (Gardiner, 1967). The majority of sturgeon species occur in the Caspean-Black Sea region and along the northern Asiatic coast. Most are diadromous.

Two genera and seven species of sturgeon are found in North America, but only two species of the genus *Acipenser* occur in the drainages of the Pacific coast. White sturgeon have been found in various drainages from Monterey, California, to the Gulf of Alaska (Clemens and Wilby, 1961). At present, the white sturgeon is the only species of sturgeon found in the Snake River drainage. Green sturgeon (*Acipenser medirostris* Ayres) which inhabit primarily brackish waters (Clemens and Wilby, 1961) are found in the lower Columbia and may have been present occasionally in the upper drainages in past times.

White sturgeon are the largest freshwater fish in North America (two species of the genus *Huso* in Eurasia may attain a larger size). Verified records exist of white sturgeon approaching 4.0 m (13 ft) in length and 591 kg (1300 lb) in weight. Most of these fish were caught in the late 1800's and early 1900's and larger unverified records have been claimed (Gudger, 1942; Clemens and Wilby, 1961). The longest sturgeon captured during our study was just under 2.7 m (9 ft) and weighed 114 kg (250 lb). Several sturgeon over 3 m (10 ft) in length have been captured from the Snake in earlier years. The largest verified record for the middle Snake River was a 312 kg (687 lb) sturgeon captured near the mouth of the Salmon River (Edson, 1956).

Other studies of white sturgeon include a California Department of Fish and Game study of abundance, movement, reproductive habits, growth and food habits of a portion of the white sturgeon stock in the Sacramento-San Joaquin River system (Pycha 1956, Chadwick 1959, Schreiber 1960 and 1962, Stevens and Miller 1970, McKechnie and Fenner 1971, Miller 1972, and Kohlhorst 1976). Bajkov (1949 and 1951) studied movements of white sturgeon in the Lower Columbia River and Haynes, Gray and Montgomery (1976) studied seasonal movements of white sturgeon in the mid-Columbia. Semakula and Larkin (1968) estimated age, growth, food habits and potential yield for white sturgeon in the lower Fraser River.

STUDY AREA

We studied white sturgeon in the unimpounded reach of the middle Snake River which extends for 173 km between Idaho and Oregon and Idaho and Washington from Hells Canyon Dam (river kilometer 398) to Lewiston, Idaho (river kilometer 225); and in the lower Snake where it extends into Washington for 48 km from Lewiston to Lower Granite Dam. Our primary study area was the 64 km of river between Johnsons Bar and the mouth of the Salmon River. Within this area our most intensive sampling occurred in the upper 38 km (Figure 1).

The middle Snake River downstream from Hells Canyon Dam flows through the deepest gorge in North America. Access to the river (other than by boat) is limited to a few unimproved dirt roads and trails. The river itself is extremely turbulent (especially above Johnsons Bar) and is known nationally for its white-water thrills.

Between the many rapids are deep pools which are the primary sturgeon holding habitat. These pools are commonly in excess of 7.5 m (30 ft) deep and a few are more than 25.5 m (100 ft) deep. They often have strong back eddies and powerfull vortices, particularly during high water.

The mean daily flow at Hells Canyon Dam since 1965 has been 636.1 cu m/s (22,460 cfs). The maximum daily discharge recorded was 2,150 cu m/s (75,800 cfs) in April, 1971, and the minimum was 140 cu m/s (4,950 cfs) in May 1968 (U.S.G.S. Water Supply Papers, 1976). Diurnal fluctuations of more than 2 vertical feet in the river level created by power peaking operations at the Hells Canyon Dam were common during the study.

While the study area was unimpounded, the upstream and downstream dams have considerable influence over the nature of the sturgeon habitat there.

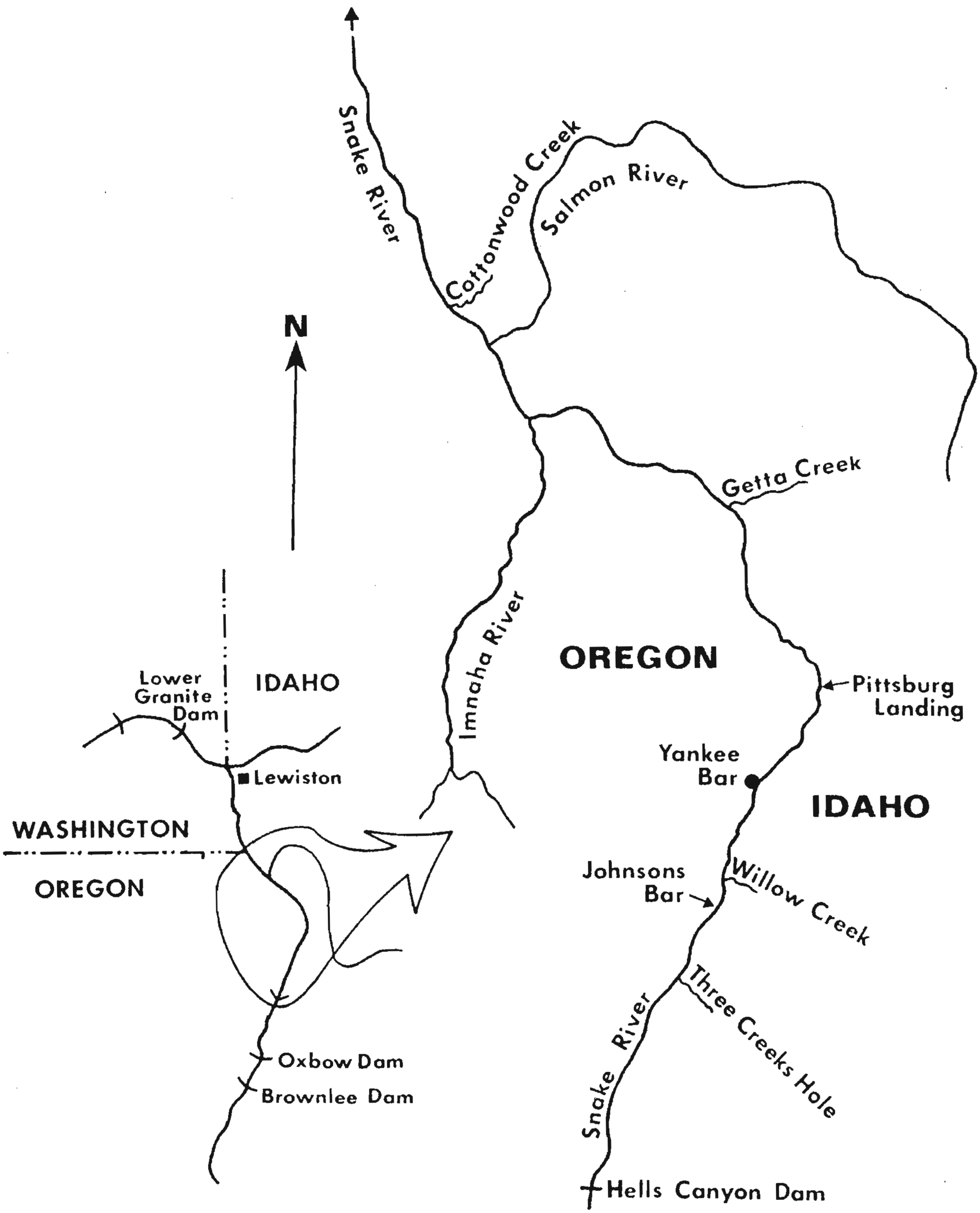

Figure 1. Map of the sturgeon study area in the Hells Canyon section of the Snake River.

The upstream reservoirs have shifted the timing of the natural flow pattern and modified the high and low temperature extremes. Flows have been increased through the fall, winter and early spring to meet power demands and empty the reservoirs prior to the spring runoff. The peak of spring runoff has been reduced and spread over a longer period. The reservoirs have also acted as huge settling basins to remove all of the bed-load and much of the suspended solids from the water prior to entering the canyon.

More directly for the sturgeon, the hydroelectric projects have isolated the middle Snake sturgeon population by restricting movement into or out of the Hells Canyon area. These same projects have drastically reduced the abundance of anadromous salmonids and lamprey eels which entered this area and thereby diminished a supply of food available to the sturgeon. In addition, power peaking may have reduced the usable habitat for aquatic insect larvae and freshwater mussles which are also food or sturgeon.

METHODS

Capture Techniques

Due to the turbulent, deep water throughout much of the middle Snake River, we used short set lines and rod-and-reel as our primary techniques to capture sturgeon. Our attempts to collect sturgeon with electroshocking, seining and fyke netting were unsuccessful.

We normally used 1/0 to 2/0 hooks baited with nightcrawler worms to capture sturgeon with rod-and-reel. At times, we used smaller or larger hooks when seeking especially small or large sturgeon. Besides nightcrawlers, we used whole or cut bait from herring, smelt, lamprey, crayfish, sucker, squawfish, carp and bass as availability permitted.

We used two kinds of set lines (large-hook and small-hook) to fish for sturgeon. The large-hook lines consisted of a 909 kg (2,000 lb) test braided nylon main line with dropper loops every 1.5 m (5 ft) and three to five rubber shock absorbers spaced throughout the line. The shock absorbers reduced the number of fish breaking free from the line and also minimized hook wounds. Harness snaps were used to attach 45 cm (18 in) long dropper lines of 228 to 456 kg (500 to 1,000 lb) test parachute chord to the loops. Kirby 11, 12 and 13/0 halibut hooks and Mustad 14/0 bronzed hooks were tied to the droppers. After some experience in the study area, we reduced all large-hook set lines to 10 or fewer hooks. The small-hook set lines had the same basic set up as the large-hook lines except that we used parachute chord for the main line and seine twine for the droppers tied 2/0 and 3/0 Mustad bronzed hooks.

We loaded the baited set line on a wooden platform extending beyond the back of the boat, attached a heavy rock to the distal end with bailing twine and cast it off as we moved over the area of the hole to be fished.

Another rock was attached to the near-shore end of the line to hold the working portion in position on the bottom of the hole and then a lead line was run to a float or tied off on shore. We used primarily carp, sucker, squawfish, bass, herring or smelt as bait. Less frequently we used chiselmouth, channel cat, black crappie, spent kokanee, lamprey, crayfish, squid, beef and pork liver, kidney and pork rind. Our choice of baits was governed mostly by availability and freshness.

Movement and Abundance

Tagging and Marking

To determine movement and abundance, we tagged sturgeon with individually numbered Floy FD-67 anchor tags at the anterior base of the dorsal fin. When it became evident that significant numbers of tags were being shed within a few months time, we began tattooing the fish as well. We used a commercially available horse-lip tattoo instrument and black tattoo ink which enabled us to imprint a three place number almost anywhere on the sturgeon. The white underside of the fish, particularly on the fleshy portion of the rostrum posterior to the barbels and on the broad flat cleithrum of the pectoral girdle, seemed to provide the best areas for lasting marks. The tattoos have proved to be ledgible for at least 982 days and probably will last much longer.

To aid in the determination of daily and seasonal movements, we equipped 11 sturgeon with sonic transmitters and one with a FM radio transmitter. Five of the sonic transmitters were standard Smith Root six-week tags while the other six were specially built for us by Donald Brumbaugh of Tucson, Arizona. The Brumbaugh tags were designed for mounting internally within the fish and had an expected transmitting life of nearly one year. The outer covering of the tags was a biologically inert plastic and wax formed into a cylindrical shape with rounded ends. They were 65 mm (2.56 in) long, 15 mm (0.6 in) in diameter and weighed 17.2 g (0.61 oz). The FM radio tag was specially built for us by Albert R. Johnson of Moscow, Idaho, and was also designed for internal mounting and about a six-month transmitting life. The maximum range of any of the transmitters in the middle Snake environment was rarely more than 0.5 km (0.3 mi) and usually much less.

We mounted the first two Smith Root transmitters externally by tying them in nylon mesh material and attaching this with plastic coated wire to the base of the dorsal fin in similar fashion to a Peterson disc tag. The remaining transmitters were all implanted internally in the abdominal cavity. All operations were performed in the field.

We implanted the transmitters by first positioning the sturgeon on their backs with the belly just above the water line and then anesthetizing them lightly with Tricaine Methanesulfonate (MS 222); small fish in a holding tank and large ones by holding a plastic bag containing anesthetic over their head and gills. We made an incision 2.5 cm (1 in) to 4 cm (1.6 in) long (depending on the thickness of the body wall) directly into the abdominal cavity along the mid-ventral line just anterior to the insertion of the pelvic fins. Care was taken to avoid injuring the large intestine which lays directly beneath this area. We then slipped the tag (which had been dipped in alcohol and then allowed to air dry) directly into the abdominal cavity alongside the large intestine. After some experimentation, we found that a cutting FS needle preswaged to 45 cm (18 in) of 00 braided silk provided the best means of closing the incision. Generally, two interrupted and one mattress sutures were sufficient for good closure.

Population Estimates

We estimated the sturgeon population in various holes and sections of the river by the methods of (1) Schnabel (1938) with modifications by Chapman (1952) and (2) Petersen (1896, cited by Ricker, 1975) with modification by Chapman (1951).

To utilize information from more than one year's tagging for the small (less than 1 m) sturgeon estimates, we assumed a 50% annual downstream movement of fish occurring outside the sampling periods. The rate of downstream movement was based on recaptures of tagged fish during the study.

Age and Growth

We made all length and weight measurements on live, unanesthetized fish. A measuring board was used for fish under 1 m (3 ft) and a steel tape for those larger than 1 m (3 ft). Small fish were hung directly by their operculum from a dial balance and weighed to the nearest 25 g (0.88 oz). Large fish were lifted in a sling from a tripod with a block and tackle and weighed to the nearest 0.25 kg (0.55 lb).

We removed a small section of the first ray of the pectoral fin from most of the sturgeon to determine age and growth history (the sections varied from 5 to 25 mm (0.2 to 0.98 in) in length, depending on the size of the fish). The ray sections were removed from 3 mm to 25 mm (0.12 to 0.98 in) from the fin articulation with horse-hoof nippers and a fillet knife on small fish and a fine-toothed hacksaw on the large fish. Semakula (1968) reported some loss of annuli in sections which were further than 19 mm (0.75 in) from the articulation. We found that the critical distance from the articulation was as little as 5 mm (0.2 in) or less on fish under 50 cm (20 in) in length and up to 35 mm (1.38 in) or more on the large fish. We also found that removing the fin ray section directly adjacent to the articulation often caused excessive bleeding, required longer for the fish to heal and tended to make the fish more susceptible to further damage than if the section was taken at the distal end of the pectoral fin ray. Large fish were more affected than small ones. Therefore, we accepted the possible loss of one or two annuli on a fish 20 or more years of age to reduce the trauma to the fish.

Following the methods of Cuerrier(1951), we used a vice and jeweler's saw to make thin transverse sections of the dried fin rays for viewing under a microscope. Following suggestions of Ivan Donaldson of Stevens, Washington, we cut rather thick sections, about .5 mm (0.02 in), and then polished both sides of the section underwater on 600 grit sandpaper until all saw marks were removed. Properly polished, the fin rays could be examined dry without any clearing agent to distort the distance between annuli. We found that dipping one side of the polished section in a saturated aqueous solution of Indigo Carmine for a few seconds sometimes eased eye strain on sections from particularly slow growing fish.

For aging and back-calculation of total lengths at previous annuli, we placed the ray sections on smoked glass slides and viewed them under a binocular dissecting microscope at 3X magnification in reflected light. The reflected light provides more detail of the ray structure than transmitted light and the dark background makes the translucent annuli stand out more clearly. We used a Bausch and Lomb Micrometer Disc 31-16-02 to measure the total straight line distance from the ray center to the maximum radial extent of each annulus in both the dorsal and ventral axes of the ray.

Using the measurements from 226 sturgeon ranging in total length from 28 to 264 cm (11 to 104 in) (Ivan Donaldson provided us with rays from three sturgeon smaller than 45 cm (17.8 in)), we found the linear relationship between the total length of the sturgeon in centimeters (Y) and the mean, dorsal-ventral ray radius in micrometer units at 3X magnification (X), was described by the equation: $Y = -8.70 + 0.768\ X$. The r^2 value of this relationship was 0.98, and the standard error of estimate 10.13. No significant improvement in fit was found for seven other tested equations which included log transformations and a second degree polynomial.

To see at what rate white sturgeon might grow when exposed to ample food supplies, we fed a 65.2 cm (25.67 in) long sturgeon at saturation levels for 108 days. The fish was held in a 946 ℓ (250 gal) circular tank under lighting and temperature conditions which approximated the June to September period in the Middle Snake River. We fed the sturgeon small pieces of smelt or herring once each day until satiated. All weight and length measurements were made on the anesthetized fish after three days of starving.

To determine how sturgeon growth is recorded in the pectoral fin ray, we added 250 mg/kg of body weight of Tetracycline Hydrochloride (Tetrachel of Rochelle Laboratories, Inc.) to the food of the lab-held sturgeon for four days. Weber and Ridgway (1967) found this sufficient for marking the bones of Pacific salmon with a thin bright yellow mark visible under ultraviolet light. We began this treatment on the 50th day of the feeding experiment.

RESULTS

Fish Tagged

We tagged, measured and released alive 876 white sturgeon during the three year study period. These sturgeon varied in total length from 45 to 274 cm (18 to 108 in) and in weight from 0.4 to 120.0 kg (0.8 to 264.0 lb). Eighty-six percent of the sturgeon were less than 92 cm (3 ft) in total length, 4% were between 92 and 183 cm (3 to 6 ft) and 10% were longer than 183 cm (6 ft).

In addition to the 876 sturgeon released alive, five sturgeon (all less than 1 m long) were mortally wounded by set line hooks (primarily the large-hook lines during high flows); we transported five other sturgeon alive to our lab for observation and development of tagging and tattooing techniques; and cooperating fishermen removed three legal sturgeon (3 to 6 ft) from the Washington portion of the lower Snake River.

We recaptured 204 (23%) of the 876 tagged sturgeon from one to eight times each. The time between captures ranged from less than one day to 1098 days.

We captured all sturgeon from 52 separate holes scattered within the 196 km (122 mi) reach of the Snake River from 8 km (5 mi) above Lower Granite Dam to 18 km (11 mi) below Hells Canyon Dam. Forty other holes between the two dams were fished at least one or more times, but no sturgeon captured. Seventy-nine percent of all captures and 62% of all holes fished were in the 64 km (40 mi) reach of the middle Snake from the mouth of the Salmon River to Johnsons Bar (Table 1).

Table 1. Number of white sturgeon tagged and released in the middle Snake River, May 1972 - June 1975.

Tagging location		Number tagged per length class (total length in cm)			Total number tagged
River km	Nearest landmark	45.0-91.5	92.0-183.0	183.5-273.5	
186.0	Knoxway Canyon	2	1	0	3
194.7	Blyton Landing	3	1	0	4
194.9	Blyton Landing	25	9[a]	3	37
290.3	Cottonwood Creek	71[b]	0	1	72
294.0	Jim Creek	20	1	0	21
298.5	Cherry Creek	1	1	2	4
299.7	Nez Perce Dam Site	23[c]	0	1	24
303.0	Mouth of Salmon River	8	0	1	9
1.6	Salmon River, Needles Eye Rapids	1	1	0	2
305.1	Upper Sheep Creek Rapids #85 (at upper gage)	1	1	4	6
311.7	Big Canyon Range	6	0	0	6
312.7	White Horse Rapids #93	0	2	0	2
320.1	Deep Creek	1	0	3	4
321.4	Big Sulphur Creek	11	0	1	12
324.9	Five Pine Rapids #109	1	0	0	1
326.7	Wolf Creek	0	0	1	1
331.2	Getta Creek	19	0	3	22
332.2	High Range Rapids #115	0	0	1	1
333.6	Lonepine Creek	5	0	1	6

Table 1. Continued.

Tagging location		Number tagged per length class (total length in cm)			Total number tagged
River km	Nearest landmark	45.0-91.5	92.0-183.0	183.5-273.5	
334.7	Lookout Creek	8	0	0	8
335.4	Cottonwood Range #2	2	1	0	3
337.6	Camp Creek	2	0	0	2
338.4	Somers Creek Range	18	0	1	19
340.1	McCarty Creek	7	0	1	8
340.7	McCarty Creek	42[d]	0[d]	4	46
341.0	McCarty Creek	17[e]	1	3	21
342.0	Davis Creek	3	0	1	4
345.5	Pittsburg Rapids #132	2	0	0	2
347.5	Klopton Creek	0	0	2	2
349.9	Upper China Creek Rapids #134	0	0	2	2
351.2	Cat Gulch	5	0	3	8
351.5	Lower Kirby Rapids #136	7	1	2	10
352.0	Kirby Range #2	3	0	0	3
352.4	Middle Kirby Rapids	1	1	0	2
353.9	Royal Gorge	0	1	1	2
354.1	Yankee Bar	29	0	3	32
354.7	Kirkwood Creek	1	0	3	4
358.1	Salt Creek	63	0	1	64
358.6	Suicide Rock	7	0	0	7
358.7	Suicide Rock	7	2[d]	0	9
359.0	Hominy Creek	0	0	3	3

Table 1. Continued.

Tagging location		Number tagged per length class (total length in cm)			Total number tagged
River km	Nearest landmark	45.0-91.5	92.0-183.0	183.5-273.5	
361.3	Unnamed Creek	1	0	2	3
363.2	Hutton Creek	0	0	0	0
364.0	Quartz Creek	0	0	1	1
365.0	High Bar Rapids #150	58[d]	5	5	68
366.1	Willow Creek	191[e]	1[c]	3	195
366.8	Sand Creek	6	0	4	10
367.4	Eagle Nest Rapids #153	0	0	1	1
368.4	Steep Creek	78	3	3	84
369.0	Sheep Creek	0	0	1	1
381.6	Dry Gulch	0	0	4	4
383.0	Three Creeks	1	0	10	11
	Total	757	33	86	876

[a] An additional three sturgeon were removed by cooperating fishermen.

[b] An additional two sturgeon were removed for laboratory study and one of these was later released with a sonic transmitter near Knoxway Canyon.

[c] One additional sturgeon was removed for laboratory study.

[d] One additional sturgeon was mortally wounded on a large hook set line.

[e] One additional sturgeon was removed for laboratory study and later released with a sonic transmitter near Granite Point.

We captured 61% of all sturgeon by rod-and-reel, 26% on small-hook set lines and 13% on the large-hook set lines. For fish less than 1 m in length, we captured as many as two at a time by rod-and-reel and nine per one 13-hook set on the small set lines. We captured up to four sturgeon longer than 2 m (6.6 ft) per set on the large, ten-hook lines. All three methods of fishing hooked sturgeon of nearly every size, however, the large-hook lines were most effective at retaining sturgeon over 2 m (6.6 ft) and least effective at capturing sturgeon less than 1 m (3.3 ft) long. Small-hook set lines readily hooked large sturgeon, but only rearely contained them. Our fishing efficiency increased significantly each year for rod-and-reel and small-hook set lines, but not for the large lines (Table 2 and 3).

Table 2. Fishing effort (March-August) and catch rate using rod-and-reel in 39 km (24 mi) of the middle Snake River from Getta Creek to Johnsons Bar, 1973-75.

Year	Hours fished	Sturgeon per hour by length class (total length, cm)			Fish per hour
		45.0-91.5	92.0-183.0	183.5-273.5	
1973	635	0.25	.01	0	0.26
1974	524	0.46	.01	<0.01	0.47
1975	101	0.83	.01	0.01	0.85

Table 3. Fishing effort and catch rate using set lines in 39 km (24 mi) of the middle Snake River from Getta Creek to Johnsons Bar, 1973-75. Data present here for small hook lines occurred during March-July and those for large-hook lines extended from March-September.

Year	Number of sets	Sturgeon per set by length class (total length, cm)			Fish per set
		45.0-91.5	92.0-183.0	183.5-273.5	
Small-hook set lines (13, 2/0 to 3/0 hooks):					
1973	21	0.33	0	0	0.33
1974	12	1.25	0.08	0	1.33
1975	126	1.44	0.06	0.01	1.51
Large-hook set lines (10 to 12, 11/0 to 14/0 hooks):					
1973	162	0.03	0.03	0.19	0.25
1974	219	0.05	0.01	0.16	0.21
1975	65	0.06	0.02	0.18	0.26

Activity and Movement

We successfully fished for sturgeon during all periods of the day and night and in every month of the year in water temperatures ranging from 2.2 to 22.2° C (36 to 72° F). As judged by catch rates with baited hooks, sturgeon feeding activity varied seasonally, but never completely ceased. We found our best fishing during daylight hours (in many of the holes fished, sturgeon inhabited depths where light penetration is nonexistent or minimal during much of the year).

Small sturgeon between 60 and 92 cm (24 and 36 in) in length tended to move downstream during the study period. We recaptured fish that had moved 1 to 39 km (0.6 to 24.2 mi) downstream. Forty-three percent of the larger recaptured sturgeon over 2 m (6.6 ft) long had moved from the original site of capture. Movements of the larger fish were both upstream and downstream and their movements were more localized than those of the small fish.

Daily

During April and May, 1975, we fished identical areas during the day and night with small-hook set lines. The mean catch rate for set lines fished in daylight hours was 1.54 sturgeon per set compared to 1.48 sturgeon per set for the same lines fished overnight. Because the distribution of "sturgeon per set" is not normally distributed, we used a Mann-Whitney U-test (Sokal and Rolf, 1969) to determine any significant difference in the day and night catches. The catches were not significantly different as the probability of obtaining a deviation as great or greater by chance alone was 0.2 - 0.4 (Table 4).

Table 4. Comparison of the number of sturgeon per set caught on small-hook set lines fished in identical areas during daylight hours and overnight, middle Snake River, April and May, 1975.

Sturgeon per set	Number of day sets	Number of night sets
0	16	29
1	18	14
2	15	10
3	4	4
5	3	2
6	0	3
7	0	0
8	1	0
9	0	1
Total number of sets	59	67
Mean number of sturgeon per set	1.54	1.48

While fishing for small sturgeon with rod-and-reel, we had the fastest short term catch rate of the study near midday (2.5 sturgeon per hour per rod from noon to 1500 on May 5, 1975). Several instances of all night fishing failed to produce better than average catch rates, even in instances where good catch rates were experienced in the same areas in the preceding daylight hours. We also obtained maximum catch rates with rod-and-reel for large sturgeon near midday in the areas upstream from Johnsons Bar where the large fish were most abundant.

At about two hour intervals during August 20-22, 1973, we followed the movements of two sturgeon (over 2 m (6.6 ft) long) equipped with sonic transmitters. The river flows were low at this time, varying from 266 to 337 cms (9,400 to 11,900 cfs) and water temperatures ranged from 20 to 21.5^{o} C (68 to 71^{o} F). Both fish had received their transmitter implants at least eleven days prior to this monitored period and appeared to have recovered from the few days of reduced movement which sometimes accompanies the operation.

During the period of intensive tracking, one fish moved only within a large eddy just downstream from Lower Kirby Rapids on the Idaho side of the river. This was the area in which it had been captured and released. The eddy was about 160 m (100 ft) long and 130 m (427 ft) wide with a maximum depth of 7.5 m (24.6 ft) at that time. During both nights, the sturgeon moved primarily to the outer edges of the hole, particularly to the more shallow upstream end just below the rapids during the second night. Near daylight of both days, it appeared to settle back near the maximum depth area of the hole. At no time, however, did it appear to remain nearly motionless between any two hour period (Figure 2).

The second sturgeon monitored during the same time had similar movements in another eddy 0.6 km (0.37 mi) downstream from Lower Kirby Rapids (Figure 3). It had moved downstream through a short rapids (Durham Rapids) to the next hole shortly after release. It was observed on August 20-22 moving within that hole, and then on the morning of August 23, found 0.6 km (0.37 mi) upstream at Lower Kirby Rapids (0.3 km (0.19 mi) upstream from its original capture and release site).

We made periodic observations of other sturgeon with sonic transmitters to determine gross movement. Nearly all such observations were made during daylight hours and most of the fish were found near the central deep portion of the hole or in the lower end. Turbulent waters shortened the transmitting range of the tags and created false directional signals so that the precise location of most of the sturgeon was impossible to ascertain and often hampered our finding the fish. These problems probably biased our observations because we could not find the sturgeon if they were in or too near rapids.

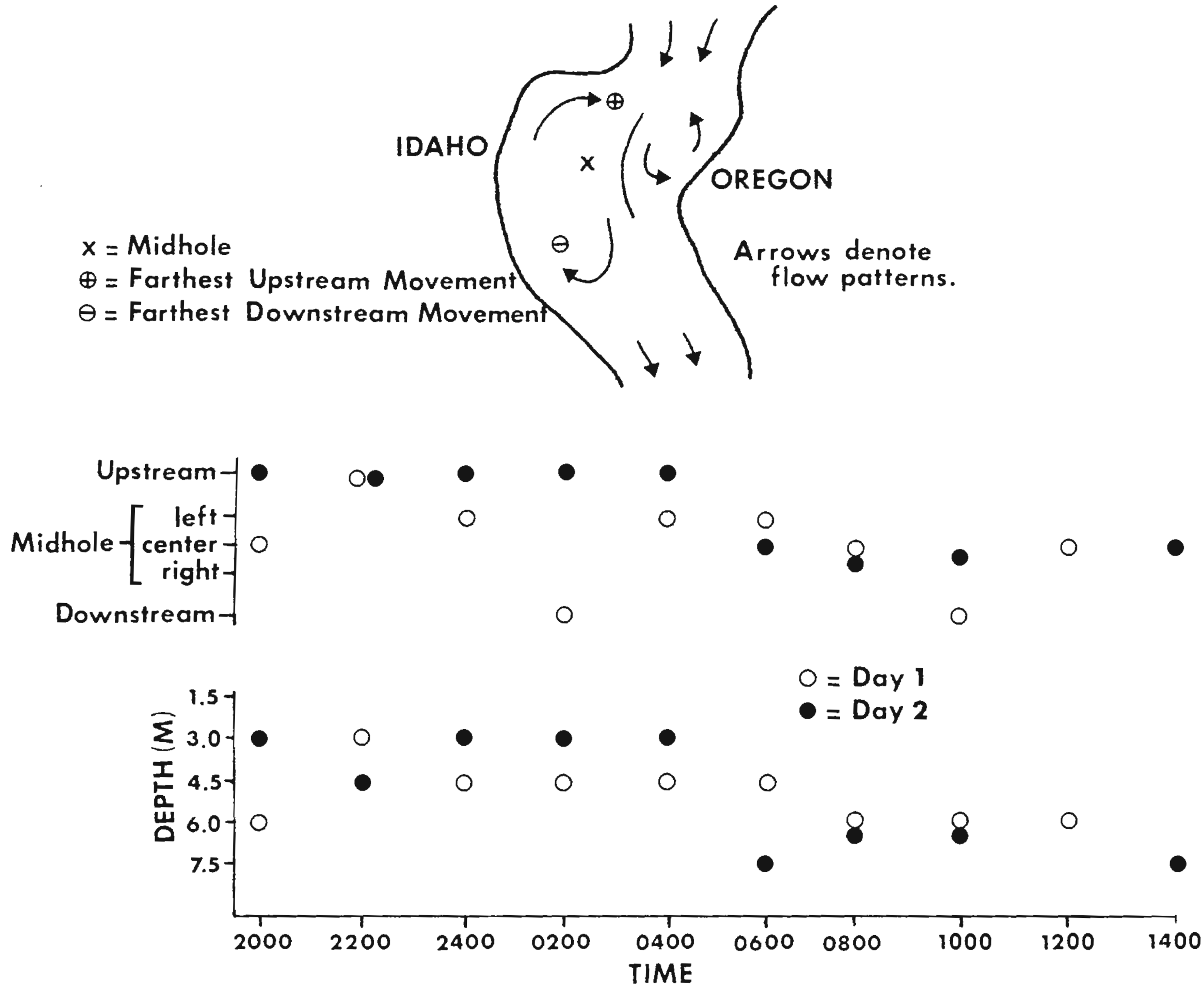

Figure 2. Daily movements of a 217 cm long white sturgeon equipped with a sonic transmitter in a large eddy just downstream from Lower Kirby Rapids in the middle Snake River, August 20-21, 1973.

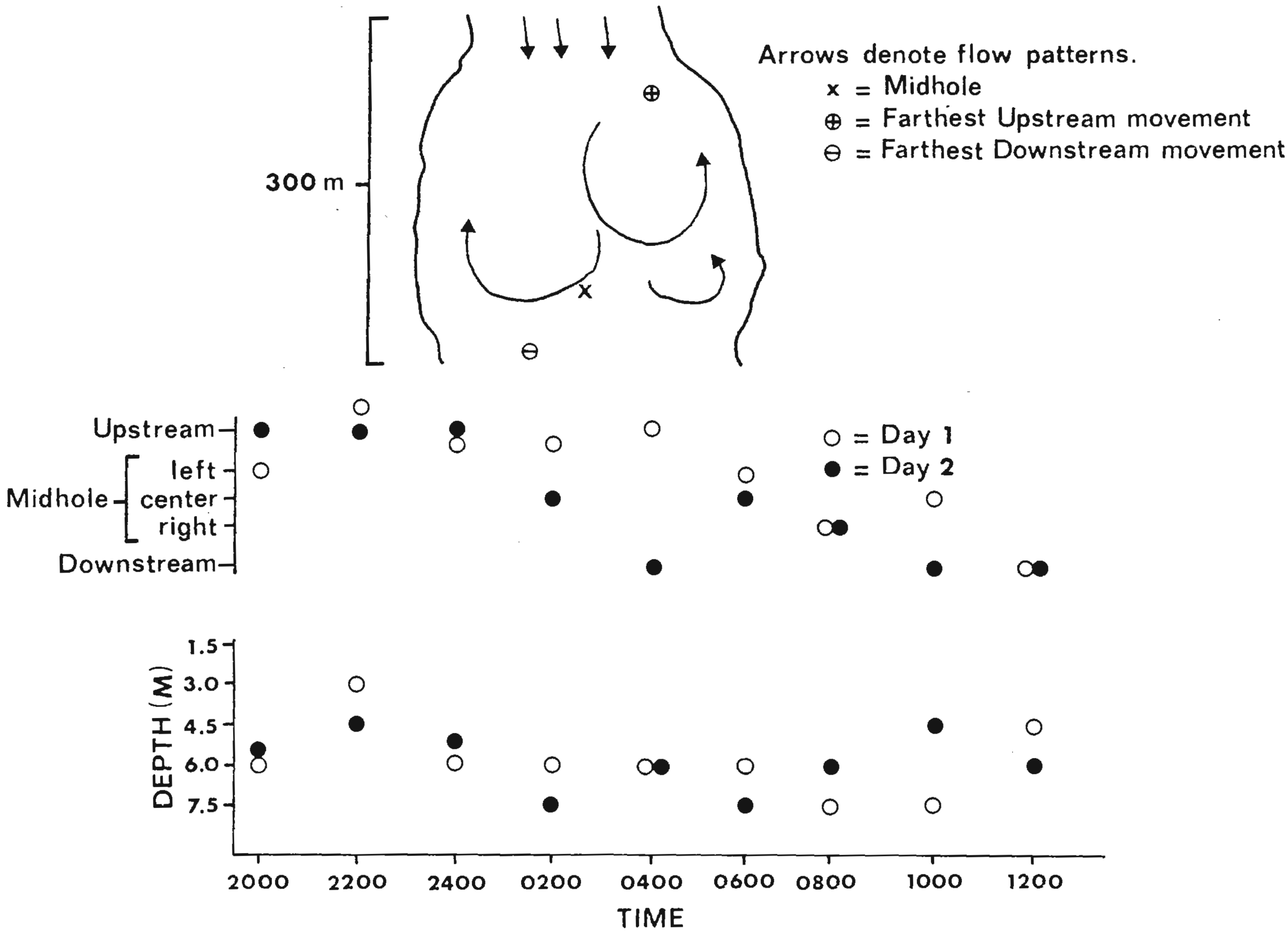

Figure 3. Daily movements of a 232 cm long white sturgeon with a sonic transmitter in a large eddy just downstream from Durham Rapids on the middle Snake River, August 20-21, 1973.

Seasonal

Because our ability to fish specific holes varied each month and year with the magnitude of water released from Hells Canyon Dam, it is difficult to establish any seasonal variation in the feeding activity of the sturgeon as indicated by changing catch rates for our fishing gear. From March through August (the period of our most intensive fishing) it appears that the catch rate for sturgeon varied as much with our knowledge of the river and how to fish it as with any difference in sturgeon feeding activity.

In 1973 (a year with small flows) our monthly rod-and-reel catch rates for small sturgeon from three selected holes were fastest during March through June (0.59 fish per hour), then decreased drastically in July and August (0.15 fish per hour). Part of this decrease was probably due to small sample size in August and inexperienced fishing. In 1974 (a year with three times the average daily flows of 1973 during May, June and July) our May and June catch rate for the same three holes was 0.74 fish per hour and dropped only to 0.53 during July and August. The monthly catch rates for large sturgeon on the large-hook set lines were fastest in June of 1973 and July of 1974. These rates may be related to the magnitude of flow which restricted the areas in which the lines could be fished and also made it harder to lay a good set. The August catch rates for large fish on the large-hook set lines were below average in both years; however, rod-and-reel fishing upstream from Johnsons Bar was excellent in August, 1974.

From November 20, 1974 to February 14, 1975, we fished intensively for sturgeon in the lower Snake River downstream from Lewiston, Idaho. Water temperatures during this time dropped from 9.4 to 2.2° C (49 to 36° F) and several weeks of day and night fishing with all three types of gear yielded only 11 sturgeon. We had captured as many sturgeon from one of these holes in a single night in July. While sturgeon activity was undoubtedly decreased at this time, there were probably other factors causing the extremely poor fishing. On December 21-22, we captured four small sturgeon in 4 hours of rod-and-reel fishing at Salt Creek, about 165 km (102.5 mi) upstream in the middle Snake River.

We recaptured 178 (24%) of our total catch of small (less than 92 cm (36 in) long) sturgeon. All but three could be positively identified as to the time and place of the original capture. Thirty-nine (22%) of the 175 recaptured fish had moved downstream from their original release sites during the study period, 4 (2%) upstream, 1 fish went upstream and then back downstream to the original release site, and 131 (75%) were recaptured in the release pools. The average total time at large for all 175 fish was 297 days (Table 5).

Table 5. Movement summary of recaptured white sturgeon 45.0 to 91.5 cm (18 to 36 in) in total length in the middle Snake River, 1972-75.

Movement direction	Number of fish	Distance (km)		Total days at large		Mean total length prior to movement (cm)
		Mean	Range	Mean	Range	
Downstream	39	8.61	1.1 to 39.3	444	30 to 998	69.6
Upstream	4	3.15	1.0 to 7.1	183	39 to 325	65.5
Multi-directional	1	1.4	-	336	-	81.0
None	131	-	-	257	1 to 1098	66.7

The 39 sturgeon found downstream had moved an average of 8.6 km (5.3 mi) in 444 days at large. The largest downstream movement recorded was 39.3 km (24.4 mi) in 270 days and the fastest was 7.6 km (4.7 mi) in 42 days. We did recapture one sturgeon downstream from Lewiston in January of 1975 which had lost its tags and had no tattoo. As judged by the location and regeneration of the pectoral fin clip, this fish would have been originally released in 1972 or 1973 a minimum distance of 95 km (59 mi) upstream.

Most downstream movement of small sturgeon occurred between the end of August and the first of April. Only four small sturgeon were recaptured downstream within 90 days or less of their previous capture. In 1974, two fish tagged after mid-March were found 74 and 78 days later in early June at 2.3 and 2.9 km (1.4 and 1.8 mi) downstream. One fish tagged on 26 April was recaptured 30 days later in May at 3.4 km (2.1 mi) downstream. Despite intensive sampling in consecutive holes, no fish tagged or recaptured during May, June, July or August of any year were recaptured downstream before April of the following year. In 1975, one fish tagged on 9 April was recaptured 42 days later 7.6 km (4.7 mi) downstream. No other recaptured sturgeon moved downstream during April and May of 1975 despite intensive and successful fishing in consecutive holes during this time.

The larger size of tagged sturgeon which we recovered downstream versus those we recaptured in the same area as tagged and the relative scarcity of fish 75 to 100 cm (30 to 39 in) in the middle Snake River area was additional evidence of downstream movement by 60 to 100 cm (24 to 39 in) sturgeon. The mean total length of the 39 sturgeon which moved downstream prior to their recaptures was 69.6 cm (29.4 in). Mean length of 74 sturgeon which were recaptured in the same hole a year or more later was 65.8 cm (25.9 in) (difference between the means is significant by a t-test at $.02>P<.01$) The number of sturgeon between 70 to 75 cm (28 to 30 in) was less than 50% of the number between 60 to 65 cm (24 to 26 in) for all sturgeon caught in the middle Snake during the study (Figure 4).

The four small sturgeon recaptured upstream had moved an average of 3.14 km (1.95 mi) and 183 days had elapsed between tagging and recapture. The fastest and farthest movement recorded was 7.1 km (4.4 mi) in 39 days

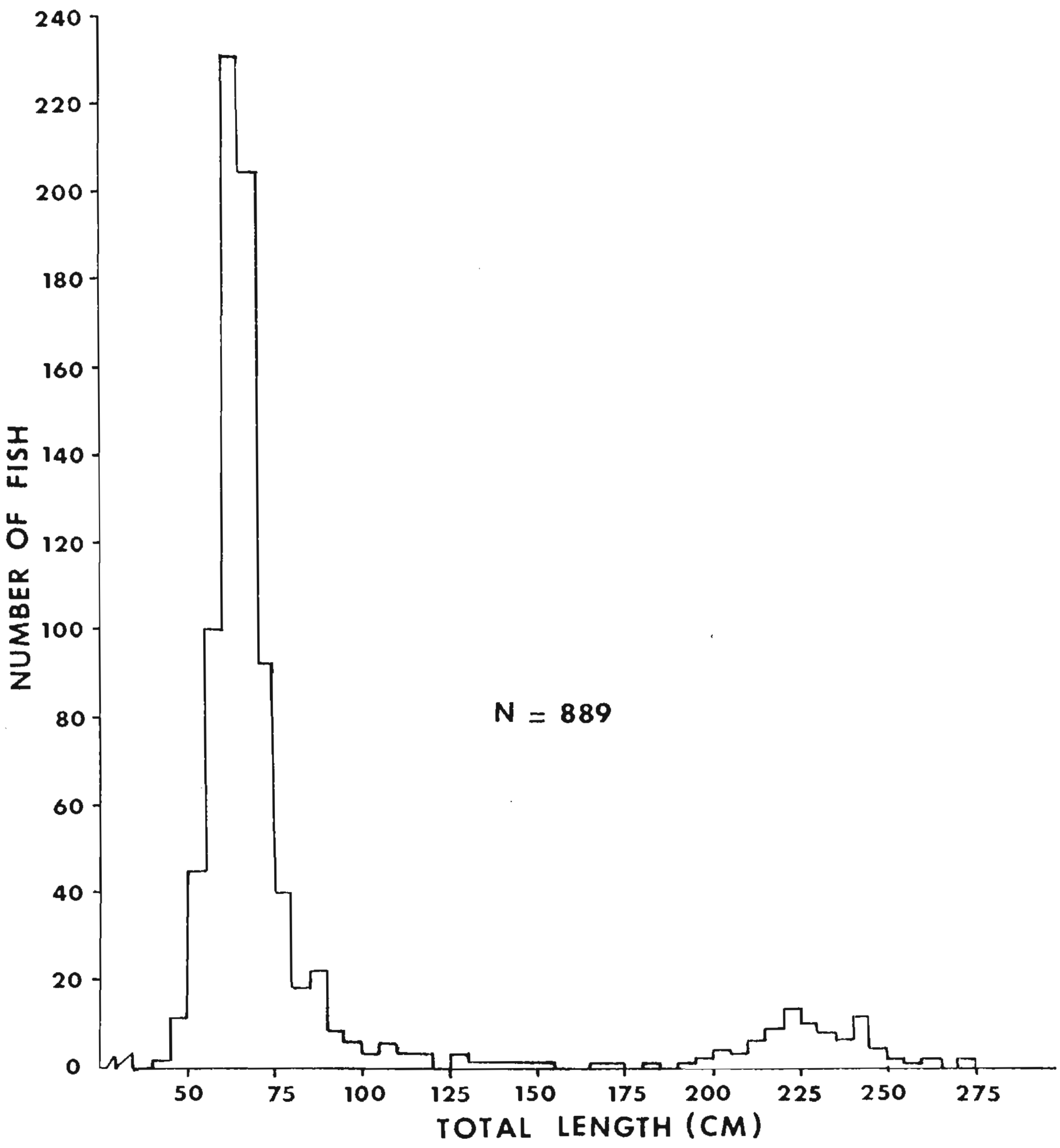

Figure 4. Length frequency distribution of white sturgeon captured by rod-and-reel and set lines in the middle and lower Snake River, river kilometer 185 to 383, 1972-75.

from June 28 to August 6, 1974. This and one other sturgeon moved during the June to August time period. The remaining two were marked in late June and early July of 1974 and recaptured in early May of 1975. The mean total length of these fish was 65.5 cm (25.8 in) (Table 5).

From May through August of 1974, we tagged 266 small sturgeon (less than 92 cm (36 in) long) in the 36 km (22.4 mi) of river between Lonepine Creek and Johnsons Bar. By June 6, 1975, we had recaptured 24 (9%) of these fish a mean distance of 9.1 km (5.66 mi) downstream from their initial 1974 locations (23 of the 24 were recaptured in April-June 1975); four (2%) at 3.1 km (1.9 mi) upstream and 21 (8%) were recaptured in the same pool in April-June 1975. These movements represent minimum estimates of the actual movement during this overwinter period.

Another estimate of the extent of movement during 1974-75 can be obtained from the proportion of the recaptured fish which moved. Forty-six percent of the fish recaptured had moved downstream and 5% upstream (Table 6). If, in 1975, we had caught an equal percentage of the sturgeon upstream and downstream from each hole with marked fish released in 1974 as we did within the hole itself, then the preceding estimates would be unbiased estimates of the percentage of fish which moved. Unfortunately, the diversity of the river, total area to be fished (two recaptures were made 39 km (24 mi) downstream) and lack of good population estimates for most of the holes fished made it difficult to determine how well this assumption was met. The disproportionate fishing effort and success in the upper holes of the study section, when compared to the many kilometers below, point to the 46% annual downstream movement as being a conservative estimate.

We recaptured only three (9%) of 33 sturgeon between 92 and 183 cm (3 to 6 ft) long. They showed no movement outside their hole of original capture. We recaptured one of these fish at least once each year from 1973-75.

Table 6. Movement of white sturgeon 45.0 to 91.5 cm long tagged from March through August 1974 and recaptured from April through June 6, 1975 in the middle Snake River. All marked fish were released from river kilometer 331.2 to 368.4 in 1974 and fishing for recaptures in 1975 covered the sample area plus 41 more kilometers downstream.

Original location	Number tagged 1974	Total number recaptured	Movement, number and percent of sturgeon recaptured in 1975					
			Downstream		Upstream		None	
			Number	Percent	Number	Percent	Number	Percent
Steep Creek	35	7	3	43	0	0	4	57
Sand Creek	3	0	0	0	0	0	0	0
Willow Creek	81	16	6	38	0	0	10	63
High Bar	46	8	4	50	2	25	2	25
Salt Creek	15	1	0	0	0	0	1	100
Yankee Bar	1	1	0	0	0	0	1	100
Lower Kirby	1	0	0	0	0	0	0	0
Lower McCarty Creek	51	5	4	80	0	0	1	20
McCarty Creek	8	0	0	0	0	0	0	0
Somers Creek Range	10	2	1	50	0	0	1	50
Lonepine Creek	4	1	1	100	0	0	0	0
Total	255	41	19	46	2	5	20	49

We recaptured 23 (27%) of 86 sturgeon longer than 183 cm (6 ft). Their mean total time at large was 352 days. One of these fish was captured 7 times from September 1972 to September 1973. In March and May 1972, it was in the same hole as released, in June it was 1.1 km (0.68 mi) downstream, in August 14.9 km (9.3 mi) and in September it had begun moving back upstream and was only 12 km (7.5 mi) below the original hole. This was the farthest downstream movement recorded for any of these large sturgeon and also the farthest gross movement. Most of the observed movements were more localized and random.

We found that 4 (17%) of the recaptured large sturgeon had moved downstream, 3 (13%) upstream, 2 (9%) showed multidirectional movement and 14 (61%) were found in the original hole. Recently, one sturgeon recaptured two years after the end of our field work and 982 days after its release was found 4 km (2.5 mi) upstream. Of the large fish moving downstream, one moved 6 km (3.7 mi) in 162 days between March and August 1974, two moved 7 and 4 km (4.3 and 2.5 mi) each from July and August 1974 to May 1975, and the fourth fish moved 3 km (1.9 mi) between August 1973 to May 1975. One fish recaptured upstream moved 2 km (1.2 mi) in 32 days from July to August 1973 while another moved a little over 2 km (1.2 mi) from June to August 1974. The third upstream recapture covered a period of more than one year and only about 1 km (0.6 mi) of movement (Table 7).

Due to tag shedding, malfunctions, or turbulent water, we could only monitor 9 of the 12 sturgeon equipped with sonic or radio transmitters for more than one day. The mean number of days from release to the final observation for these nine fish was 62 days. During that time we found a mean net movement from the hole of release of 2.5 km (1.6 mi) downstream (3.0 km (1.9 mi) upstream if we eliminate one fish which may have shed the transmitter. We did not calculate gross movement for most of the tagged fish as we were not able to monitor them on a continuous basis and any estimate would understate the actual movement (Table 8).

Table 7. Movement summary of recaptured white sturgeon 183.5 to 273.5 cm (72.2 to 107.7 in) in total length in the middle Snake River, 1972-75.

Movement direction	Number of fish	Distance (km) Mean	Range	Number of days between first and last capture Mean	Range
Downstream	4	5.1	3.4 to 7.1	356	162-677
Upstream	3	1.7	1.3 to 2.3	380	32-696
Multi-directional	2	9.9	1.9 to 17.9	498	342-654
None	14	0.1	0.0 to 0.3	324	34-745

Table 8. Movement of white sturgeon with sonic transmitters in the middle Snake River, 1972-75.

Total length (cm)	Date released	Days to final observation	Net movement from original hole (km)[a]	Remarks
115	7/14/72	20	-5.5	Tag may have been shed
116	6/5/74	1	0	Tag was shed
144	7/24/73	1	0	Tag malfunctioned
196	6/13/74	130	0	
217	8/7/73	16	0	
226	8/6/74	51	0	
229	7/3/74	56	+2.7	Gravid female
231	7/26/72	1	0	
233	8/9/73	29	+0.3	
236	8/27/74	68	0	
244	6/26/74	178	0	Moved 1 km upstream before returning to hole of release
274	4/21/74	14	0	FM radio transmitter

2 A net movement of zero does not indicate that the fish remained in the identical spot in which released, but that it was still within the defined habitat area or hole in which it was released. Some of the defined habitat areas are as much as 0.3 km long and 0.2 km wide.

Five of the nine transmitterized fish were never observed outside the hole of release, but with days or weeks between observations the fish may have moved out of the holes and returned between observations. One gravid female released 3 July 1974 remained in the same general area for the next six days and then 17 days later was found 1.9 km (1.2 mi) upstream. The fish remained at this new hole for at least 19 days and then was not found again until 14 days later when it was discovered another 0.8 km (0.5 mi) upstream. This was the last fix we were able to obtain on this fish, even though the transmitter should have had several months of life left. One fish, as already noted under daily movements, appeared to return to near its capture site after being displaced downstream shortly after release. The third fish found moving was monitored over the longest period of the study (178 days). It was a recaptured fish when transmitterized in June 1974 and was known to have been 0.6 km (0.37 mi) upstream in July 1973. During July and August, it moved back to the 1973 capture site 0.6 km (0.37 mi) upstream where frequent observations indicated that it probably remained through 6 August. On 7 August it was found back downstream at the June 1974 release site and then on 8 August back upstream 0.8 km (0.5 mi). On 9 September, we found it another 0.3 km (0.18 mi) upstream, on 26 September back downstream 0.3 km (0.18 mi) and in November it was back to the June 1974 release site (Figure 5).

The only other fish found moving was one which went downstream 5.5 km (3.4 mi) in less than 20 days. This fish represented our first externally mounted transmitter. This, and the fact that the areas in which the tag was located were not always what we have found to be usual habitat for most sturgeon, indicates the tag might have come off and washed downstream.

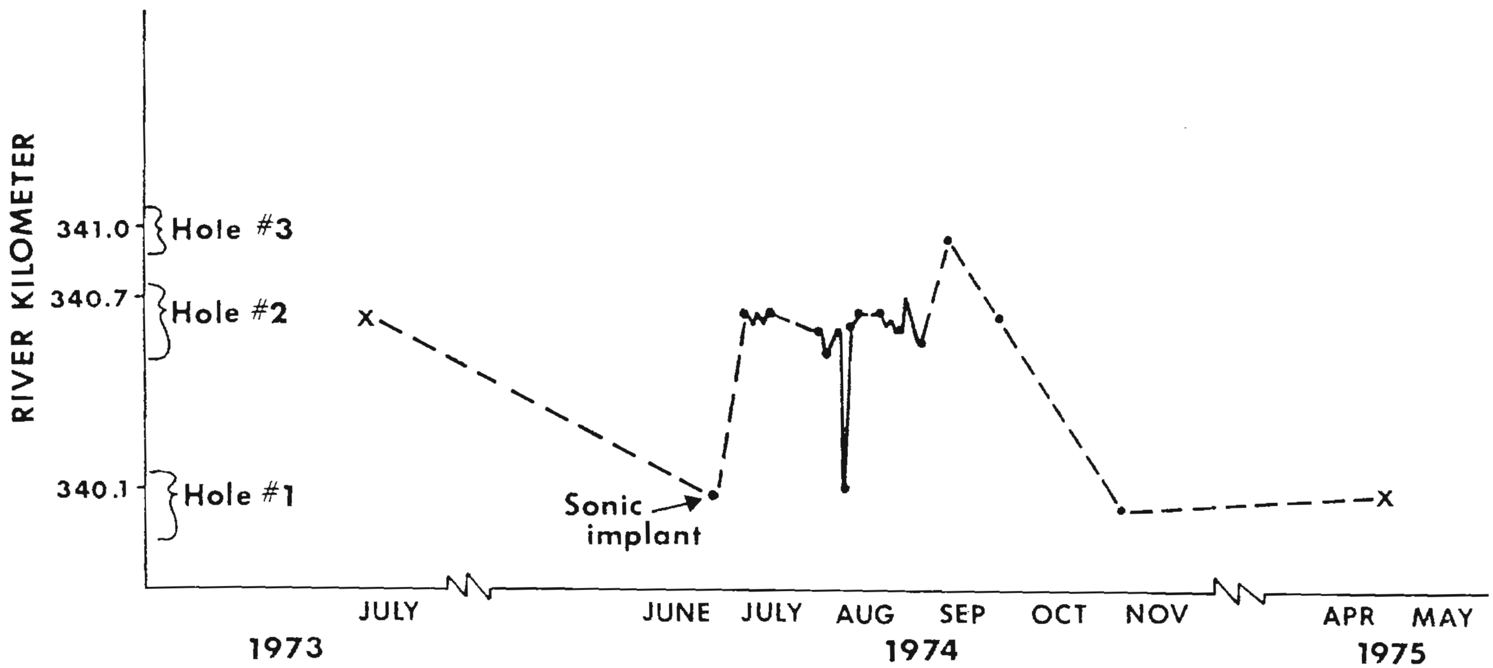

Figure 5. Movement of a 244 cm long white sturgeon in the middle Snake River as determined by recapture and monitoring of a sonic transmitter within the fish, 1973-75.

Abundance

Using our standard fishing gear, we could successfully catch sturgeon 45.0 to 274 cm (18 to 108 in) total length. Small sturgeon were fully recruited to the gear when 60 cm (23.6 in) in length. Undoubtedly, smaller sturgeon do exist somewhere in the study area, but limited electroshocking, seining and fyke net sets, in addition to our standard fishing, failed to produce any. A few larger sturgeon were probably also present.

The sample of 889 white sturgeon captured during the study consisted of 765 (86%) less than 92 cm (3 ft) long, 38 (4%) from 92 to 183 cm (3 to 6 ft) and 86 (10%) over 183 cm (6 ft). The recapture percentages for each of these three size classes (23, 14, and 27%,respectively) indicate that the sampled abundance of each class as a proportion of the whole sample may not precisely reflect the true population composition. Mid-size sturgeon were recaptured at a lesser rate than smaller or larger fish, perhaps because they were moving out of the area we sampled. We believe the sample reflects the length class abundance of sturgeon 60 to 274 cm (23.6 to 107.9 in) presently found in the middle Snake River. Sturgeon captured from six intensively fished holes had similar size-abundance patterns (Figures 6 and 7). Most of the fish were small, with few mid-size fish and a larger number of large fish.

Due to the sturgeon movement patterns, the variable habitat of the river, and unequal past fishing pressure, we expected to find differences in the length class abundance of the fish within various sections of the study area. We found that the most apparent differences in relative abundance occurred in the white-water region above Johnsons Bar (the head of navigation for most boaters) and in the lower river downstream from Lewiston which was just upstream from Little Goose Reservoir at the time of the study (Figure 7).

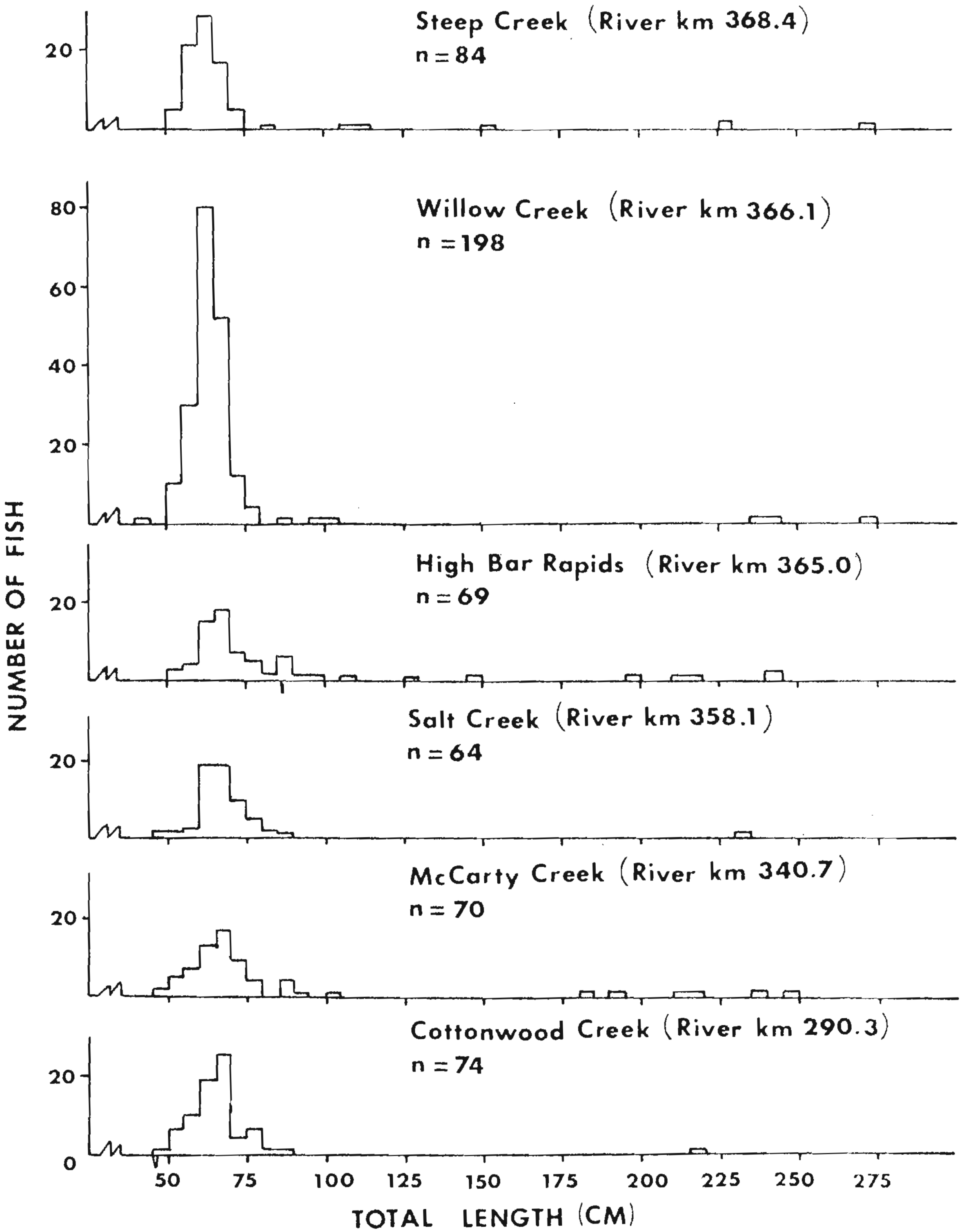

Figure 6. Length frequency distributions of white sturgeon captured by rod and reel and set lines for six separate holes in the middle Snake River, 1972-75.

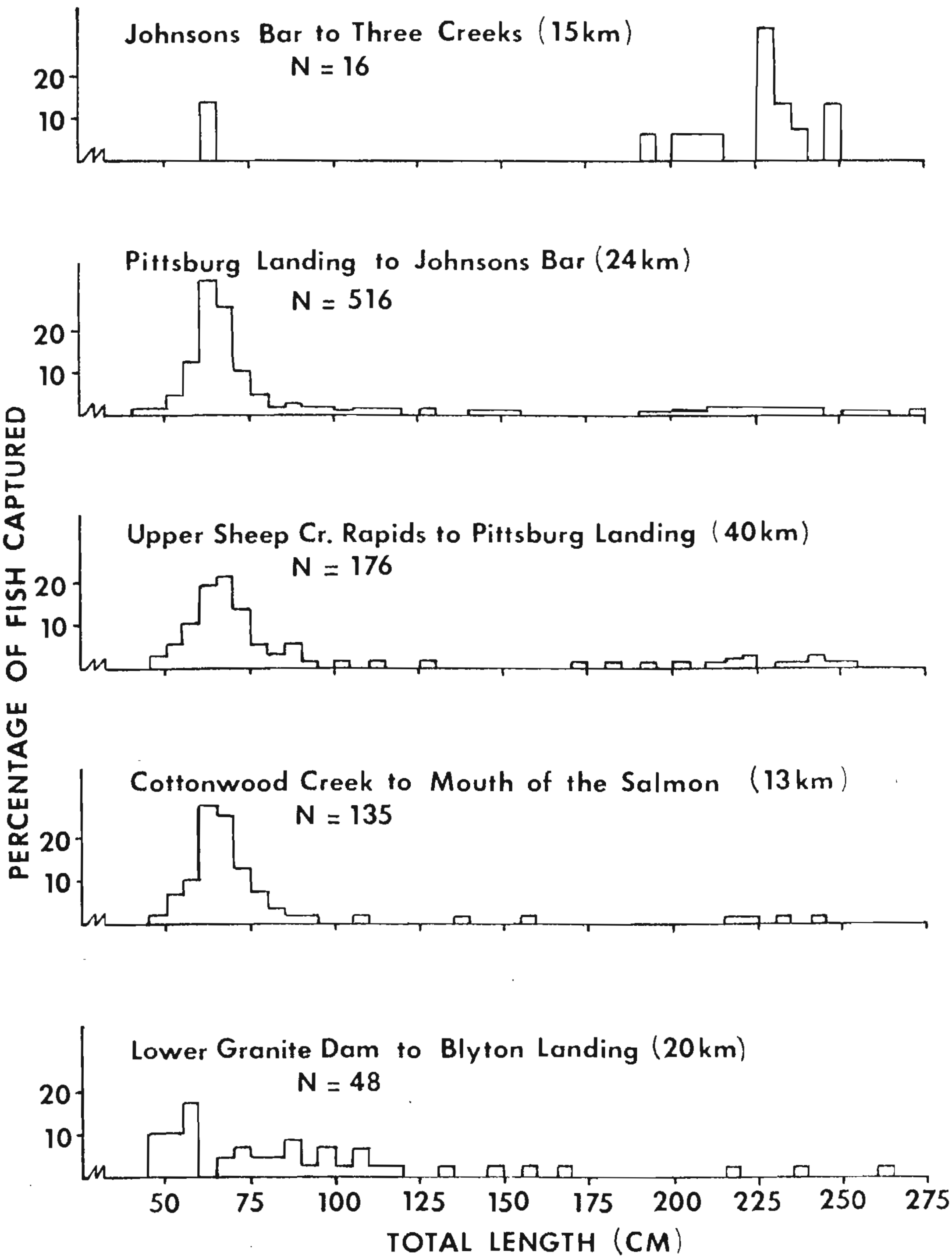

Figure 7. Length frequency distributions of white sturgeon captured by rod and reel and set lines in five different sections of the middle and lower Snake River, 1972-75.

Limited sampling in the holes above Johnsons Bar indicated that large sturgeon over 2 m (6.6 ft) long may be at least twice as abundant per hole in this area as in any of the sections below. Very few small sturgeon were caught in this area in proportion to the large fish, but this may be due to insufficient sampling.

From Johnsons Bar downstream to Pittsburg Landing, 24 km (15 mi), large populations of small sturgeon were found in the big, sandy-bottomed holes at Steep Creek, Willow Creek, High Bar Rapids, Salt Creek and Yankee Bar. Downstream from Pittsburg Landing to near the mouth of the Salmon, 40 km (25 mi), the canyon narrows and the smaller, deeper and more turbulent holes produced a slightly larger proportion of large and middle sized fish. The 13 km (8 mi) of river which we sampled directly downstream from the mouth of the Salmon had large, deep, sandy-bottomed holes which contained large numbers of small sturgeon.

In the 20 km (12.4 mi) of river upstream from Lower Granite Dam (pre-impoundment), we found a larger proportion of mid-sized sturgeon than in any of the upstream sections in spite of continued legal fishing for 92 to 183 cm (3 to 6 ft) sturgeon. Twenty-nine percent of the sturgeon sampled downstream from Lewiston were between 92 and 183 cm (3 to 6 ft) long, compared to 3% for the entire area upstream. The lower river had fewer deep holes than found above, but the ones we fished were large, sandy-bottomed holes with similar depths as holes in the upper section which contained large numbers of sturgeon.

We estimated the abundance of small sturgeon in nine holes within the middle Snake. The best estimates were for the Willow Creek Hole, particularly the 1973 estimate (Table 9). Data for the other eight holes was too scanty in all but one year to provide acceptable estimates (Table 10).

Table 9. Estimation of the number of small white sturgeon (45.0 to 91.5 cm long) inhabiting the Willow Creek hole of the middle Snake River, 1973-75. The estimates are based on the method given by Schnabel (1938) with an adjustment suggested by Chapman (1952). The number of marked fish present is adjusted by 50% annual downstream movement occurring outside the sampling period.

Date	Marked fish at large	Number caught	Recaptures	Population estimate
1973				
13 June	69	12	6	118
14 June	75	11	3	206
15 June	83	7	3	145
25-29 June	87	31	9	270
17-27 July	109	7	4	153
20 August	112	2	1	112
			26	
Total estimate				219
95% Confidence Interval				156-348
1974				
27 May-3 June	56	14	4	157
4-6 June	66	13	8	95
13 June	68[a]	7	2	159
18-19 June	73	14	6	146
20-25 June	91	13	4	237
1-3 July	100	3	2	100
19-23 July	101	8	5	135
24-26 July	104	10	4	208
14-30 August	110	10	3	275
7 September	117	2	2	78
			40	
Total estimate				190
95% Confidence Interval				143-273
1975				
9-11 April	59	14	6	118
6 May	67	8	4	107
7 May	71	8	3	142
8 May	76	7	4	106
10 May	79	7	2	184
16-20 May	84	6	6	72
3-4 June	84	4	3	84
			28	
Total estimate				133
95% Confidence Interval				95-207

[a] Three mortalities were subtracted from the number of marked fish at large.

Table 10. Estimation of the number of small white sturgeon (45.0 to 91.5 cm long) inhabiting various holes of the middle Snake River, 1974-75. The estimates are based on the method given by Schnabel (1938) with an adjustment suggested by Chapman (1952). The number of marked fish present is adjusted by a 50% annual downstream movement occurring outside the sampling period.

Date	Marked fish at large	Number caught	Recaptures	Population estimate
Steep Creek (River km 368.4) 1975				
5-6 May	20	29	2	193
7-8 May	47	15	4	141
10-16 May	58	6	4	70
17-21 May	60	3	1	90
			11	
Total estimate				151
95% Confidence Interval				92-336
High Bar Rapids (River km 365.0) 1975				
7-18 May		13	3	75
24 May-4 June		9	3	74
			6	
Total estimate				85
95% Confidence Interval				46-271
Salt Creek (River km 358.1) 1975				
9-10 April		13	4	26
15-26 April		5	1	48
6-10 May		10	4	46
16-20 May		18	0	-
24 May-5 June		13	2	204
			11	
Total estimate				132
95% Confidence Interval				81-294
Yankee Bar (River km 354.1) 1975				
16-17 May		16	1	80
18-24 May		5	1	63
26 May-5 June		9	1	131
			3	
Total estimate				137
95% Confidence Interval				62-910

Table 10. Continued.

Date	Marked fish at large	Number caught	Recaptures	Population estimate
Lower McCarty (River km 340.1) 1974				
30 July-2 August	11	11	2	40
5-9 August	19[a]	10	1	95
19 August-9 Sept.	28	14	4	78
			7	
Total estimate				88
95% Confidence Interval				49-241
Nezperce Dam Site (River km 299.7) 1975				
22-24 April	9	12	2	36
2 May-6 June	19	5	2	32
			4	
Total estimate				41
95% Confidence Interval				20-203
Jim Creek (River km 294.0) 1975				
22-23 April	6	7	2	14
2-4 May	11	9	2	33
6 June	18	2	1	18
			5	
Total estimate				30
95% Confidence Interval				15-111
Cottonwood Creek (River km 290.3) 1975				
9-10 March	9	11	1	50
1-2 April	19	5	1	50
22-23 April	23	15	3	86
24 April-4 May	35	11	1	193
6 June	45	5	1	173
			7	
Total estimate				144
95% Confidence Interval				80-410

[a] One mortality was subtracted from the number of marked fish at large.

The 1975 population estimate for Willow Creek was 39% less than for 1973 (217 to 133 sturgeon). We believe this was not a true reflection of the actual population change. In 1975, we could only fish small portions of the outer area of the hole as river flows were four times larger than they had been during our 1973 fishing. In 1975, we believe we were fishing mostly on a subpopulation of fish which inhabited a small area of the hole and did not have time to become randomly mixed with the entire population, a situation which would underestimate the total population.

In all cases where we calculated population estimates from only 1975 marks and recaptures, we obtained lower estimates than previous years estimates or lower estimates than when we used marks from several seasons and an adjustment for migration loss between years. Estimates for holes which we believed (from catch rates and habitat similarities) should contain similar numbers of fish were similar within the same years (Table 11). Thus, we believe the 1973 Willow Creek estimate is the best we have. The estimates for most of the other holes (made mostly from 1975 data) are probably underestimates, perhaps to the same degree that Willow Creek shows a population decrease from 1973 to 1975.

Because of the large area involved, unequal sample percentages of the populations within various holes, and the movement of the fish, we were unable to make an unbiased population estimate for the entire study area. However, using an estimated percentage of the 1973-74 marked fish still at large in 1975, we made a mark-recapture estimate of the population of small sturgeon in the 38 km of river from Getta Creek to Johnsons Bar (Table 12). The total estimate of 1,450 sturgeon would be a very conservative estimate. Our guess would be closer to 2,000 small sturgeon from 45 to 92 cm (18 to 36 in) in length. To expand our population estimates to the entire 222 km (138 mi)

Table 11. Comparison of population estimates of small white sturgeon based on single season and multi-season marking of fish, middle Snake River, 1973-75.

	Population Estimate					
	1973		1974		1975	
Location	Single season	Multi-season	Single season	Multi-season	Single season	Multi-season
Steep Creek	-	-	112	-	116	151
Willow Creek	217	-	386	190	120	133
High Bar Rapids	-	-	150	101	37	85
Salt Creek	-	-	-	-	129	204
Yankee Bar	-	-	-	-	137	-
Lower McCarty Creek	-	-	88	102	-	-
Nezperce Creek	-	-	-	-	34	41
Jim Creek	-	-	-	-	27	30
Cottonwood Creek	-	-	-	-	127	144

Table 12. Estimation of the populations of small white sturgeon (45.0 to 91.5 long) inhabiting the middle Snake River, 1975.

Interval	Marked fish at large	Number caught	Number recaptured	Population estimate
Getta Creek to Pittsburg Landing (15 km)				
12 May - 6 June 1975	83	34	9	286
95% Confidence Interval				167-714
Pittsburg Landing to Johnsons Bar (23 km)				
9 April - 6 June 1975	232	268	53	1161
95% Confidence Interval				904-1548

of river between the two dams is rather risky. However, based on our sampling experience, knowledge of the river habitat, and other intuitive feelings, we would expect to find not less than 7,000 nor more than 10,500 small white sturgeon between 45 and 92 cm (18 and 36 in) in total length between Lower Granite and Hells Canyon dams.

From Getta Creek to Johnsons Bar, about 3% of the captured sturgeon less than 183.5 cm (6 ft) long were longer than 91.5 cm (3 ft). Three percent of the estimated sturgeon population less than 183 cm (6 ft) in this area would amount to 44 mid-sized sturgeon (3 to 6 ft). Three percent of our population guess (2000 fish) for the same area would be 60 mid-sized sturgeon. Continuing the expansion to the whole study area, we would have expected to find not less than 500 nor more than 750 white sturgeon 92 to 183.5 cm (3 to 6 ft) in length inhabiting the Snake River from Lower Granite to Hells Canyon Dam in 1975. Over one-half of the fish would have been in the lower 50 km (31 mi) of the river prior to impoundment by Lower Granite Dam.

We were able to maintain a random sampling pattern fishing for large sturgeon between Getta Creek and Johnsons Bar. Small numbers of fish per hole, high recapture rates, the ability to fish nearly any kind of hole with the large lines, and no evident migratory movement all contributed to making our population estimate for these fish as unbiased as possible.

Our Schnabel estimate was 88 white sturgeon longer than 183 cm (6 ft) inhabiting the middle Snake River in the 38 km (23 mi) from Getta Creek to Johnsons Bar (Table 13.) Based on this estimate, the relative abundance of sturgeon in the area above Johnsons Bar and the approximate number and size of holes suitable for harboring large sturgeon throughout the study section, we would expect to find no fewer than 700 nor more than 1,000 white sturgeon longer than 183 cm (6 ft) inhabiting the Snake River between Lower Granite and Hells Canyon dams.

Table 13. Estimation of the number of large white sturgeon greater than 183 cm (6 ft) inhabiting the 38 km (23 mi) of the middle Snake River from Getta Creek to Sheep Creek, 1974-75. The estimates are based on the method of Schnabel (1938) with an adjustment suggested by Chapman (1952).

Monthly interval	Marked fish at large	Number caught	Number recaptured	Population estimate
1974				
June	27	8	3	54
July	32	17	5	91
August	44	9	5	66
1975				
April	48	3	1	72
May	50	11	6	79
			20	
Total estimate				88
95% confidence interval				60-152

Age and Growth

We aged a sample of 605 white sturgeon from 45 to 258 cm (18 to 102 in) in total length and 0.4 to 120.0 kg (0.9 to 264 lb) in weight. This sample approximates the length distribution of all the sturgeon captured during the study. We could not age all the fin ray sections. Many of the small fish had evidently sustained an injury to their pectoral fin at some time and this resulted in the obliteration of the inner annuli of the ray by an amorphous replacement tissue. Most of the large fish showed some degree of erosion of the anterior edge of the fin ray which, in several cases, was enough to destro an unknown number of annuli formed early in life.

Our age estimates for the sturgeon sampled ranged from 2 to 56 years. Extremely slow growth rates for most of the fish during one or more periods made aging very difficult, especially for the final years of the older fish. Our age sample included the smallest and the heaviest fish caught, but not the longest. Ages 7-12 made up 61% of the entire sample. These fish ranged in mean total length from 63 to 73 cm (24.8 to 28.7 in). No fish over 2 m (6.6 ft) long was found to be less than 24 years old (Table 14).

The extremely rapid growth of two-year old sturgeon, as indicated by their length at capture may be biased by gear selectivity for only the largest fish of that age class. This selectivity may exist in decreasing amounts for every age class up to and including 11 year old fish and may overestimate the true annual mean growth rate of the small sturgeon. We therefore used only sturgeon 12 years of age or older for back-calculating past growth.

From back-calculation of fin ray sections, we estimated that the 1957-63 age classes of sturgeon grew most rapidly during the first four years of life (maximum of 21.4 cm (8.43 in) between years one and two). From age 6 to 12, the sturgeon grew at a nearly constant rate of about 3.3 cm (1.3 in) per year, and then the growth began to accelerate again (Table 15).

The growth of the 1920-51 year classes of sturgeon, as determined by back-calculation, showed a similar growth pattern to that of the 1957-63 age classes (Table 16). However, from age 4 to 15, the 1920-51 year class fish had increasingly larger annual growth rates than the 1957-63 year classes. By age 15, we estimated the mean length of fish from year classes 1920-51 was 15.6 cm (6 in) longer than that of sturgeon from the 1957-63 year classes. Comparison of the variances of calculated total length at each year for these two groups indicated that growth of fish during the two periods was statistically different (Table 17).

Table 14. Age, mean length, length increment between ages and mean weight of white sturgeon captured by set lines and rod-and-reel in the middle Snake River, 1973-75.

Age	Number of fish	Total length (cm)		Length increment (cm)	Mean weight (kg)
		Mean	Range		
2	4	48.4	45.0-51.0	-	0.475
3	11	52.2	45.5-64.0	3.8	0.561
4	31	58.2	51.5-69.0	6.0	0.768
5	30	58.2	48.5-66.5	0.0	0.782
6	31	60.6	52.0-69.5	2.4	0.947
7	49	63.2	52.0-73.5	2.6	1.012
8	54	64.1	55.5-81.0	0.9	1.085
9	80	66.3	51.0-92.0	2.2	1.236
10	76	67.7	59.5-82.0	1.4	1.271
11	53	69.0	54.5-92.5	1.3	1.476
12	55[a]	72.5	59.5-88.0	3.5	1.660
13	27	75.2	60.5-99.0	2.7	1.940
14	17	77.7	57.0-100.5	2.5	2.268
15	12	78.3	60.5-94.0	0.6	2.190
16	10	94.2	72.0-118.0	15.9	4.272
17	4	104.1	81.5-127.0	9.9	5.410
18	2	97.3	80.0-114.5	-6.8	4.400
19	3	135.0	102.0-156.0	37.7	15.5
20	0	-	-	-	-
21	1	152.5	-	-	17.3
22	0	-	-	-	-
23	0	-	-	-	-
24	2	194.2	185.0-203.0	-	39.2
25	2	169.2	127.5-211.0	-	34.4
28	3	196.4	192.0-201.0	-	45.6
29	2	214.6	205.5-223.5	-	60.7
30	2	202.5	172.5-232.5	-	57.3
32	2	218.5	216.0-221.0	-	61.6
33	2	226.0	217.0-235.0	-	79.5
34	6	218.3	197.0-242.5	-	68.2
35	2	224.8	223.5-226.0	-	84.6

Table 14. Continued

Age	Number of fish	Total length (cm) Mean	Range	Length increment (cm)	Mean weight (kg)
36	4	216.7	200.5-231.0 85.3"	-	70.8
37	3	209.9	190.5-219.5	-	57.7
38	5[b]	231.4	213.5-244.0	-	86.6
39	1	237.5	-	-	75.5
40	4[b]	229.2	205.5-244.0	-	78.6
41	2	215.0	212.0-218.0	-	60.6
42	1	237.5	-	-	87.6
43	2	232.0	216.0-248.0	-	72.7
44	1[b]	249.0	-	-	-
45	1	221.5	-	-	67.7
47	2[b]	228.6	226.0-231.0	-	66.4
48	1	244.0	-	-	102.3
52	1	231.0	-	-	70.9
53	3	257.5	247.5-264 101.4"	-	111.4
56	1	255.5	-	-	120.0

[a] Two fish not weighed.

[b] One fish not weighed.

Table 15. Back-calculated total lengths and increments of growth for white sturgeon of year classes 1957-63 captured in the middle Snake River, 1973-75

Year class	Mean calculated total length (cm) at annulus										
	1	2	3	4	6	8	10	12	13	14	15
1963	13.3 (11)*	32.1	39.5	44.1	52.3	58.9	65.9	72.4			
1962	12.4 (19)	36.0	43.7	48.6	55.5	62.5	68.5	74.6			
1961	13.1 (16)	31.1	39.7	45.6	53.8	60.7	67.7	72.2			
1960	10.2 (15)	35.3	43.6	49.0	57.6	64.3	70.3	76.7	79.4 (8)	81.9	88.4 (6)
1959	15.3 (5)	31.4	42.1	46.4	53.7	59.6	69.0	76.0	78.9	81.8	87.3 (4)
1958	12.4 (2)	29.9	38.4	42.0	52.4	58.5	62.9	76.6	79.8	82.7	85.0
1957	14.7 (2)	46.6	53.3	56.4	61.6	69.7	77.5	84.4	86.4	91.9	96.9
Total weighted mean	12.5 (17)	33.9	42.1	47.2	55.0	61.8	68.4	74.6	80.1	83.2	88.8 (14)
Increments of growth		21.4	8.2	5.1	7.8	6.8	6.6	6.2	5.5	3.1	5.6

( )* Number sampled; unchanged until noted.

Table 16. Back-calculated total lengths and increments of growth for white sturgeon of year classes 1920-51 captured in the middle Snake River, 1973-75.

Year class	Mean calculated total length (cm) at annulus													
	1	2	3	4	6	8	10	12	15	20	25	30	35	40
1940-51	16.0 (16)*	31.5	41.4	50.7	63.7	74.4	83.5	94.5	114.6	150.0 (14)	176.6 (9)	199.5 (2)		
1931-39	15.9 (18)	32.0	39.8	49.2	61.8	70.8	78.2	86.2	102.9 (17)	103.1 (16)	155.4 (15)	176.5 (13)	194.2	204.0 (5)
1920-30	15.1 (6)	18.5	39.5	45.0	51.7	57.3	62.9	69.4	81.7	106.7	141.1 (5)	154.0 (2)	169.5	189.7
Total weighted mean	15.8 (40)	31.3	40.4	49.2	61.0	70.2	78.1	87.0	104.4 (39)	133.9 (36)	159.5 (29)	176.6 (17)	191.0 (15)	199.9 (7)
Increments of growth		15.5	9.1	8.8	11.8	9.2	7.9	8.9	17.4	29.5	25.6	17.1	14.4	8.9

( )* Number sampled; unchanged until noted.

Table 17. Comparison of the back-calculated growth for white sturgeon in year classes 1920-51 versus that for year classes 1957-63, captured in the middle Snake River, 1973-75. We used an approximate t-test because the sample variances are not homogeneous.

	Year class	Annulus								
		1	2	3	4	6	8	10	12	15
Mean calculated total length (cm)	1920-51	15.8	31.3	40.4	49.2	61.0	70.2	78.1	87.0	104.4
	1957-63	12.5	33.9	42.1	47.2	55.0	61.8	68.4	74.6	88.8
Difference in growth		+3.3	-2.6	-1.7	+2.0	+6.0	+8.4	+9.7	+12.4	+15.6
df		108	108	108	108	108	108	108	108	51
Computed t'		2.81*	-1.73ns	-1.11ns	-1.18ns	3.02*	3.58*	3.66*	4.08*	3.74*
$t'_{.05}$		2.01	2.02	1.95	2.02	2.02	2.02	2.02	2.02	2.07

* Denotes significant difference

We plotted age versus total length at capture to visualize the general form of the middle Snake sturgeon growth curve (Figure 8). Back calculations of length-age estimates superimposed on the same graph indicate that calculated length of young or old sturgeon was underestimated. This was probably caused by using fin sections taken further from the base of the fin on large fish than from small fish. Thus, the difference in growth between the 1920-51 year classes of sturgeon and the 1957-63 year classes might be larger than our estimates.

The growth of small tagged sturgeon, 45.0 to 91.5 cm (18 to 36 in) long, appeared to be retarded by the tagging and fin clipping. Measured growth was so slight that our errors in measuring live, unanesthetized fish was almost as great as the estimated annual growth. While the back-calculated growth rate indicated a minimum annual mean growth rate of 3 cm (1.2 in), our recaptured small sturgeon were estimated to grow less than 1 cm (.39 in) per year. This rate coincides more closely with that observed from our length-and-age-at-capture data for the 7-11 year old fish with a mean annual growth of about 1.4 cm (0.55 in).

Two fish tagged in 1972 and recaptured in 1975 showed growth rates of 2 and 3 cm (0.8 and 1.2 in) per year. However, the mean growth of all other recaptures at large for a year or more was less than 1 cm (.39 in). Not only was the growth in length of tagged sturgeon slow, but many of them also lost weight during the study. Small sturgeon captured and tagged in March and July 1973 and recaptured during other time periods had positive increases in weight. The mean weight change was negative for fish tagged at any other time period. The largest losses occurred in March through May or early June of 1974 and 1975 (Table 18).

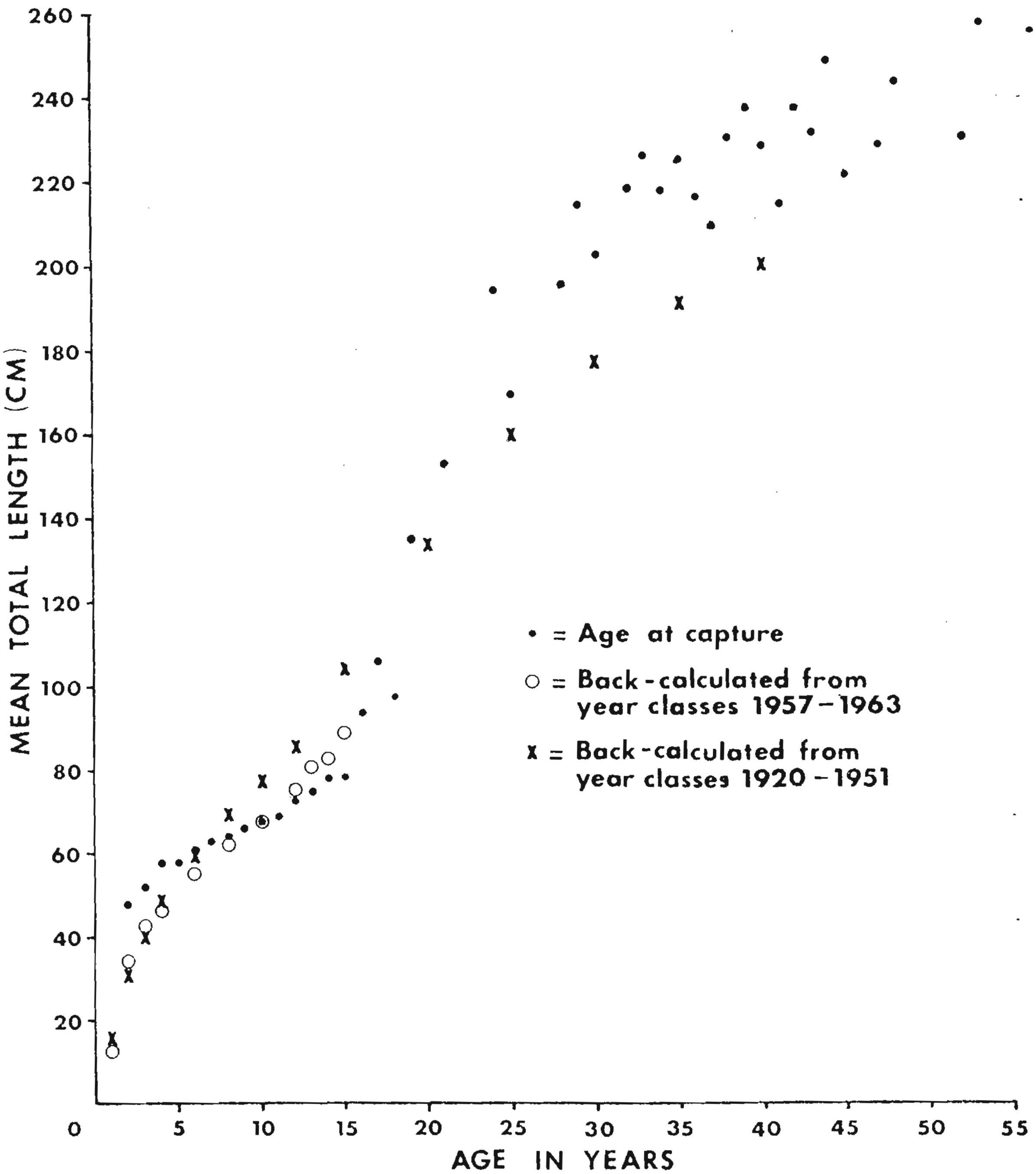

Figure 8. Growth of white sturgeon in the middle Snake as determined by age at capture and by back-calculation.

Table 18. Growth of tagged white sturgeon 45.0 to 91.5 cm in total length inhabiting the middle Snake River, 1972-75.

Mean date		Mean number days between captures	Number of fish	Growth				Mean growth rate	
				Length(mm)		Weight(g)		Length	Weight
Captured	Recaptured			Mean	Range	Mean	Range	mm/year	g/year
5/31/72	6/4/75	1098	1	60.0	-	-	-	20	-
7/29/72	4/23/75	959	1	80.0	-	25	-	30	10
3/21/73	6/23/73	94	7	1.4	0 to 5	39	-50 to 75	5	151
3/21/73	8/1/73	133	3	6.6	5 to 10	100	-50 to 200	18	274
3/22/73	6/9/74	444	7	8.5	0 to 25	100	25 to 150	7	82
3/21/73	7/24/74	490	3	8.3	5 to 10	42	-75 to 125	6	31
3/22/73	5/13/75	783	4	11.3	10 to 15	44	0 to 125	5	21
6/17/73	6/9/74	357	11	2.7	0 to 5	-14	-150 to 300	3	-14
6/17/73	5/17/75	699	8	10.0	0 to 15	-109	-300 to 50	5	-57
7/18/72	6/7/74	324	3	8.3	0 to 20	167	-50 to 350	9	188
7/22/73	5/17/75	661	3	16.7	0 to 35	158	-125 to 500	9	87
3/19/74	6/7/74	79	3	6.7	0 to 10	-100	-125 to -75	31	-462
6/12/74	4/10/75	302	5	2.0	0 to 5	-50	-100 to 0	2	-60
6/14/74	5/17/75	337	16	7.5	0 to 10	-167	-375 to -50	8	-181
7/12/74	4/13/75	215	4	2.5	0 to 5	-6	-50 to 50	3	-8
7/15/74	5/20/75	310	16	4.4	0 to 10	-139	-425 to 50	5	-164
4/12/75	5/17/75	35	19	5.5	0 to 15	-38	-125 to 75	57	-396
	Total	326	114	7.2		-		8	-
		319	113			-41			-47

For 19 small sturgeon which we recaptured 1 to 3 years later, we removed a section of the first pectoral fin ray from the right or unclipped fin and compared a cross section of it with the previous sample. We found that the rays were nearly identical and could be used to positively identify a fish which had lost its tags (much as finger printing). One fish clipped originally in May 1972 showed two additional annuli by June 1975 and had grown 6 cm (2.4 in) in length. A second fish clipped in July of 1972 showed additional fin ray growth, but no further annulus formation by April 1975. The average increase in length of these fish was 1.1 cm (0.43 in). Of the remaining 12 sturgeon which were clipped about one year apart, eight showed no detectable fin ray growth, resorption or annulus formation, one showed slight fin ray growth and annulus formation. The mean increase in length of these three groups was 0.6, 0.5 and 0.7 cm (0.24, 0.20 and 0.28 in), respectively.

After 45 days of saturation feeding in a laboratory tank, a 65.2 cm (25.7 in) long sturgeon grew 4.3 cm (1.7 in) in length and added 600 g (21.2 oz) in weight. During the warmer summer and declining fall temperatures of the feeding trial, the fish fed less often. At the end of the 108 day trial, it had grown a total of 8.4 cm (3.3 in) in total length and added 825 g (29.1 oz). The growth was double any observed of mean back-calculated growth for middle Snake sturgeon of this size from year classes 1957-68.

The fin ray removed from the sturgeon after the feeding trial showed a large area of recent opaque growth. Back-calculation of the fin ray measurements indicated that this growth estimated a change in total length of 6.3 cm (2.48 in), 2.1 cm (0.83 in) less than observed. A thin bright yellow band of tetracycline was clearly evident within the section about midway through the opaque growth on the ventral sice and about one-third of the way through on the dorsal side of the ray. This would indicate that fin ray growth occurs nearly simultaneously with growth in total length as the tetracycline was given near the midpoint of the feeding trial.

Food Habits

Because of the tenuous status of the white sturgeon population in the middle Snake, we did not plan to sacrifice a portion of the fish for stomach samples. Pumping the stomachs of the live fish proved to be ineffective for representative samples. However, we were able to examine the stomach contents of seven incidental mortalities and one planned mortality.

For three sturgeon from 95 to 132 cm (37.4 to 52 in) in total length the most common food items found were clams (*Corbicula* sp.), crayfish, caddisfly, dipteran larvae, and snails. For the five mortalities form 64 to 73 cm (25.2 to 28.7 in) long, the most common items found were crayfish and caddisfly larvae. Also present were other aquatic insect larvae, clams, carp scales, sand and algae.

Observation of sturgeon held in the lab indicated that the fish would rarely eat spoiled or fungused food and little vegetable matter. They were observed to capture and eat small live fish held in the same tank.

Impoundment

We equipped ten white sturgeon with sonic transmitters in the lower Snake River upstream from Lower Granite Dam prior to impoundment of the river. These fish ranged in total length from 74 to 170 cm (29 to 67 in) and were released 4.0 to 17.2 km (2.5 to 10.7 mi) upstream from the dam. Six of the sturgeon were transmitterized 2 to 4 weeks prior to impoundment and four were transmitterized within the final week before impoundment (Table 19).

Table 19. Vital statistics of ten white sturgeon equipped with sonic transmitters and released into the Lower Snake River in the 18 km immediately upstream from Lower Granite Dam prior to impoundment on 14 February 1975.

Released[a]			Final observations	
Date	River km	Total length (cm)	Date	Net movement km)
1/10/75	194.5	79.5	6/9/75	+26.3
1/13/75	194.5	169.5	4/30/75	+16.0
1/15/75	194.8	105.5	4/3/75	+19.9
1/23/75	194.8	83.0	4/30/75	+9.6
1/26/75	186.2	92.0	6/9/75	+31.1
1/28/75	186.2	86.0	2/1/75	-7.6
2/10/75[b]	182.6	84.0	6/20/75	+38.7
2/10/75[c]	186.0	74.0	6/26/75	+37.9
2/14/75	194.5	74.5	6/27/75	+26.8
2/14/75	194.5	83.5	6/27/75	+29.4

[a] All sturgeon except two were released at point of capture within 1 hour of tagging.

[b] This fish was originally captured at River kilometer 341.0 on 10/1/72 and held in our lab until its release into the study area.

[c] This fish was originally captured on 2/3/73 and held in our lab until its release into the study area.

Of the eight sturgeon transmitterized before the day of impoundment (14 February 1975), only one moved more than 0.5 km (550 yd) from its release site prior to the formation of slack water. This fish moved 7.6 km (4.72 mi) downstream in four days and was last observed at the upstream face of Lower Granite Dam on 1 February 1975. We believe it probably moved through the dam and out of the study area before impoundment began.

All nine transmitterized sturgeon known to be present above Lower Granite Dam at the time of impoundment began moving upstream shortly after the reservoir began filling. By the end of the first week after impoundment, they had moved an average distance of 3.3 km (2.07 mi) upstream (Figure 9). By the end of the second week after impoundment, the mean upstream migration amounted to 15.5 km (9.63 mi). All six sturgeon which could still be located after the first of June (about four months after impoundment), were in the 7 km (4.35 mi) of river immediately downstream from the mouth of the Clearwater River. The mean upstream movement of the six fish was 31.7 km (19.70 mi). The portion of the reservoir where the fish were observed in June 1975 is 38.9 km (24.18 mi) above Lower Granite Dam and has considerable current. We interpret the movements of these sturgeon as evidence the sturgeon prefer the flowing water of the river rather than the reservoir.

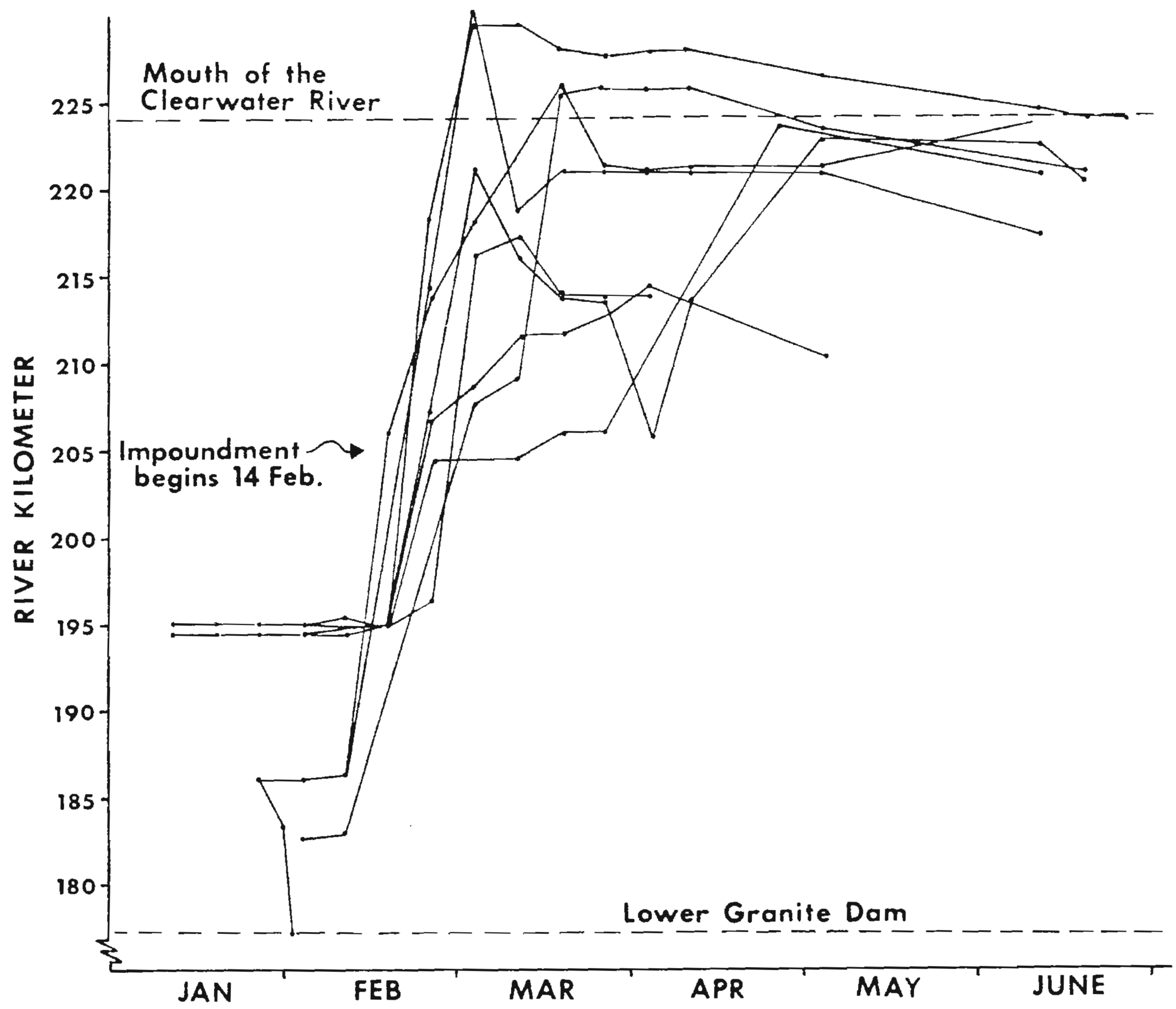

Figure 9. Movement of 10 white sturgeon (74 to 170 cm long) equipped with sonic transmitters in the Lower Snake River before, during and after impoundment by Lower Granite Dam, 14 February 1975.

DISCUSSION

We estimate 8,000-12,000 sturgeon inhabited the Snake River from Lower Granite Dam upstream to Hells Canyon Dam during the period 1973-75. This estimate is based on our mark-recapture population estimates for selected pools in the Hells Canyon section of the Snake River, catch rates throughout the study area, and our assessment of the amount of sturgeon habitat. Since filling of the pool behind Lower Granite Dam, a portion of the habitat which supported the 8,000-12,000 fish population has been inundated and we suspect that section of the river no longer supports as many sturgeon as when the river was free-flowing from Asotin downstream to Lower Granite Dam.

Although a sizeable number of sturgeon still live in the study area, most (86%) were small fish less than 92 cm (3 ft) in length. We estimate that only 4% of the sturgeon in the study area were 92-183 cm (3 to 6 ft) in length, the size range that were kept by anglers prior to the no kill regulation instituted in 1970. Ten percent of the sturgeon population was larger than 183 cm (6 ft).

The smaller number of 92-183 cm (3 to 6 ft) sturgeon was probably a result of overexploitation when anglers were allowed to keep fish and the tendency of 60 to 92 cm (2-3 ft) fish to move downstream. Sufficient time has not elapsed since initiation of the no kill regulation for a significant number of fish to grow into the 92-183 cm (3 to 6 ft) range. Most 92 cm (3 ft) sturgeon were 15 years of age and required another 10 or more years of growth before reaching 183 cm (6 ft) in length. The three year period between the Start of the no kill fishing and our study was not sufficient time for a large number of sturgeon to grow into the 92 to 183 cm (3 to 6 ft) length range. The dams constructed in the Columbia and Snake rivers have increased the likelihood that sturgeon moving downstream past the dams will not return upstream (fish counters at the dams have only rarely observed sturgeon moving up through the fish ladders). In addition, angling regulations in the lower Snake in Washington still permit the harvest of 92-183 cm (3 to 6 ft) sturgeon.

Even without a consumptive fishery in Hells Canyon, a significant number of sturgeon are lost to the downstream fishery or can't get back past the dams because they move downstream out of the middle Snake River upon reaching 60 to 75 cm (23.6 to 29.5 in). Thus, only a small population of residual fish are left to grow (if they can) into the large adult sturgeon formerly abundant in the middle Snake. If many of the 92-183 cm (3 to 6 ft) sturgeon in the Hells Canyon section of the Snake River were produced downstream from Lewiston, the sturgeon population in the Hells Canyon section may never regain its former abundance or size distribution.

On examining the growth patterns of sturgeon produced prior to the construction of dams in the Hells Canyon area (1920-1951) and sturgeon produced since the construction of the three Hells Canyon dams (1957-1963), we found evidence of reduced growth in recent years. The Snake River is a productive stream but the three reservoirs at the upper end of Hells Canyon eliminated large runs of anadromous salmonids and lampreys and may be trapping most of the inflowing nutrients and thus reducing the food supply available to sturgeon. The slow rate of growth of many of the sturgeon we tagged and recaptured may be additional evidence of a reduced growth rate in the Hells Canyon section of the river and/or evidence of slower growth caused by the capture and tagging operation. We do not believe sturgeon growth was affected by our handling for more than a few weeks.

Sturgeon seem to be well suited to the no kill fishing regulation. We captured 204 of the 876 sturgeon caught during the three years of study. Some fish were caught as many as eight times and some were recaptured within one days time.

The sturgeon population in the Hells Canyon stretch of the Snake River is not in eminent threat of extinction. However, the population may not thrive as well as in prior years because food may not be as plentiful as in the past and rearing areas in the lower Snake River have been lost.

Small sturgeon appeared to be relatively abundant in the middle section of river, thus at the present time reproduction appears to be adequate. There is some question in our minds, however, whether the small fish will be able to successfully rear in the middle section of the Snake River and grow into the large sturgeon observed in prior years.

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