FEDERAL AID IN FISH RESTORATION

Job Performance Report, Project F-73-R-7 Subproject IV:
River and Stream Investigations Study I: Hells Canyon
White Sturgeon Investigations

James R. Lukens
Principal Fishery Research Biologist

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JOB PERFORMANCE REPORT

State of:	Idaho	Name:	RIVER AND STREAM INVESTIGATIONS
Project No.:	F-73-R-7	Title:	Hells Canyon White Sturgeon Investigations
Subproject No.:	IV		
Study No.:	I		

Period Covered: 1 March 1984 to 28 February 1985

ABSTRACT

From April through October, 1982-1984, 531 white sturgeon (49 of which were recaptures) were caught from the Snake River between Captain John Creek (Rkm 261.5) and Johnson Bar (Rkm 369.7). Rod and reel fishing yielded 370 sturgeon in 1,573 hours of effort for a catch rate of 4.3 hours per fish, and setline fishing accounted for 161 sturgeon in 1,873 hours of effort for a catch rate of 11.6 hours per fish. Total lengths of sturgeon sampled ranged from 45.0 to 280.0 cm and averaged 82.1 cm. The proportion of sturgeon in the 91.5 to 182.8 cm length group (the 3 to 6 foot length group which was harvested prior to 1970) has increased 14% since the earlier study (1972-1975). Sturgeon ranged in age from 3 to 53 years and grew at an average rate of 3.4 cm per year (fish 3 to 21 years old).

Since termination of the sturgeon harvest in 1970, mean length at age has increased, condition has improved, and total instantaneous mortality has decreased from 0.43 to 0.13.

An estimated 2,683 white sturgeon, 45.0 to 280.0 cm long, inhabit the Snake River between Captain John Creek and Johnson Bar. Expansion of this estimate to the total free-flowing portion of the Snake River between Lewiston and Hells Canyon Dam produces an estimated population of 3,955 sturgeon.

Author:

James R. Lukens
Principal Fishery Research Biologist

INTRODUCTION

Since 1970, the white sturgeon (Acipenser transmontanus) sport fishery in the Hells Canyon reach of the Snake River has been managed as catch-and-release.

Prior to 1970, harvest was allowed only on sturgeon 91.5 cm to 183 cm (3 to 6 feet) total length. A 4-year study initiated in 1972 by the Idaho Cooperative Fishery Research Unit and the Idaho Water Resources Research Institute documented the population status soon after the regulation change (Coon et al. 1977). The current study was initiated in 1982 to determine the effect catch-and-release regulations may have had upon the white sturgeon population in the Snake River from Lower Granite Dam to Hells Canyon Dam.

OBJECTIVES

Collect white sturgeon life history data and compare to the findings of Coon et al. (1977) to determine what effects catch-and-release regulations have had upon the Hells Canyon population.

Determine white sturgeon movement patterns in the Hells Canyon reach of the Snake River.

RECOMMENDATIONS

Continue catch-and-release regulations for white sturgeon in the Hells Canyon portion of the Snake River or adopt consumptive regulations which would permit the harvest of no more than 15 fish, 125-183 cm long, for a period of five years followed by an evaluation.

DESCRIPTION OF STUDY AREA

The Snake River flows 224.5 km from Hells Canyon Dam to Lower Granite Dam (Washington) forming the Oregon-Idaho border for 114.2 km and the Washington-Idaho border for 59.0 km (Fig. 1). Most of this river section flows through Hells Canyon, the deepest canyon in North America. At its deepest and widest point, measured from He Devil Mountain in the Seven Devils mountain range, the canyon is 2,408 m deep and approximately 14.5 km wide.

Stream gradient is fairly constant and averages 1.8 m/km for the river section between the Wallowa-Whitman National Forest boundary (Rkm 289.9) and Hells Canyon Dam (Rkm 397.4). Stream gradient decreases in the lower river to an average of 0.7 m/km.

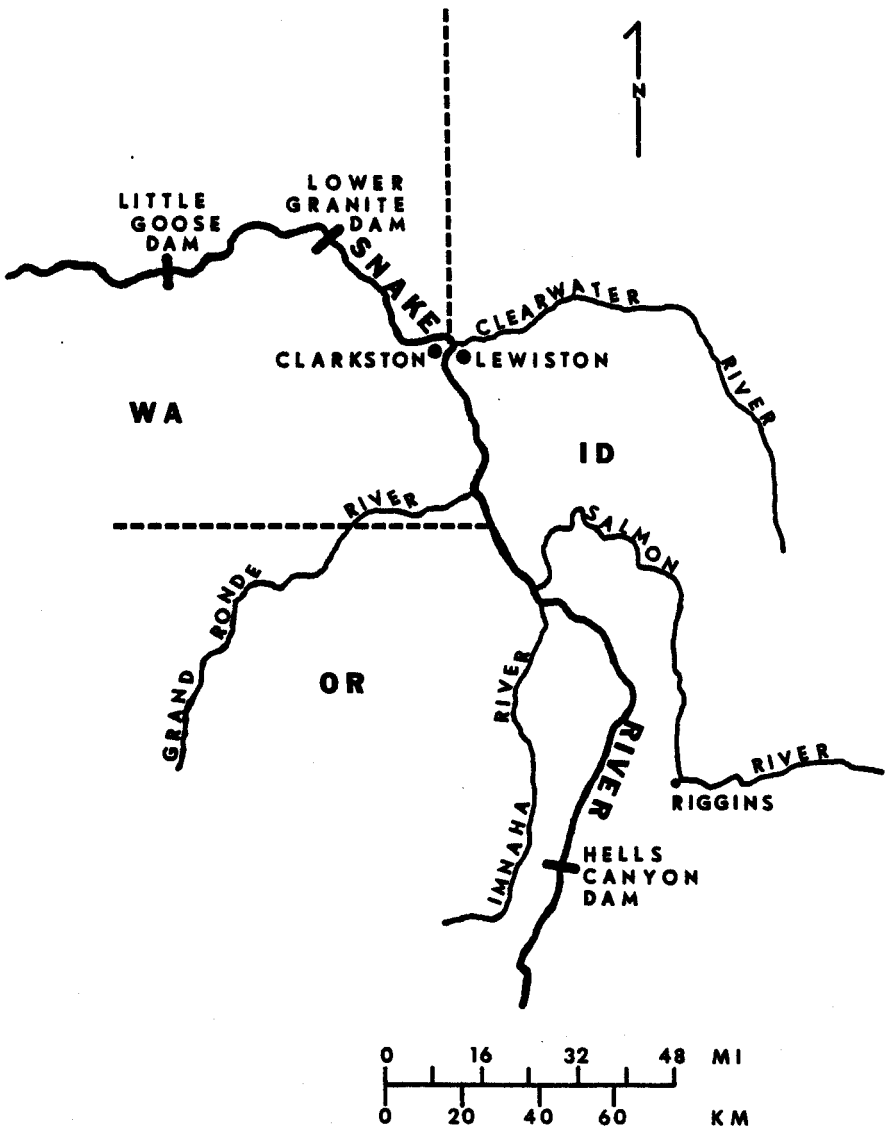

Figure 1. Map of the Snake River study area from Little Goose Dam to Hells Canyon Dam.

During the 1982-1984 study period (April through October), average monthly streamflow at the Anatone, Washington gage (Rkm 269.0) ranged from 3,789 cu m/s to 649 cu m/s (Fig. 2). At Hells Canyon Dam, 128.4 km upstream and above the three major tributaries: Grande Ronde, Salmon, and Imnaha rivers, average monthly streamflow ranged from 1,948 cu m/s to 362 cu m/s.

River temperatures, measured at the Anatone gage during the study period, ranged from 25.0 to 6.0 C (Fig. 3).

TECHNIQUES USED

Sturgeon Sampling

Sturgeon were captured utilizing both conventional fishing tackle and setlines. Setlines were constructed from 13 m of braided nylon rope with a breaking strength of 412 kg. Six loops were tied in the main line, spaced 2 m apart, to which 46 cm droppers were attached with harness clips. When fishing for smaller sturgeon, we used 93 kg test braided nylon twine droppers with 4/0 to 8/0 hooks baited with nightcrawler worms or Pacific lamprey ammocoetes. When seeking larger sturgeon, 11/0 to 14/0 hooks tied to 225 kg test parachute cord droppers were used. These were baited with rainbow trout, black crappie, smallmouth bass, or adult Pacific lamprey. Weights were attached to each end of the setline and a line, tied to the near-shore end of the setline, was secured to the shore. Hooks utilized with conventional fishing tackle ranged from 4/0 to 8/0 and were baited with all of the aforementioned baits, depending on the size of sturgeon being sought.

Time of day, location of capture, and amount of fishing effort (hours) were recorded for each sturgeon caught. All fish under 90.0 cm long were measured with a measuring board to the nearest 0.1 cm total and fork length. Sturgeon longer than 90.0 cm were measured to the nearest 0.2 cm with a nylon tape. Weights were recorded to the nearest 0.1 kg for fish under 9.0 kg and to the nearest 0.2 kg for heavier fish. The smaller sturgeon were weighed with a hand scale, and larger fish were weighed using a warehouse scale, sling, and tripod apparatus.

Marking and Tagging

All fish were individually marked with a three-digit tattoo placed on the ventral surface of the rostrum, or the pectoral girdle, with a horse-lip tattoo gun. Also, each fish was tagged with a plastic anchor tag in the area of the dorsal fin insertion. In 1983 and 1984, we also used a marking technique described by Thomas (1975) which involved painting a number on the underside of sturgeon with a silver nitrate applicator. Initially, marks were dark brown in color and easily recognizable. After a short period of time, however, most marks faded beyond recognition.

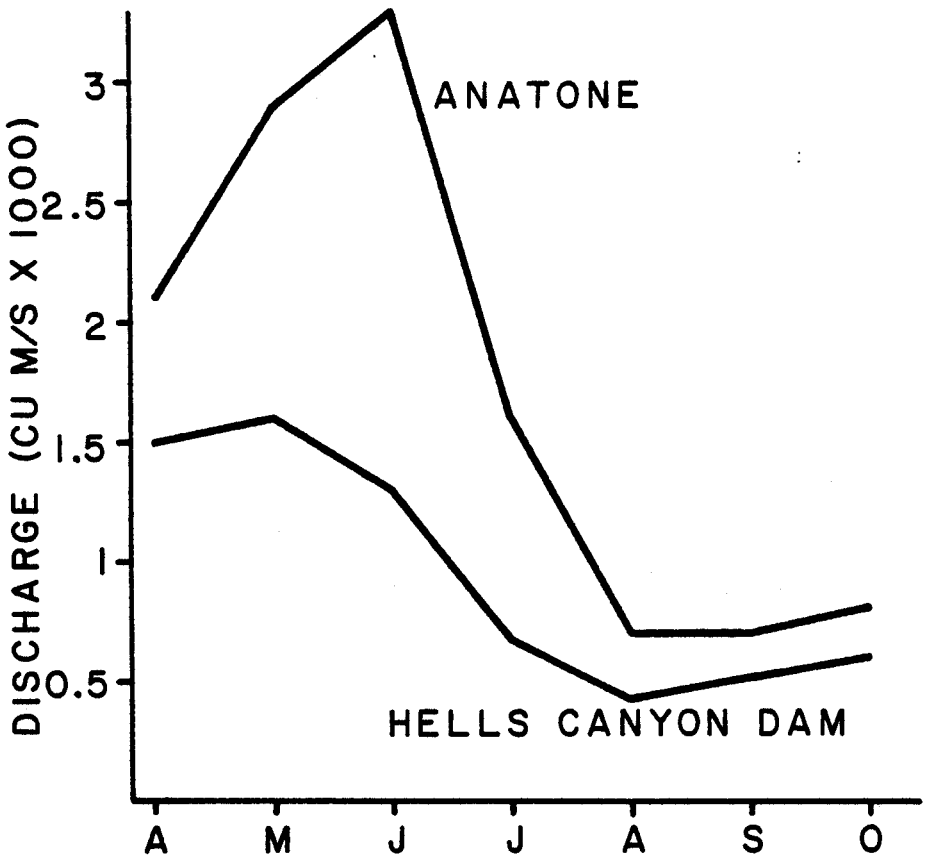

Figure 2. Mean monthly discharge measured at gage station #13334300 near Anatone, Washington (Rkm 269.0) and at gage station #13290450 near Hells Canyon Dam (Rkm 397.4), April through October, 1982-84.

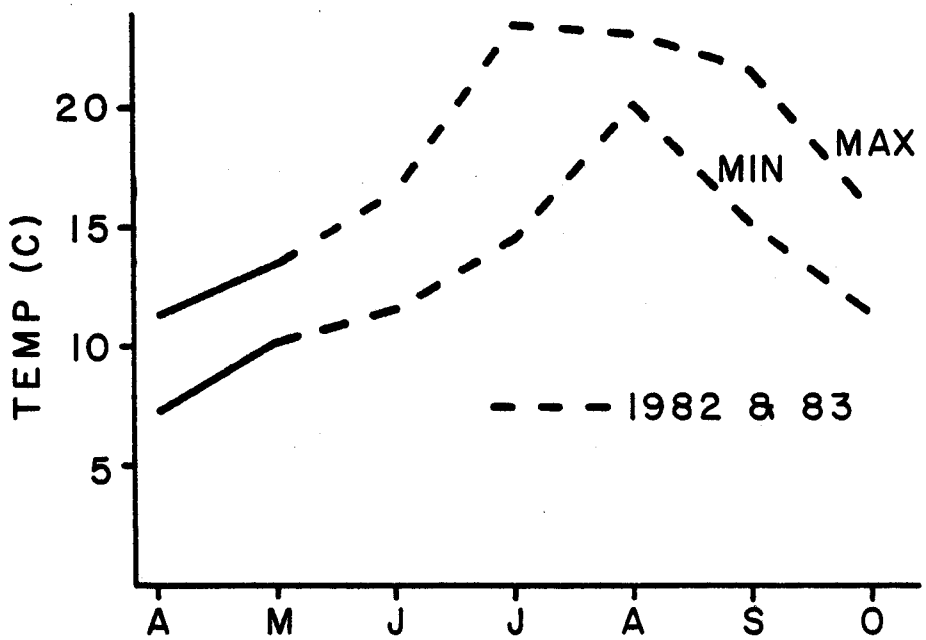

Figure 3. Mean monthly maximum and minimum temperature of the Snake River measured at gage station #1334300 near Anatone, Washington, April through October, 1982-84.

Age and Growth

A small section of the leading ray of the right pectoral fin was removed from each fish for use in age and growth determinations. This ray segment was removed and processed as described by Currier (1951). The scar tissue which formed over the area of the incision left a permanent and readily identifiable mark. Coon et al. (1977) sampled fin rays from the left side; therefore, recaptures from this earlier study could be distinguished from our recaptures even when fish had lost all other marks.

Population Estimates

Sturgeon population estimates were calculated using the Schnabel mark-recapture technique with modifications by Chapman (Ricker 1975). The first interval used was the entire 1982 sampling period (April through August). None of the recaptured fish caught during this period were used in the calculations in order to reduce sampling bias due to nonrandom distribution of marked fish within the population. Subsequent intervals consisted of 60-day periods during the 1983 and 1984 sampling seasons and only those recaptures marked during a previous interval were used in the calculations. The following equation was used to estimate population size:

$$1/N = \frac{(m_t \; r_t)}{(c_t \; m_t^2)}$$

Where:

N = population estimate.
m_t = total marked fish at large at the start of the tth period.
c_t = total sample taken during the tth period.
r_t = number of recaptures in the sample c_t.

Due to the low number of usable recaptures (8.4%), this value was treated as a Poisson variable for calculation of 95% confidence intervals. The equation used to calculate variance was:

$$r' = r_t + 1.92 \pm 1.96\sqrt{r_t + 1}$$

Confidence intervals were calculated using the equation:

$$N = \frac{c_t m_t}{r'}$$

Mortality

Total instantaneous mortality rates were calculated from the descending limbs of catch curves. Catch curves were plotted as the natural log of the number of sturgeon sampled from each age class.

Computer Population Simulation

An inland fish population simulation model described by Taylor (1981) with modifications by Cochnauer (1983) was used to predict future population abundance. The model utilizes age, sex, and time specific parameters for growth, recruitment, natural and fishing mortality to predict population trends for a 15-year period. The program was run twice to model an entire generation (30 age classes).

The model provides for up to 12 user-specified periods per simulation year. For simulating Hells Canyon sturgeon populations, each year was divided into four periods based on water temperatures and growth:
January-February, March-May, June-August, and September-December. No growth was assumed to occur during period one when temperatures were lowest, 20% of the growth was assumed to occur in each of periods two and four during increasing and decreasing water temperatures, and the remaining 60% of the annual growth was assumed to occur during period three when temperatures peaked.

Growth is calculated from a vector of length at age. Lengths used for fish one to five years of age were back-calculated by Coon et al. (1977). Weight at length is calculated from a length-weight regression with user
supplied coefficients. Growth is assumed to occur in a linear fashion within each interval.
The model allows for a density-dependent growth function, but none was used for the hells canyon data.

Natural mortality, including any mortality due to illegal harvest, was estimated from a catch curve for fish 6 to 30 years of age. Mortality for the younger age classes was adjusted from age one through five to produce the appropriate number of fish recruiting to age six (the age of full recruitment to our sampling gear and the first year for which a population estimate exists).

The model allows for a user-specified exploitation rate during any specified season with length limits including: no limits, slot limits, minimum lengths, or window limits.

Recruitment to age one for 1985 was estimated by calculating potential egg deposition (PED) and assuming an egg to age one mortality of 90%. This is the same procedure utilized by the model to predict abundance of age one fish for subsequent years. The ratio of eggs produced to kg of body weight was described by the equation: Eggs = -1982 + 639 Weight (Fig. 4).

Maturity was assumed to occur at a length of 125 cm which corresponds to the estimated length at first maturity for upper Snake River stocks (Cochnauer 1983) and is similar to values reported in the literature for other white sturgeon stocks (Table 1).

Table 1. Length and age of first maturity for white sturgeon reported in the literature.

Drainage (Author)	Age	Length (cm)
Columbia (Stockley 1981)	15	165
" (Galbreath 1979)	15 - 20	152 - 183
Sacramento (Kohlhorst (1980)	14	135
" (Miller 1972a)	--	114
" (Pycha 1956)	11 - 12	127
Fraser (Semakula and Larkin 1968)	11 - 34	86 - 180
Snake (Cochnauer 1983)	12	125
Kootenai (Partridge 1983)	27	160

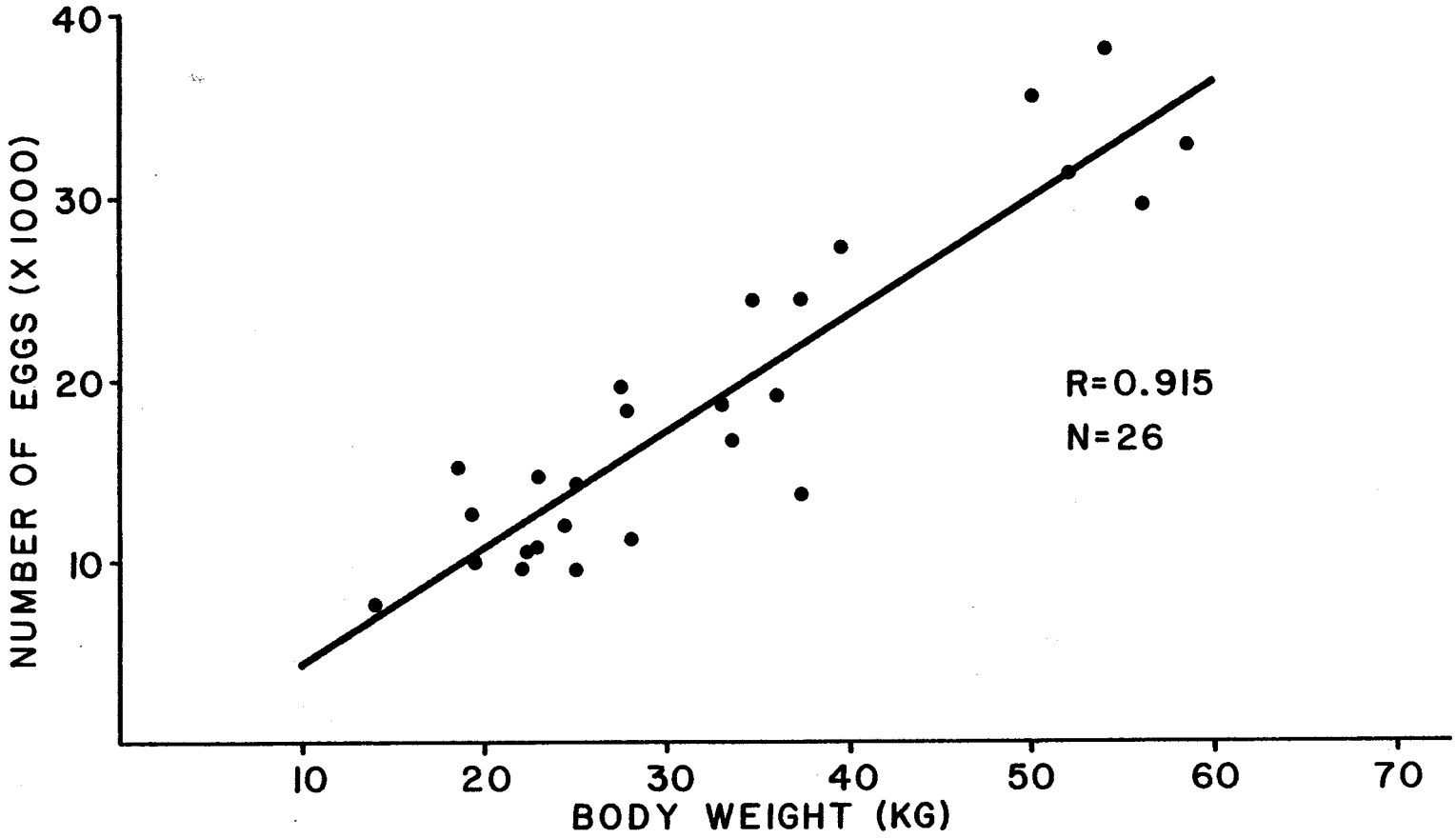

Figure 4. Fecundity relationships for white sturgeon used in the population simulation model. The data was collected from the Sacramento River drainage (California Department of Fish and Game, unpublished data) and the number of eggs was divided by 10 to simulate spawning at 10-year intervals.

RESULTS

Sturgeon Sampling

From April through October, 1982-1984, 531 white sturgeon (49 of which were recaptures) were caught from the Snake River between Captain John Creek (Rkm 261.5) and Johnson Bar (Rkm 369.7). Rod-and-reel fishing yielded 370 sturgeon in 1,573 hours of effort for a catch rate of 4.3 hours per fish. Yearly catch rates ranged from 3.3 to 5.4 hours per fish (Table 2) which were slightly higher than the rates of 1.2 to 3.8 hours per fish reported by Coon et al. (1977) for similar periods in 1973-1975.

Setline fishing accounted for 161 sturgeon (17 of which were recaptures) in 1,873 hours of effort for a catch rate of 11.6 hours per fish. Yearly catch rates ranged from 9.1 to 17.2 hours per fish (Table 3).

Total lengths of 479 sturgeon sampled in 1982-1984 ranged from 45.0 cm to 280.0 cm and averaged 82.1 cm (Fig. 5). Sturgeon less than 91.5 cm total length comprised 79.5% of the total sample and averaged 1.45 kg (Table 4). Sturgeon in the 91.5 to 182.8 cm length group (the length group harvested prior to 1970) made up 18.4% of our sample and weighed an average of 11.30 kg. The remaining 2.1% of the sample was made up of individuals longer than 182.8 cm, and the 10 fish in this group averaged 69.11 kg.

The proportion of fish 91.5 to 182.8 cm long has increased 14% since the earlier study (Fig. 6). An increase in this length group was expected since there have been 14 years of protective regulations and it requires approximately 10 years for a fish to grow from 91.5 cm to 182.8 cm.

The results of a T-test indicated no significant difference between the mean length of fish caught by rod and reel and fish caught by setlines (P = 0.95).

Recaptures and Movement

From 1982 to 1985, project personnel and sportsmen recaptured 52 sturgeon with identifiable marks, 14 of which had moved from the original capture site (Table 5). Three fish exhibited extensive downstream movement between successive years. Fish number 171 moved 65.3 km; fish 437, 20.6 km; and fish 396, 13.8 km. These fish ranged in length fr om 61.0 cm to 87.2 cm. This movement pattern was similar to that described by Coon et al. (1977). They found that juvenile sturgeon, 60 to 92 cm long, tended to move downstream during the fall and winter months. Movements of larger individuals were both upstream and downstream and more localized than those of smaller fish, a trend identical to that reported by the earlier study.

Table 2. Monthly rod and reel sturgeon fishing effort, number of fish caught and catch rates, 1982-1984. (Recaptures in parentheses.)

	Hours			Fish			Hours/fish		
Month	1982	1983	1984	1982	1983	1984	1982	1983	1984
April	144	27	-	27	3	-	5.3	9.0	-
May	256	27	42	27(1)	6(1)	2	9.5	4.5	21.0
June	178	116	74	15	37(5)	33(4)	11.9	3.1	2.2
July	141	66	72	60(5)	24(3)	40(5)	2.4	2.8	1.8
August	112	106	75	26(1)	27(2)	14(1)	4.3	3.9	5.4
September	-	-	43	-	-	6(2)	-	-	7.2
October	-	48	**46**	**-**	20(2)	3	-	2.4	15.3
Totals	831	390	352	155(7)	117(13)	98(12)	5.4	3.3	3.6

Table 3. Monthly setline sturgeon fishing effort, number of fish caught and catch rates, 1982-1984. (Recaptures in parentheses.)

	Hours			Fish			Hours/fish		
Month	1982	1983	1984	1982	1983	1984	1982	1983	1984
April	82	-	-	4(1)	-	-	20.5	-	-
May	56	-	-	2	-	-	28.0	-	-
June	123	108	98	23	10(2)	18(2)	5.4	10.8	5.4
July	96	86	156	11(1)	3	22(6)	8.7	28.7	7.1
August	43	64	415	4(1)	2	27(4)	10.8	32.0	15.4
September	-	-	108	-	-	3	-	-	36.0
October	-	-	438	-	-	32	-	-	13.7
Totals	400	258	1,215	44(3)	15(2)	102(12)	9.1	17.2	11.9

Table 4. The number of sturgeon sampled and mean weights for each of three length groups, 1982-1984.

Length (cm)	Number of fish	Percent	Mean weight (kg)
45.0 - 91.4	380	79.5	1.45
91.5 - 182.8	88	18.4	11.30
182.9 - 280.0	10	**2.1**	69.11

Table 5. Movement of recaptured white sturgeon, 1982-1985.

Tattoo no.	Length (cm)	Initial capture River km	Initial capture Date	Recapture River km	Recapture Date	Distance (km) moved
276	130.0	353.8	8/21/82	354.6	8/23/82	0.8 upstream
210	57.6	364.9	7/12/82	366.7	8/24/82	1.8 upstream
746	251.5	359.0	8/29/74	361.4	10/19/82	2.4 downstream
171	87.2	364.9	6/18/82	299.6	5/6/83	65.3 downstream
339	114.0	338.4	6/23/83	340.6	7/29/83	2.2 upstream
287	134.6	353.8	8/23/82	350.9	7/29/83	2.9 downstream
294	76.5	302.5	5/6/83	299.6	7/31/83	2.9 downstream
151	153.4	273.0	5/25/82	277.1	8/6/83	4.1 upstream
389	65.5	294.8	8/27/83	291.1	9/5/83	3.7 downstream
382	146.4	299.6	8/19/83	305.1	10/4/83	5.5 upstream
437	61.0	281.9	6/8/83	261.3	6/21/84	20.6 upstream
498	71.2	364.9	6/22/83	366.0	7/13/84	1.1 upstream
396	63.6	299.6	10/4/83	285.8	8/20/84	13.8 downstream
467	147.2	353.8	7/9/84	361.4	5/19/85	7.6 upstream

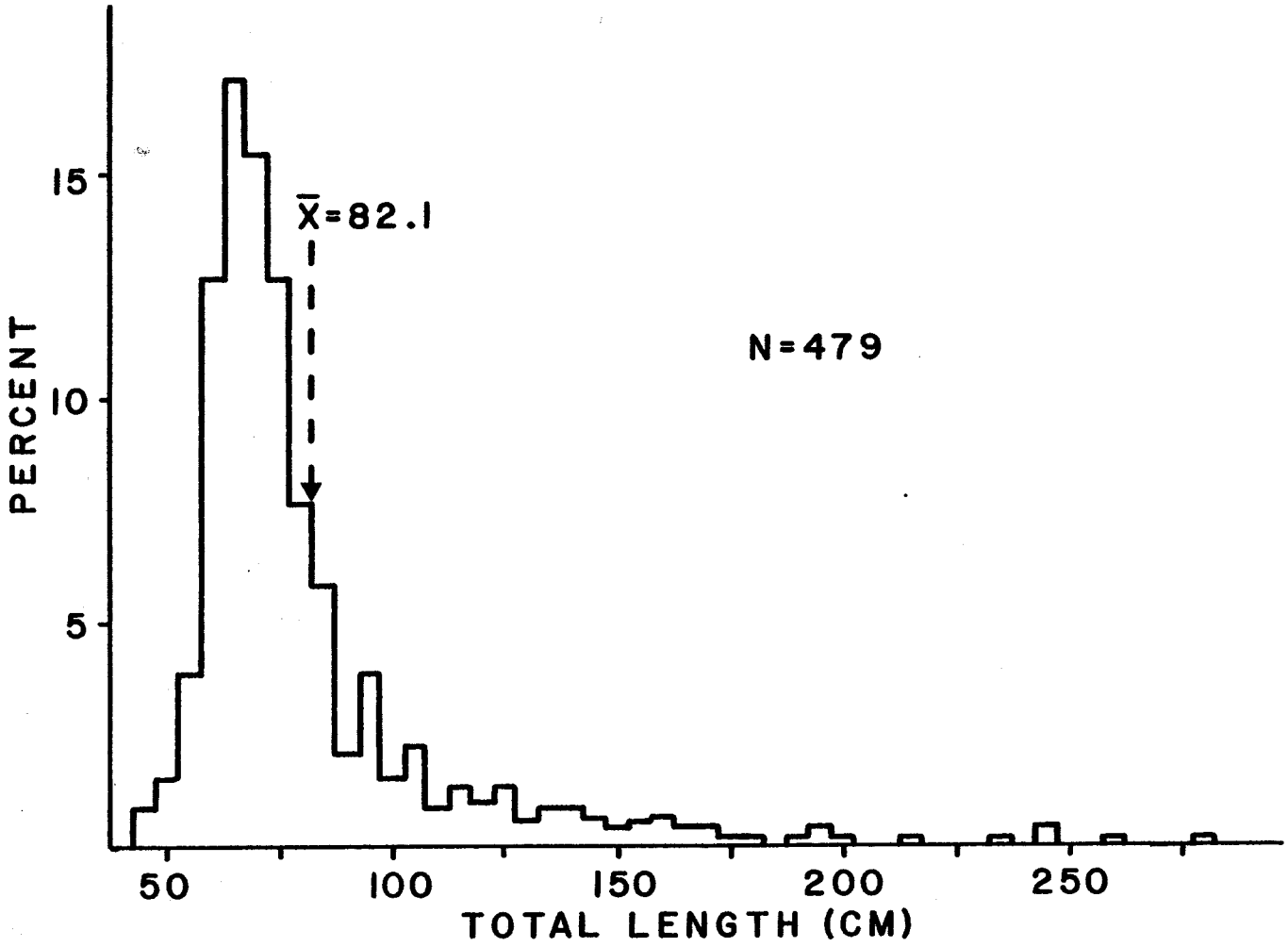

Figure 5. Length frequency of white sturgeon captured in the Snake River with rod and reel and setline by project personnel, 1982-84.

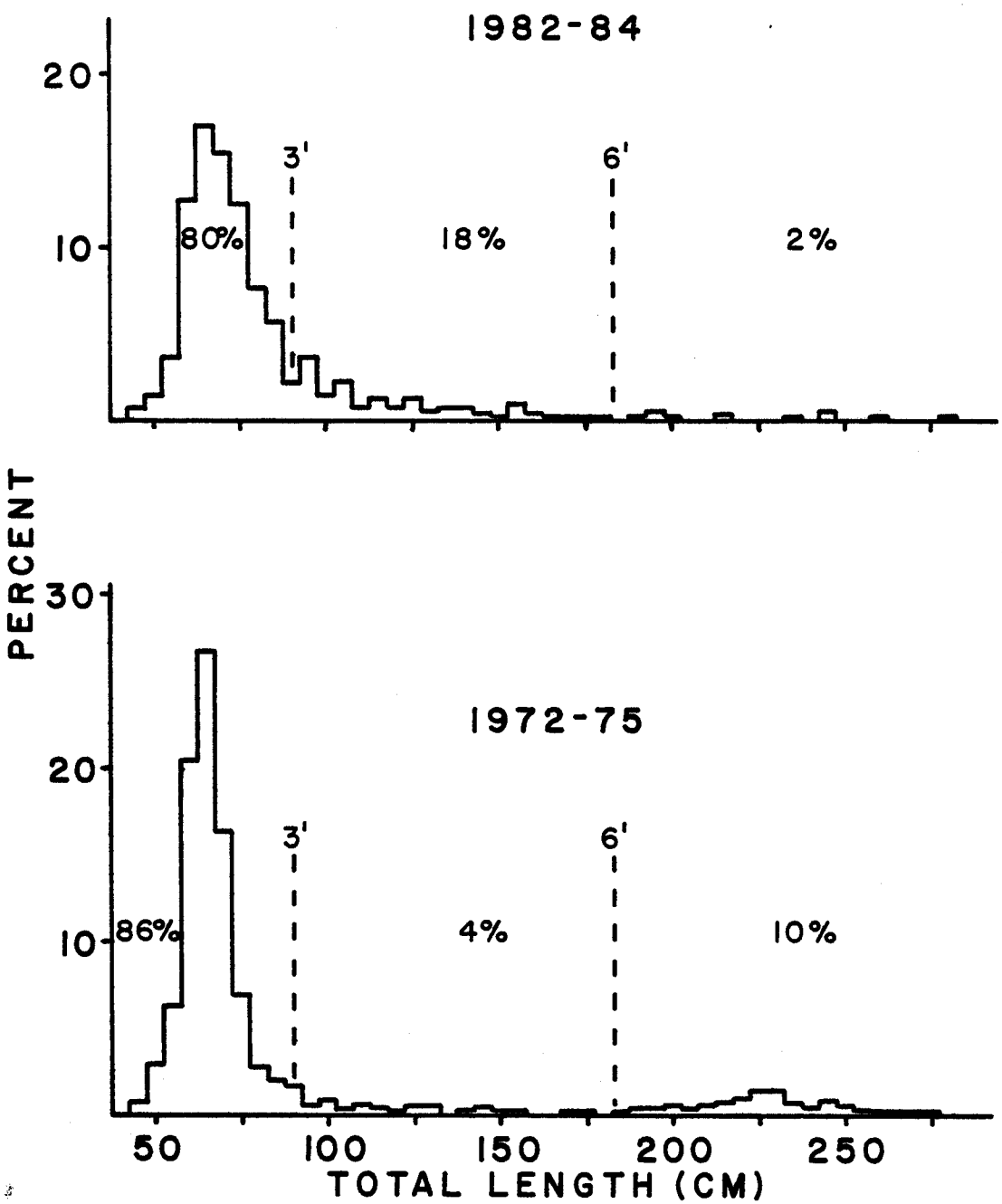

Figure 6. The length frequency of sturgeon sampled from the Hells Canyon portion of the Snake River,1982-84 and 1972-75 (Coon et al. 1977).

Between 1982 and 1984, 42 sturgeon were recaptured which had been sampled during the earlier study (identified primarily by left pectoral fin ray scars). Only five fish had legible marks and one individual, 251.5 cm long, had exhibited a net movement of 2.4 km downstream from the original capture site in 8 years, 51 days at large.

Age and Growth

Sturgeon sampled between 1982 and 1984 ranged in age from 3 to 53 years (Table 6). Growth was fairly constant for ages 3 through 15, increased through age 25, then declined (Fig. 7).

Coon et al. (1977) believed that tagging and fin clipping retarded growth of fish sampled during the earlier study and may have resulted in weight loss also. This was not proven during this study. Annual growth increments of recaptured sturgeon varied considerably and ranged from 0 to
20.5 cm per year (Table 7). The mean annual growth of 3.4 cm per year, however, was similar to the 4.4 cm per year calculated from fin ray samples of fish 3 to 21 years of age. On the average, recaptured sturgeon exhibited a slight loss in weight; however, the results of a Wilcoxin signed rank test and a paired T-test indicated no statistical difference between actual and predicted weights (calculated with the length-weight equation).

Sturgeon growth appears to have increased since the earlier study. For sturgeon 3 through 16 years of age (sample sizes for older age classes are too small for comparisons), mean length at age is greater for fish captured during this study compared to those captured during 1972-1975 (Fig. 8). Lack of data from the earlier study precluded statistical comparisons; however, differences may be significant for ages 9 through 12, 14, and 16. Mean length at these ages for fish from the earlier study falls outside the 95% confidence intervals calculated for fish sampled during this study.

The length-weight relationship developed for sturgeon caught in 1982-1984 is shown in Figure 9. The relationship is defined by the equation:

$$W = 6.50 \times 10^{-7} (L^{3.43})$$

Where:

W = weight (kg)
L = total length (cm)

The length-weight relationship for sturgeon caught in 1972-1975 is defined by the equation:

$$W = 1.14 \times 10^{-6} (L^{3.31})$$

Table 6. Mean length and weight at age for 409 sturgeon sampled in Hells Canyon, 1982-1984.

Age	Number of sturgeon	Length (cm) Mean	Length (cm) Range	Weight (kg) Mean	Weight (kg) Range
3	8	52.5	45.2 - 61.3	0.55	0.30 - 0.90
4	18	59.1	54.3 - 65.1	0.76	0.30 - 1.10
5	37	60.0	45.0 - 67.6	0.85	0.15 - 1.10
6	31	62.8	51.4 - 77.0	0.95	0.55 - 1.60
7	24	65.4	57.0 - 77.5	1.08	0.60 - 2.20
8	28	68.1	58.2 - 96.8	1.33	0.80 - 3.20
9	31	70.2	56.8 - 88.5	1.45	0.80 - 3.00
10	21	71.5	64.4 - 81.9	1.52	1.10 - 2.70
11	29	72.0	64.0 - 88.0	1.56	0.90 - 3.30
12	30	76.6	62.4 - 104.2	2.05	1.10 - 5.40
13	21	78.7	63.7 - 104.0	2.30	1.10 - 5.65
14	24	82.0	69.5 - 106.4	2.59	1.45 - 6.35
15	11	83.1	71.5 - 106.0	2.59	1.40 - 6.10
16	15	86.4	66.0 - 119.2	3.20	1.10 - 8.60
17	13	90.4	74.9 - 153.4	4.42	1.80 - 20.70
18	13	105.3	77.7 - 134.2	6.50	2.20 - 15.60
19	17	111.0	74.5 - 160.4	9.41	2.40 - 30.20
20	8	128.7	100.0 - 166.0	13.86	4.00 - 25.50
21	9	131.8	98.0 - 171.2	13.88	4.80 - 29.80
22	3	162.5	138.0 - 192.0	26.13	17.50 - 38.60
23	0	---	---	---	---
24	6	165.0	133.8 - 200.4	31.78	12.70 - 57.30
25	3	155.8	147.4 - 171.0	27.10	20.00 - 34.50
26	1	162.0	---	24.80	---
27	1	177.5	---	35.90	
28	1	154.5	---	26.40	
30	1	195.0	---0	44.50	
33	1	214.3	---	58.20	---
38	1	235.0	---	80.90	---
49	1	260.0	---	81.60	
53	2	243.9	242.8 - 245.0	87.75	84.10 - 91.40

Table 7. Growth of recaptured white sturgeon sampled in Hells Canyon, 1982-1984.

Date		Days between	Size at capture		Growth		Growth/yr.	
Capture	Recapture	capture	Length (cm)	Weight (kg)	Length (cm)	Weight (kg)	Length (cm)	Weight (kg)
8/13/82	6/24/83	316	118.0	9.10	3.0	0	3.5	0
6/18/82	5/6/83	323	69.1	1.40	18.1	-0.3	20.5	-0.3
5/3/72	10/6/83	4,171	58.5	--	7.5	--	0.7	--
6/8/83	6/21/84	378	61.0	0.90	0	0.1	0	0.1
6/22/83	7/13/84	386	69.3	1.50	1.9	0.2	1.8	0.2
10/6/83	7/17/84	285	114.4	7.70	2.0	-0.3	2.6	-0.4
6/19/74	7/11/84	3,672	64.5	1.2	7.5	0.2	0.7	0.02
6/25/74	7/11/84	3,666	65.0	1.2	6.8	0.5	0.7	0.05
8/11/83	8/16/84	370	105.3	5.70	1.5	-0.2	1.5	-0.2
10/7/83	10/3/84	361	90.5	4.30	2.7	-0.1	2.7	-0.1
8/27/74	10/10/84	3,694	236.2	90.50	23.8	-8.9	2.4	-0.9

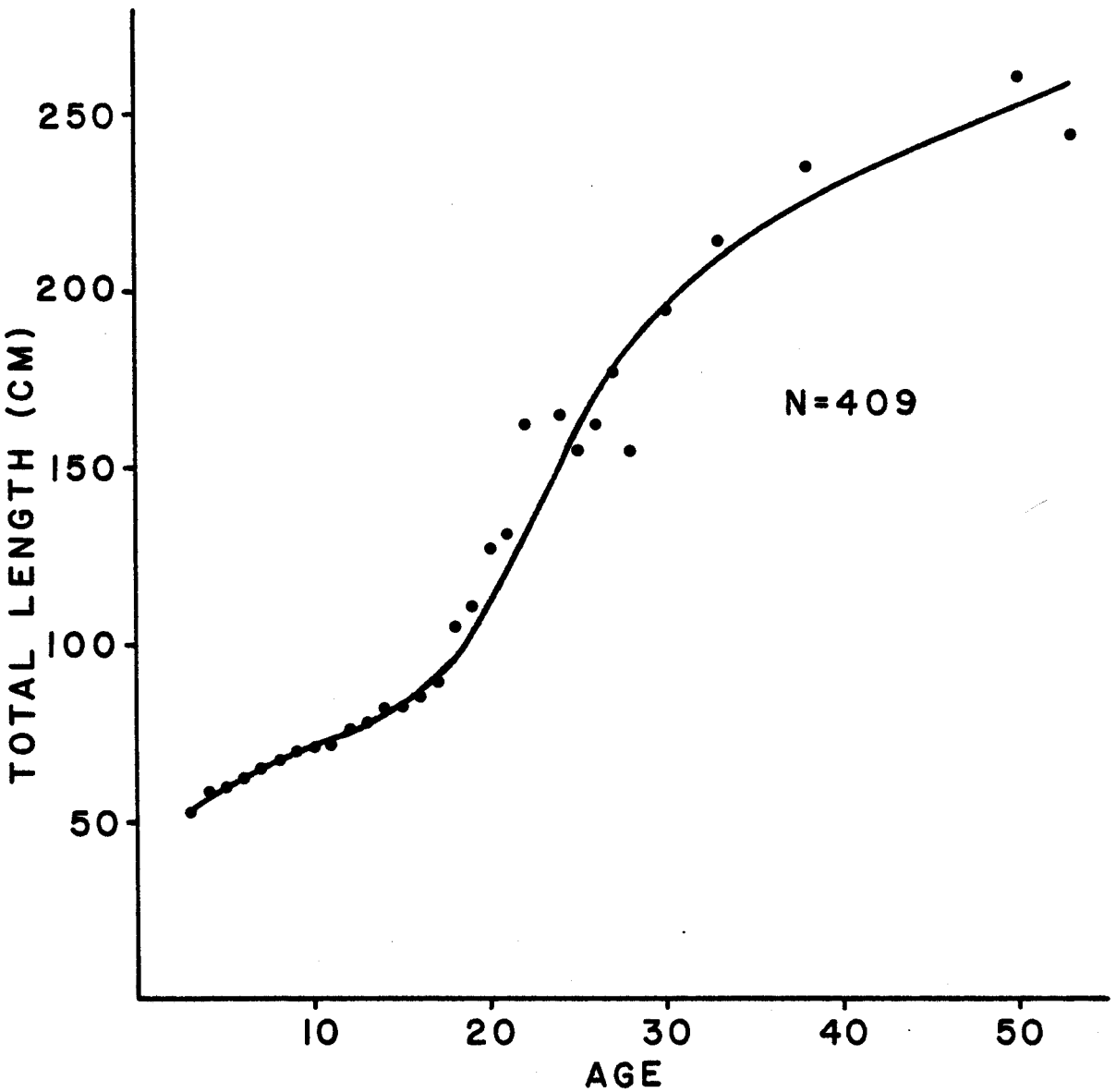

Figure 7. Mean total length at age for white sturgeon sampled in Hells Canyon, 1982-84.

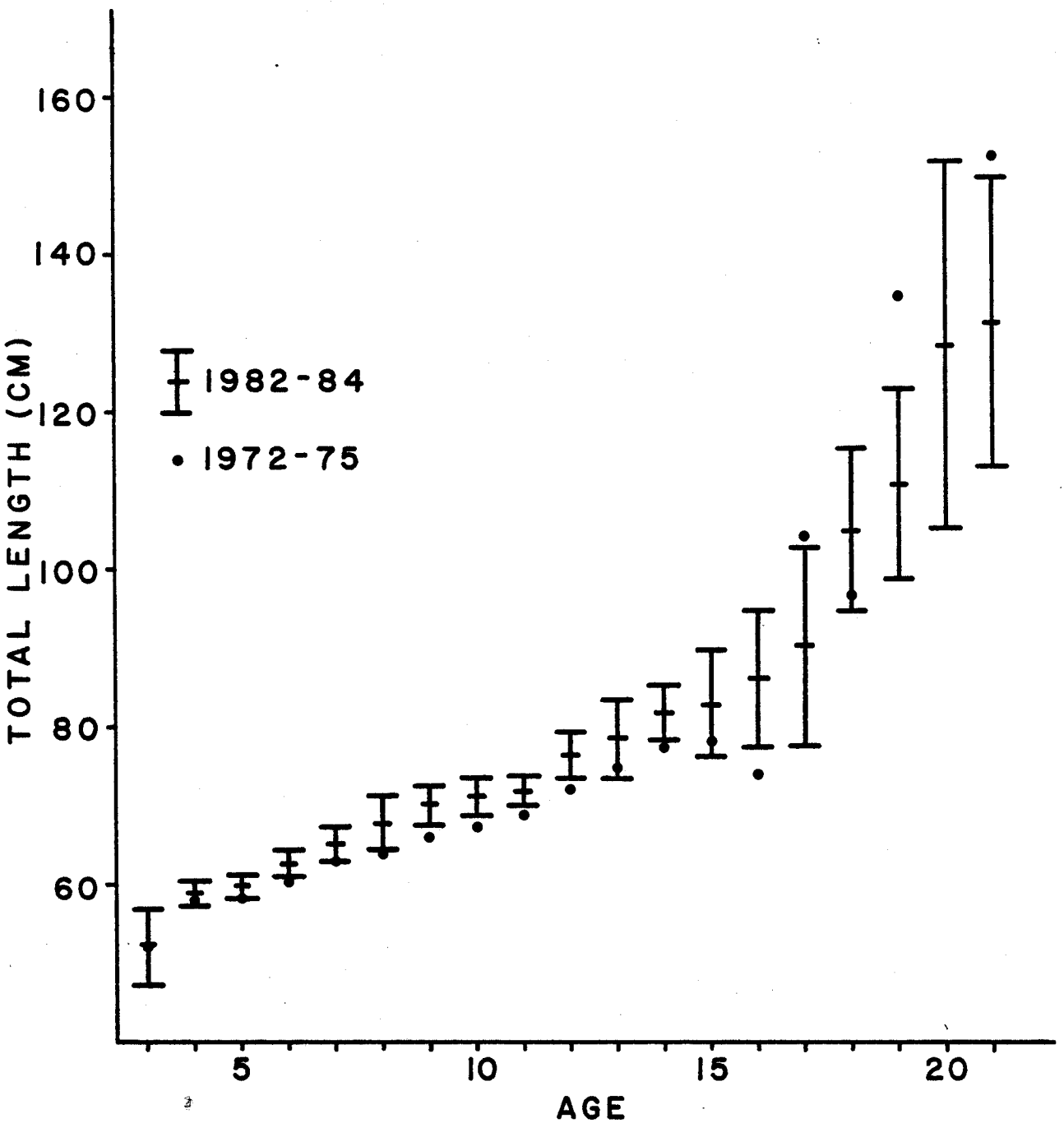

Figure 8. Mean length at age, bracketed by 95% confidence intervals, for sturgeon sampled in 1982-84 and mean length at age for sturgeon sampled from 1972-75 by Coon et al. (1977).

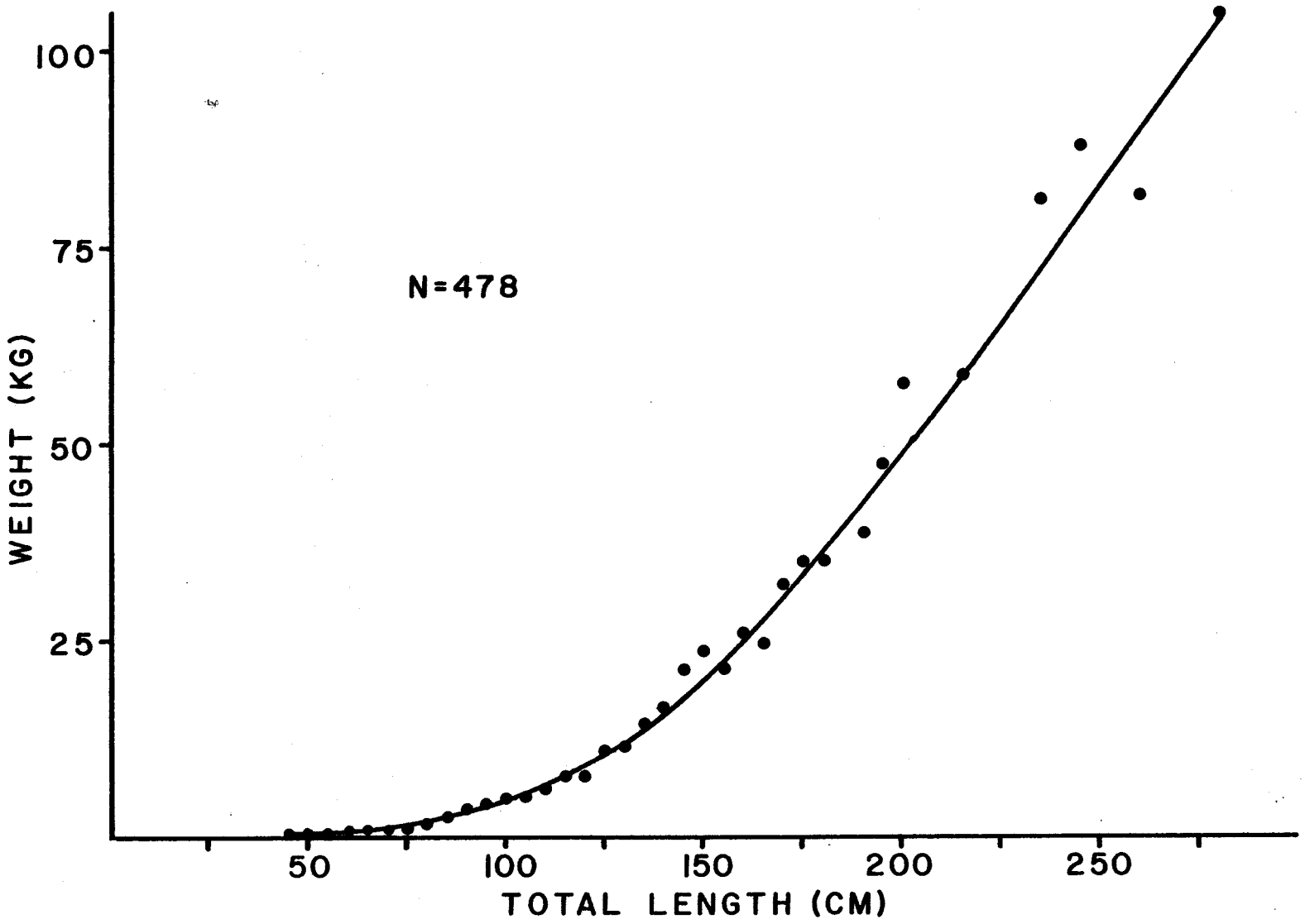

Figure 9. Length-weight relationship for white sturgeon captured in Hells Canyon, 1982-84. Weight at total length is mean weight for 5 cm length groups.

Comparison of these two relationships suggests that fish condition has improved since the earlier study, particularly for larger fish (Fig. 10). T-tests (P=0.95) of mean weights for 5 cm length groups did not show that these differences were significant, however.

Population Estimates

An estimated 2,683 white sturgeon (95% confidence intervals of 1,944 to 3,664), 45.0 to 280.0 cm long, inhabit the Snake River between Captain John Creek and Johnson Bar. This estimate includes 2,133 fish between 45.0 and 91.5 cm long, 494 fish between 91.5 and 182. 8 cm, and 56 sturgeon
between 182.8 and 280.0 cm. Expanding this estimate to the total free-flowing portion of the Snake River between Lewiston and Hells Canyon Dam would result in an estimated population of 3,955 sturgeon.

Mortality

Mortality rates were calculated from catch curves. Sturgeon were fully recruited to the sampling gear at six years of age (62.8 cm), and estimates were made for fish through age class 25 (sample sizes for older
age classes were too small) (Fig. 11). Total instantaneous mortality (Z) was 0.13, and total annual mortality (A) was 0.12 for sturgeon 6 to 25 years of age.

Total annual mortality for similar age classes has decreased by two-thirds since the earlier study (Fig. 12). A rate of 0.35 was estimated for sturgeon 10 to 20 years of age, collected in 1973-1975. While sturgeon from the earlier study recruited to identical gear at an older age, the lengths were similar--67.7 cm compared to 62.8 cm for this
study. The results of a T-test comparing the slopes of the two regressions (Dixon and Massey 1969), using only those portions for fish 10 to 20 years of age, showed that the difference was significant.

Computer Population Simulation

Input data for the population simulation model, including estimated number of fish by age class, mean length at age, mortality rates and exploitation rates, is shown in Table 8. The initial run utilized catch-and-release regulations to predict population trends under current
regulations (Fig. 13). The predicted trend in spawner (fish 125 cm and larger) abundance exhibited major oscillations, presumably due to a disproportionate number of fish in age classes 6 to 14 and their resulting progeny. This large number of juvenile fish moving through the population masked the effects of various exploitation rates used in subsequent population modeling.

Table 8. Summary of data used in simulation modeling of the white sturgeon population In the Hells Canyon portion of the Snake River.

	Age Classes														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Numbers	13981	2097	524	262	231	201	190	179	242	138	209	168	106	168	50
Total length (cm)	13	34	42	47	55	63	65	68	70	71	72	77	79	82	83
Mortality rate	0.85	0.75	0.50	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Exploitation rate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Age Classes														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Numbers	82	82	50	91	41	50	17	0	41	24	9	9	9	0	9
Total length (cm)	86	90	105	111	129	132	150	155	160	165	170	177	180	190	195
Mortality rate	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.03	0.03	0.03	0.03	0.03
Exploitation rate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Number of years to simulate: 15. Number of periods per year: 4. Number of age classes: 30. Julian date which begins each period: 1, 60, 152, 244. Julian date season starts: 1. Julian date seasons ends: 365. Period in which spawning occurs: 2. Length at maturity: 125 cm. Proportion of average growth attained each period: 1. 0%. 2. 20%, 3. 60%, 4. 20%. Eggs per female equation: Eggs = -1982 + 639 Weight. Hooking mortality: 0%. Type of fishery: Catch and release. Minimum size susceptible to fishery: 45 cm. Length weight equation: Weight = 0.00000065 $Length^{3.406}$

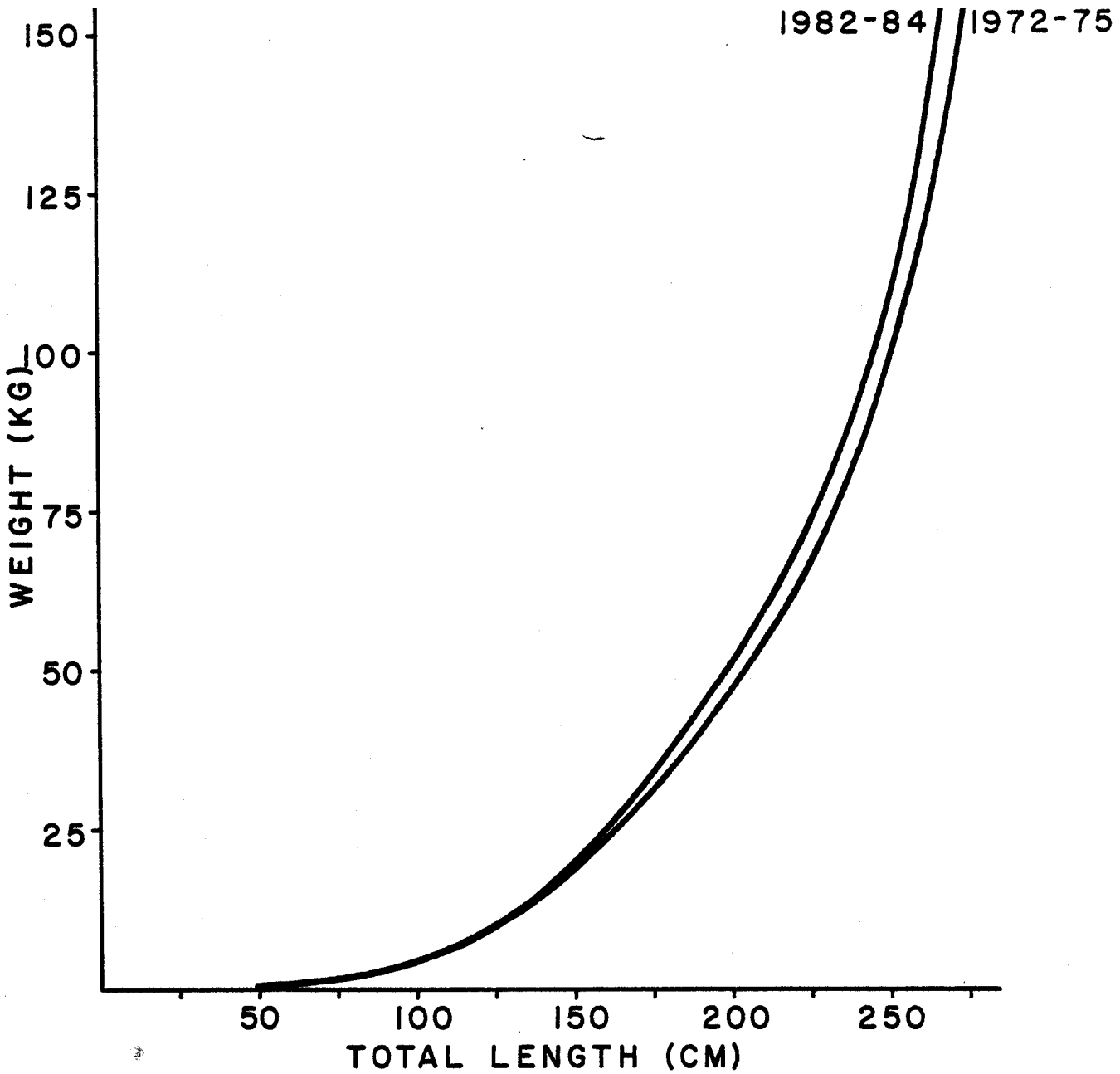

Figure 10. Length-weight relationships for white sturgeon captured in Hells Canyon in 1982-84 and in 1972-75 (Coon, unpublished data). Curves were developed from the length-weight equations.

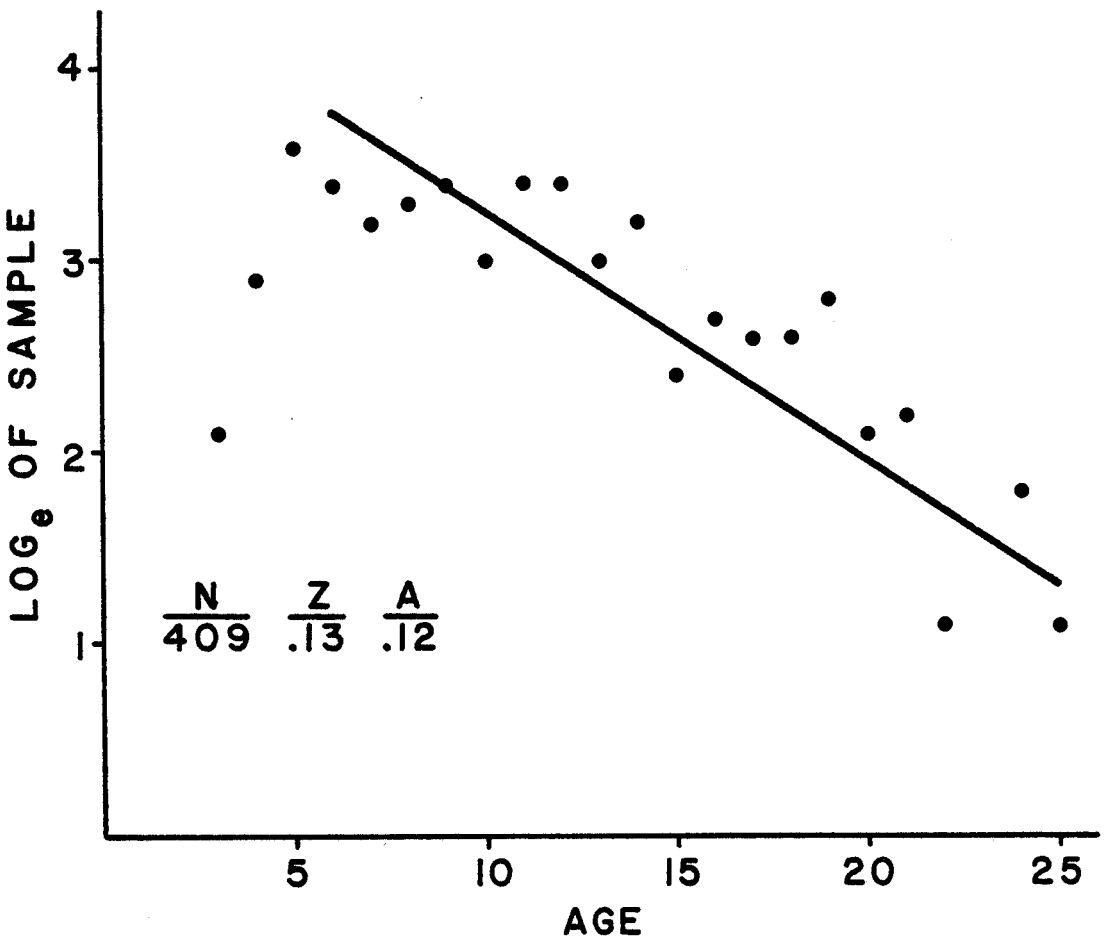

Figure 11. Catch curves, total instantaneous (Z) and annual (A) mortality rates for sturgeon, age 6 to 25 years, sampled from the Hells Canyon portion of the Snake River, 1982-84.

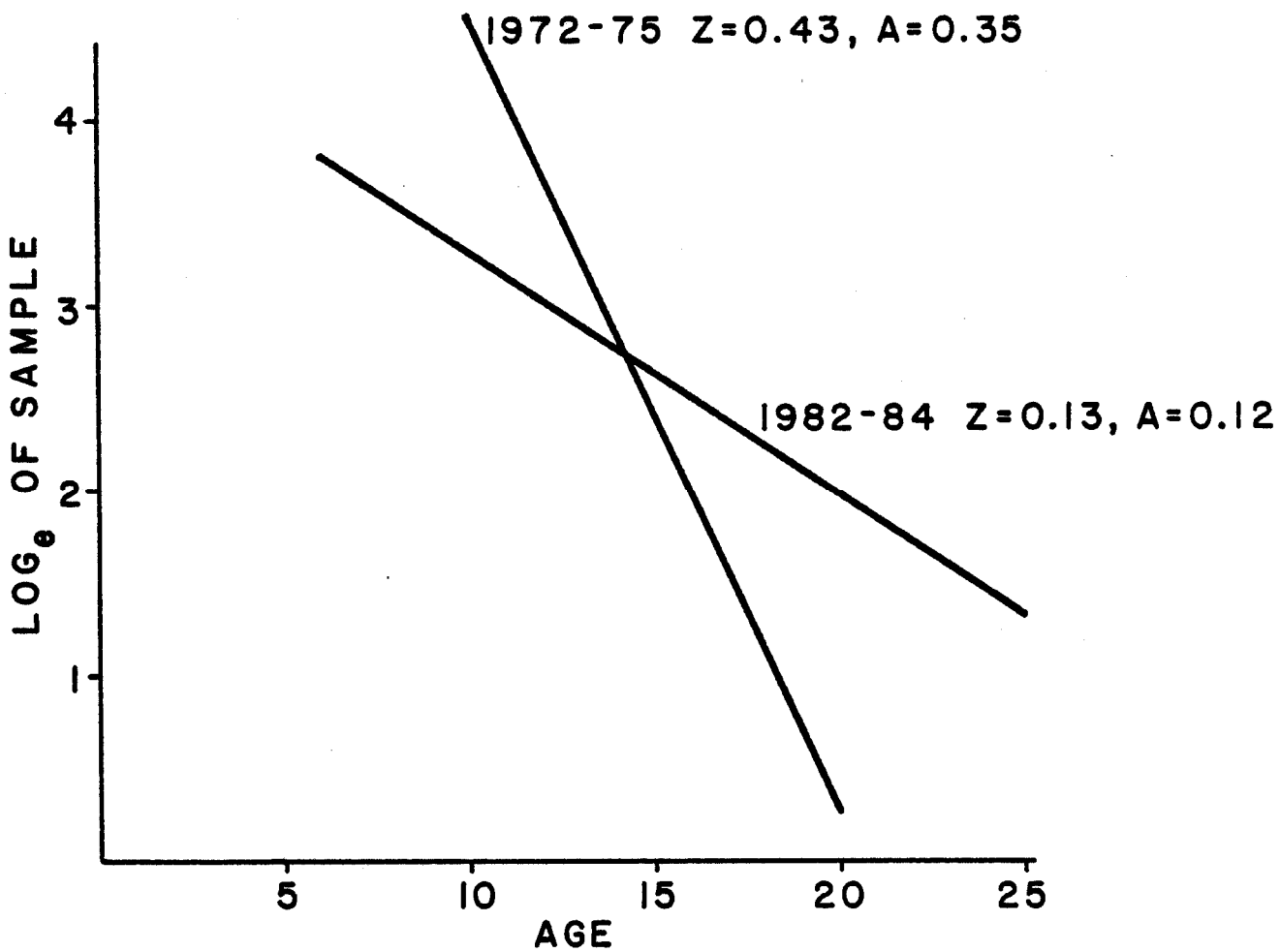

Figure 12. Catch curves, total instantaneous (Z) and annual (A) mortality rates for sturgeon sampled from Hells Canyon in 1972-75 (10 to 20 years of age) (Coon et al., unpublished data) and in 1982-84 (6 to 25 years of age).

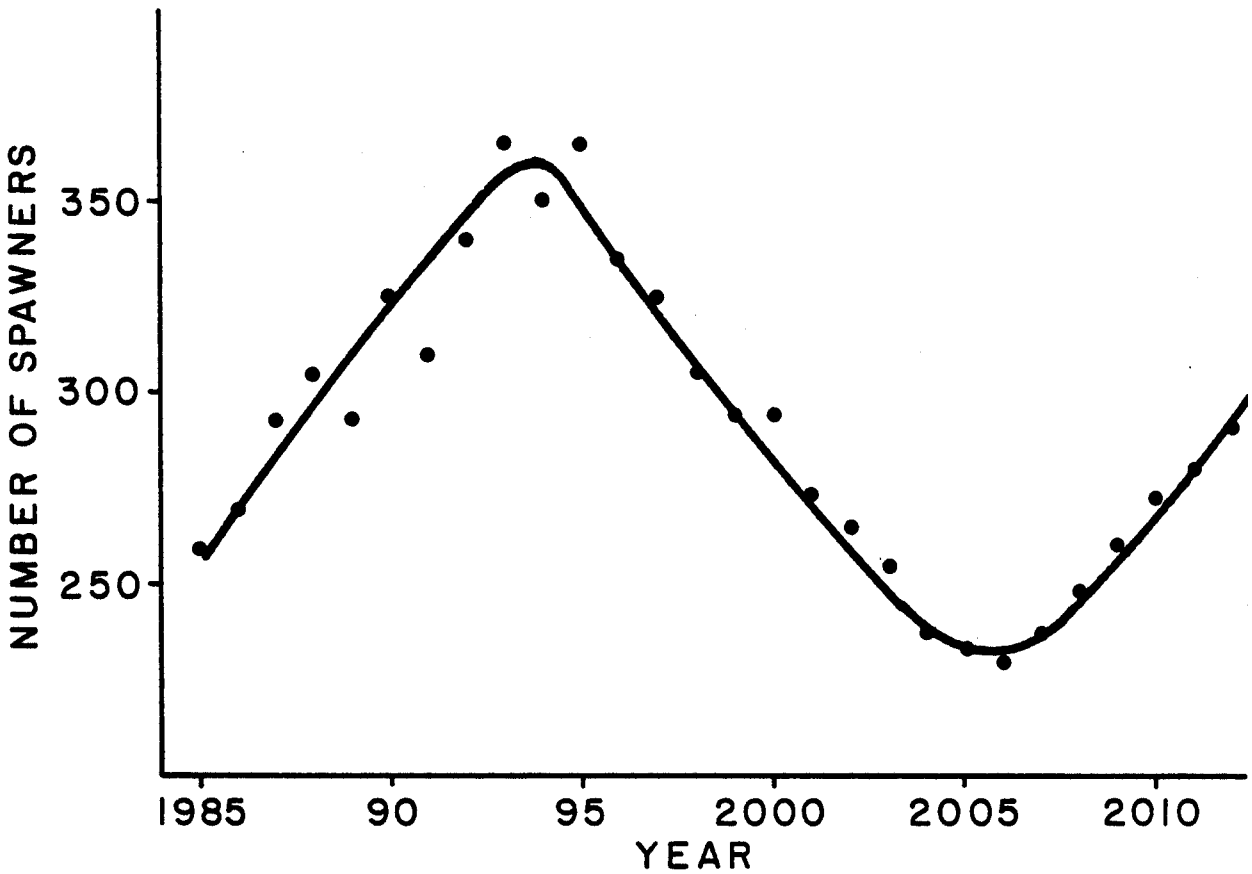

Figure 13. Simulated abundance of sturgeon spawners (fish 125 cm and longer) for a 30-year period maintaining current catch-and-release regulations.

DISCUSSION

Eliminating the harvest of sturgeon between 91.5 and 182.8 cm long in 1970 has had several beneficial effects on the population. The proportion of the population within this length group has increased 14%. Mean length at age has increased and condition has improved, presumably because the harvest of faster growing fish has been eliminated; however, comparisons of our population estimates with those determined by Coon et al. (1977) would not be accurate enough to reflect changes in population abundance (Lukens 1984). Total instantaneous mortality (Z) has decreased from 0.43 to 0.13. If we assume that all mortality that occurred during this study was natural (M = 0.13) and this was the same rate of natural mortality occurring during the earlier study, then the remaining 0.30 can be attributed to fishing mortality (F).

Coon et at. (1977) documented a tendency for small sturgeon to migrate downstream during the winter months and suggested that these fish may migrate over Lower Granite Dam and be lost to the Hells Canyon population. Limited project sampling and a popular consumptive sport fishery in the Lower Granite Dam tailrace area did not yield any sturgeon previously marked in Hells Canyon (Lukens 1984).

A disproportionate number of 6 to 14-year-old fish in the sample produced waves in the predicted spawner population abundance, making it impossible to predict effects of various consumptive angling regulations. These were the same size fish that demonstrated a strong downstream migratory tendency. Most of these fish (68%) were sampled from sites located below the mouth of the Salmon River. The large proportion of these fish in the sample was not a result of disproportionate effort since total effort was fairly evenly divided above and below the mouth of the Salmon River; 53% and 47%, respectively. Some of these fish were undoubtedly Snake River emigrants, but many were probably Salmon River
emigrants. While the exact status of white sturgeon in the Salmon River is not known, anglers report good catch rates and the population seems healthy and successfully reproducing, particularly in the lower river. Therefore, this area of the Snake River between the mouth of the Salmon River and Asotin, Washington (the upper end of Lower Granite Pool) is probably very important as a juvenile sturgeon rearing area.

After 15 years of protective regulations, the Hells Canyon sturgeon population may have recovered sufficiently to allow some level of harvest. With average growth rates, the population has not fully recovered from the effects of harvest; however, only those fish older than 32 years in 1985 were influenced. Total instantaneous mortality has declined to 0.13 and is low when compared to values reported in the literature for other white sturgeon stocks (Table 9). Cochnauer (1983) determined that numbers of sturgeon spawners in the upper Snake River would gradually decline when fish 125-183 cm long were subjected to exploitation rates of 0.05 to 0.10 when total instantaneous mortality rates were 0.06 and 0.27. With the same exploitation rates but slightly lower total mortality, spawner numbers would increase slightly. In the Sacramento-San Joaquin estuary, annual survival of 0.84-0.88 and exploitation rates of 0.06-0.07 for fish 102 cm and longer seem adequate

Table 9. Total instantaneous mortality (Z), instantaneous rate of fishing mortality (F), instantaneous rate of natural mortality (M) and exploitation rate (u) for white sturgeon populations reported in the literature.

Drainage (Author)	Age	Z	F	M	u
Sacramento (Miller 1972b)	--[a]	--	--	--	0.065 - 0.073
Sacramento (Kohlhorst 1979)	--[a]	--	--	--	0.056
Sacramento (Kohlhorst 1980)	9-20	0.0569	--	--	--
Fraser (Semakula and Larkin 1968)	11-25	0.219	0.17	0.05[b]	0.15
Kootenai (ID. Dept. of Fish and Game, unpublished data)	19-35	0.24	0.05	0.19	0.04
Upper Snake (Cochnauer 1983)	4-15	0.27	--	--	--
Upper Snake (Cochnauer 1983)	16-30	0.06	--	--	--
Middle Snake, Hells Canyon (Coon et al., unpublished data)	10-20	0.43	0.30	0.13	0.24
Middle Snake, Hells Canyon (this study)	6-25	0.13	0.0	0.13	0.0

[a]Sturgeon $\geq$ 102 cm. [b] Estimated.

to maintain a stable population (Miller 1972b, Kohlhorst 1980). While it is difficult to compare mortality rates of various sturgeon populations which vary in productivity, it seems intuitively that white sturgeon populations would not withstand exploitation rates greater than 0.10 for extended periods.

I have assumed that the rate of natural mortality during the earlier study was 0.13. If this was true, then the exploitation rate was 0.24 (Table 9). This rate resulted in severe depletion of fish 91.4-182.8 cm long. Most of the sportsmen that fish for sturgeon in Hells Canyon have experienced the beneficial effects of catch-and-release regulations, and the fishery is gaining in popularity. Because large sturgeon can now be caught regularly and repeatedly, few anglers would probably support consumptive regulations. If a consumptive fishery was chosen as a management option, however, it would have to restrict harvest to a limited number of fish of a given length. A window limit of 125-183 cm would allow most of the fish to spawn once and protect larger trophy fish for the catch-and-release fishery. Exploitation. rates of 0.05, 0.07, and 0.10 would allow the annual harvest of 10, 14, and 20 fish, respectively, between 125 and 183 cm long.

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Submitted by:

James R. Lukens
Principal Fishery Research Biologist

Approved by:

IDAHO DEPARTMENT OF FISH AND

Jerry M. Conley, Director

Monte R. Richards, Chief
Bureau of Fisheries

David W. Ortmann
Fishery Research Supervisor