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## PROGRESS REPORT ON WHITE STURGEON STUDIES<sup>1</sup>

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On April 1, 1954, for the first time in 35 years, it became legal to take sturgeon (*Acipenser transmontanus* and *A. medirostris*) in California waters. Heavy commercial fishing had led to serious depletion by 1900. Earlier, they had been abundant enough to have been considered a nuisance.

The commercial fishery was closed in 1901, reopened to a limited extent in 1910, and then closed completely in 1917.

In recent years sturgeon have again become fairly abundant. On the basis of recommendations by the Department of Fish and Game, the commission established a sport fishery in 1954, with a one-fish-per-day bag limit, a 40-inch minimum size limit, and no closed season.

In order to gather information necessary for the future management of this new sport fishery a life history study of the white sturgeon, the most important species in the fishery, was begun in July of 1954. The immediate objectives were to observe the growth of the new fishery, and to learn enough of the life history to evaluate and improve the present regulations.

Work was centered in the Sacramento-San Joaquin Delta and San Pablo Bay, where sturgeon are most abundant.

### METHODS

To measure exploitation by fishermen, intensive tagging of sturgeon was carried on in San Pablo Bay from August to November, 1954. Fish were captured with salmon trammel nets 225-250 fathoms long and 5 fathoms deep. Mesh sizes ranged from 7½ to 9½ inches stretched measurement, with trammel meshes 31 inches stretched measurement. The nets were drifted across mud flats in the north half of San Pablo Bay in 6 to 12 feet of water. The 28-foot research vessel STRIPER was used for this work.

It was found that schools of sturgeon could be located by scouting for concentrations of jumping individuals. Six-foot fish made splashes that could easily be seen a mile away.

When a school was located, the net was drifted over it. As soon as three or four fish were seen to hit the net, it was reeled in. Usually 30 or more sturgeon were caught, and one drift took 115. Most of them were held securely enough to pull in over the stern roller with the net (Figure 1). Very large specimens had to be lassoed around the caudal

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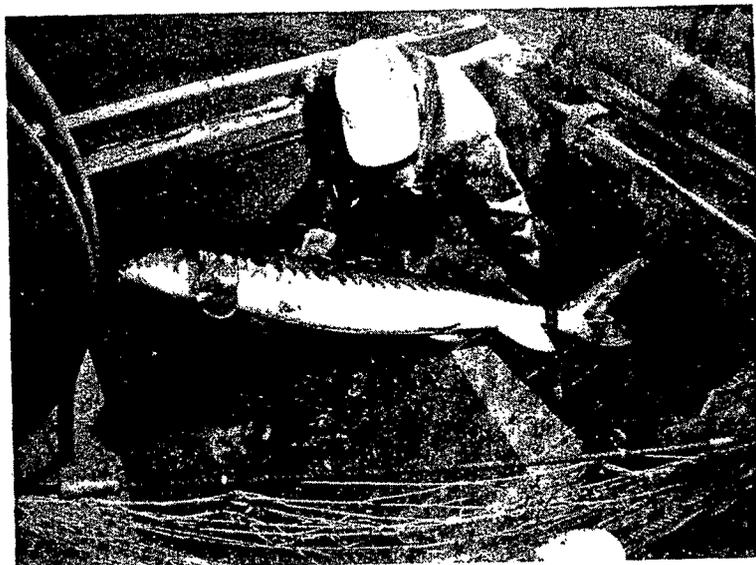


FIGURE 1. Newly tagged white sturgeon in the well of the STRIPER. The stern roller is in the right background. Photograph by William Dillingner.

peduncle and hauled in by two or three men. The two largest individuals, 93 and 94 inches long, were estimated to weigh approximately 300 pounds.

The fish were laid on their bellies in the well of the boat, measured with a steel tape, tagged, and then turned on their side while a one-inch section of the first pectoral ray was removed with a small hacksaw and knife. They were reasonably calm as long as they were kept upright, but could be held still only with difficulty when turned on their sides.

Several types of tags were used in tagging method experiments, including Petersen disks and stainless steel wire (type 302) on the base of the upper lobe of the caudal fin, plastic "spaghetti" type G tags inserted between two dorsal scutes, tantalum wire disk-dangler tags below the dorsal fin, and disk-dangler tags on the upper lobe of the caudal fin (Table 1). Most fish were double tagged.

Type of tag and position	Number
Petersen disk on caudal base	886
Plastic "spaghetti" between two dorsal scutes	641
Disk-dangler below dorsal	211
Disk-dangler on caudal base	62
Total	1,800

Altogether, 1,003 individuals were tagged.

Fin ray sections were removed from a total of 520 fish. Of these, 443 were netted, 45 were obtained from anglers, and 32 small fish ranging in length from 8 to 18 inches were taken at the fish screens of the Tracy Pumping Plant. Lengths and weights of 163 fish were obtained from

anglers and party boat operators. Total length measurements are used throughout this discussion because the data from anglers were in this form.

Fin rays were air-dried and cross-sectioned with a fine-toothed jeweler's saw. The sections were polished on one side, glued to cellulose acetate slides with "Duco" cement, and ground down to about 0.015 inch on silicon carbide paper (Pycha, 1955). They were examined under a dissecting microscope, using either transmitted or reflected light. Most sections showed annular rings clearly.

Cuerrier (1951) shows several examples of fin ray sections of lake sturgeon (*A. fulvescens*) much like those of white sturgeon.

Sections from 125 fish were damaged or were too questionable to be included in the results, leaving a total of 395 sections aged with confidence. The questionable sections came from fish scattered throughout nearly the entire size range. All sections were aged at least twice with independent determinations.

#### LENGTH-FREQUENCY OF SAN PABLO BAY STURGEON

The fish tagged in San Pablo Bay ranged from 31 to 94 inches in total length (Figure 2). It is believed that those over 40 inches were

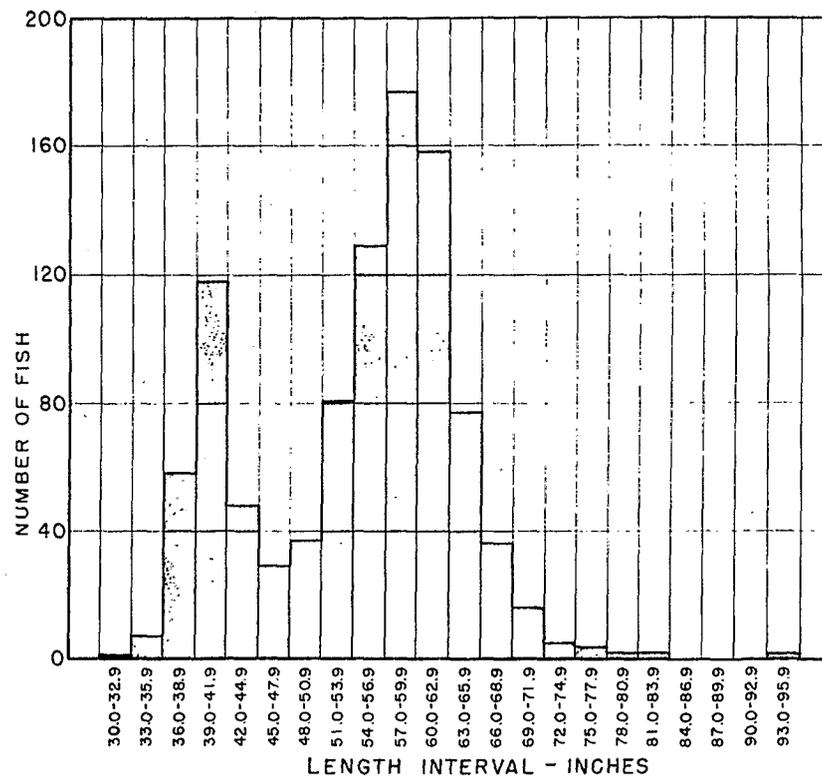


FIGURE 2. Length frequency of white sturgeon tagged in San Pablo Bay.

fully vulnerable to the nets used. The small number of fish between 42 and 51 inches is therefore probably representative of the population. Angling records from San Pablo Bay and the entire Delta area also show very few fish of that size range caught. The implications of the length-frequency distribution will be discussed in a later section.

#### SIZE OF SAN PABLO BAY WHITE STURGEON POPULATION

Enough tagged fish were recaptured during the netting operation to estimate the sturgeon population in San Pablo Bay in the fall of 1954. A total of 966 was tagged, and 45 were recaptured (Table 2). The population estimate is:

$$\hat{P} = \frac{\Sigma (AB)}{\Sigma C} = \frac{501,936}{45} = 11,154$$

where  $P$  = estimated population

$A$  = number of fish tagged on a given day

$B$  = number of fish tagged prior to the given day

$C$  = number of recaptured fish in a given day's sample

TABLE 2

Data for Estimation of White Sturgeon Population in San Pablo Bay

Day fished	(A) Number caught	(B) Total at large	(C) Number of tagged fish recaptured
1st*	13	49	1
5th	32	155	1
6th	50	186	3
7th	48	233	1
8th	31	279	1
9th	29	309	1
10th	13	336	0
11th	30	349	2
12th	41	377	1
13th	21	416	1
14th	25	439	0
15th	22	461	0
16th	50	486	0
17th	11	531	1
18th	7	574	0
19th	68	581	2
20th	35	611	3
21st	92	676	5
22nd	115	763	10
23rd	32	868	2
24th	42	898	4
25th	35	976	5
26th	36	966	1

\* Fishing was started several days before this day, but only a few fish were caught and none recaptured.

The 95 percent binomial confidence limits are 8,806 and 15,734. The recapture by commercial fishermen of two tagged fish that had migrated out of San Pablo Bay while tagging was still in progress indicated the estimate may be too large because of migration of tagged fish from the fishing area. However, the time intervals at large of the recaptured fish

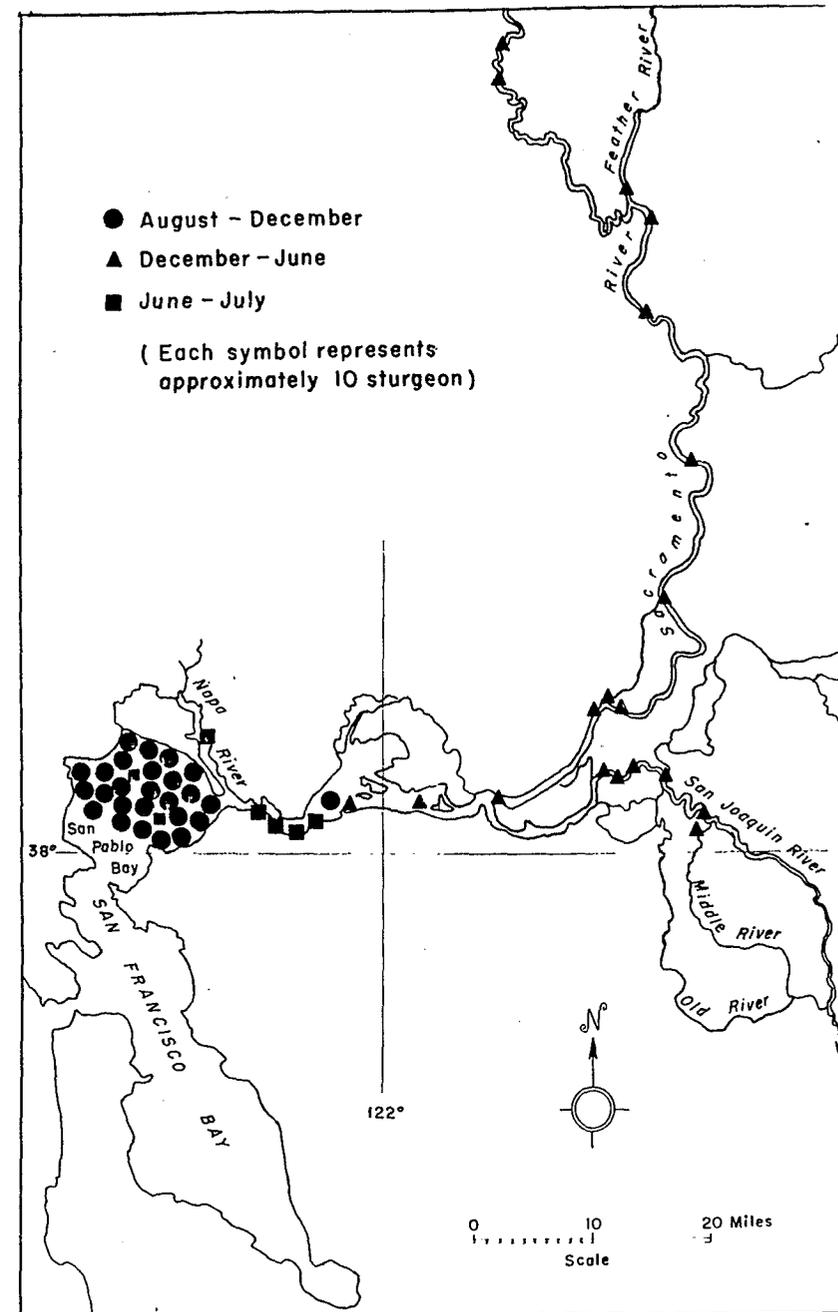


FIGURE 3. Locations where anglers caught sturgeon during the period April 1, 1954, to April 1, 1955. (Data from newspaper reports, Fish and Game warden reports, personal interviews, and communications.)

TABLE 3  
Frequency Distribution of Various Age Groups, Mean Lengths of Various Age Groups, Corresponding Values on "Failed-in" Growth Curve, and Annual Increments of White Sturgeon

Length in inches	Age group														
	0	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
0-2.0															
3.0-5.9															
6.0-8.9	1														
9.0-11.9	29														
12.0-14.9															
15.0-17.9		1													
18.0-20.9			2												
21.0-23.9															
24.0-26.9						1									
27.0-29.9															
30.0-32.9						2									
33.0-35.9						5									
36.0-38.9						16	2	1							
39.0-41.9						21	4	4	2						
42.0-44.9						10	1	7	1	1					
45.0-47.9						2	4	4	1	3					
48.0-50.9							1	3	1	1					
51.0-53.9								1							
54.0-56.9											1				
57.0-59.9															
60.0-62.9															
63.0-65.9															
66.0-68.9															
69.0-71.9															
72.0-74.9															
75.0-77.9															
78.0-80.9															
81.0-83.9															
84.0-86.9															
87.0-89.9															
90.0-92.9															
93.0-95.9															
No. fish	30	2	6			4	54	12	20	4	9	1	2	2	18
x Length	10.4	18.0	21.2			31.5	39.8	43.0	44.6	42.8	45.5	55.5	51.0	52.5	54.7
"Failed-in" value	10.5	18.0	23.0	28.0	32.0	35.3	38.5	41.0	43.6	45.8	47.9	50.0	52.2	54.5	56.8

TABLE 3—Continued

Frequency Distribution of Various Age Groups, Mean Lengths of Various Age Groups, Corresponding Values on "Failed-in" Growth Curve, and Annual Increments of White Sturgeon	
Age group	Mean Length
XV	55
XVI	125
XVII	10
XVIII	15
XIX	6
XX	5
XXI	2
XXII	2
XXIII	
XXIV	
XXV	1
XXVI	1
XXVII	
XXVIII	
XXIX	1
XXX	1
XXXI	1
XXXII	1
XXXIII	1
XXXIV	1
XXXV	1
XXXVI	1
XXXVII	1
XXXVIII	1
XXXIX	1
XXXX	1

gave no evidence of a systematic migration through the bay, so this is probably not a serious source of error.

Fin ray sections gave no evidence of growth during the brief tagging period, and mortality is believed to have been negligible. Aside from one fish caught by the Petersen disk tag, no evidence of differences in behavior of tagged and untagged fish was noted. This fish was not included in the recaptures. The Petersen disk tags had caused irritation on some fish, but all other types had healed well. Loss of tags during the period involved is therefore believed to have been negligible.

#### MIGRATION OF WHITE STURGEON

By April 1, 1955, only six tags had been returned by anglers: four from San Pablo Bay, and two from the Sacramento River. One had migrated approximately 60 miles upstream. The upstream migrants were taken during the winter of 1954-1955.

Tags were removed from five other fish by commercial salmon fishermen who caught them while salmon fishing, and several others have been reported caught, but the tags have not been returned.

The frequency of sturgeon catches in the Sacramento and San Joaquin rivers in the spring, and in San Pablo Bay in the fall (Figure 3), suggests an annual winter or spring upstream migration and summer downstream migration of large fish. Small fish less than 40 inches long seem to be present throughout the Delta area all year.

Columbia River sturgeon are known to enter the ocean (Bajkov, 1951). Knowledge of the extent to which Californian fish enter the ocean is incomplete. Occasional catches by commercial fishermen off the central California coast have been reported, but the origin of these fish was not known. Tagging data are expected to further clarify this phase of the life history.<sup>3</sup>

#### VALIDITY OF THE FIN RAY AGE DETERMINATIONS

The fin ray method of age determination has been well validated for other sturgeons, but not for this species. Final validation is impossible with only a single year's collection. However, indications are that the method is valid.

The number of "annular" rings per section increases progressively in the expected manner with the size of the fish (Table 3). Age group modes correspond reasonably well with length-frequency modes for at least the first six years. Moreover, large numbers of six- and sixteen-year-old fish correspond almost exactly with the two modes of the length-frequency distribution, suggesting a typical dominant year class type of age distribution.

If there are strong seven- and seventeen-year-old groups in a large 1955 sample, the method will be well validated.

<sup>3</sup>A sturgeon tagged November 5, 1954, in San Pablo Bay, California, was recovered in the Columbia River near Astoria, Oregon, on October 26, 1955.

#### AGE COMPOSITION OF THE STURGEON POPULATION

It is apparent from the age class distribution (Table 3) that spawning success of sturgeon has fluctuated greatly. Age groups VI and XVI comprised 50 percent of all the fish over four years old. Age groups IX through XIII contained only 15 fish, and all age groups older than XX were also poorly represented. Most large fish that hit the nets could be seen, and few are believed to have escaped. If the year classes before 1936 (age group XVIII) had been very abundant, more should have been caught.

Since sturgeon weighing several hundred pounds were once common, it seems safe to assume that natural mortality is very low and could not account for the present scarcity of fish older than 20 years. The bulk of the stock now available to anglers came from the 1937 through 1940 year classes, with the 1938 year class providing most of the fish.

From all indications another sizable year class (1948) is just entering the fishery. Its relative size is uncertain, because many of the fish were probably too small to catch in the nets used. Many of the small fish observed going through the nets may have been slow-growing members of the 1948 year class.

#### GROWTH IN LENGTH

The first fin ray was commonly fused with the second ray and grown around it, making back calculations of growth impractical. Moreover, growth of most fish appeared to be relatively constant from year to year, making back calculations of little use in validating age determination. Lengths at capture of the various age groups have therefore been used to express growth.

Mean total lengths for each age group were calculated (Table 3) and plotted against age (Figure 4). One year was added to each age

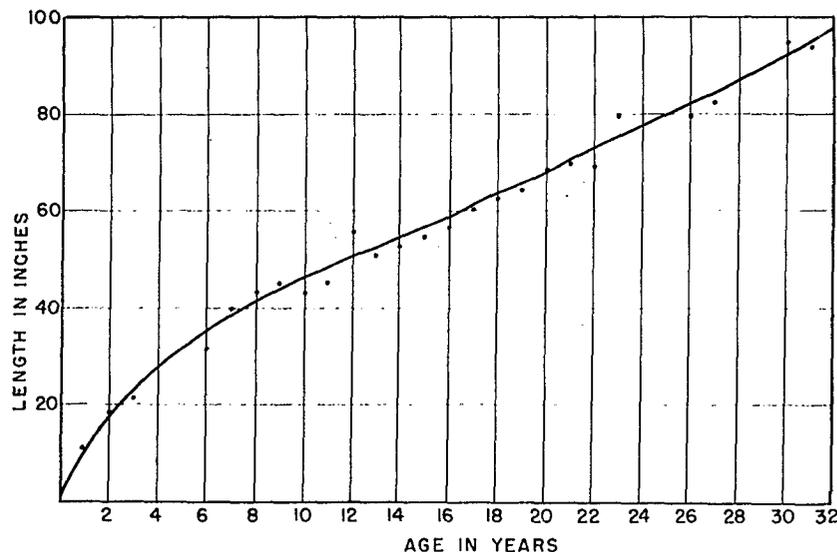


FIGURE 4. Growth in length of white sturgeon.

group because one growth season was presumably completed after the last annulus. An approximate growth curve was then "faired-in" (Table 3).

Annual length increments are large for the first four years, but decline to a nearly constant increment of 2.1 to 2.6 inches after the eighth year (Table 3). Although some differences in growth rate between the sexes might be expected, data were insufficient to clarify this point.

Sturgeon begin to reach the 40-inch minimum legal length in the seventh growing season, and almost all of them do so by the ninth growing season.

If growth in length continues at a similar rate after the thirtieth year, the 14- to 16-foot specimens reported in the early days of the fishery must have been 60 to 75 years old.

#### GROWTH IN WEIGHT

The total lengths and weights of 163 sturgeon caught by anglers, and of several small fish taken at the Tracy Pumping Plant screens, were plotted to determine the length-weight relationship (Figure 5). The regression line did not appear to be a simple curve, so an approximate line was "faired-in."

Weight increases slowly until the fish are about 35 inches, after which it speeds up. It slackens again between 50 and 60 inches, increasing again beyond that length.

The unusual change in slope of the regression curve between 40 and 55 inches should be noted. Most fish in the 50- to 53-inch range weighed between 35 and 50 pounds, while those in the 40- to 43-inch range weighed only 12 to 20 pounds.

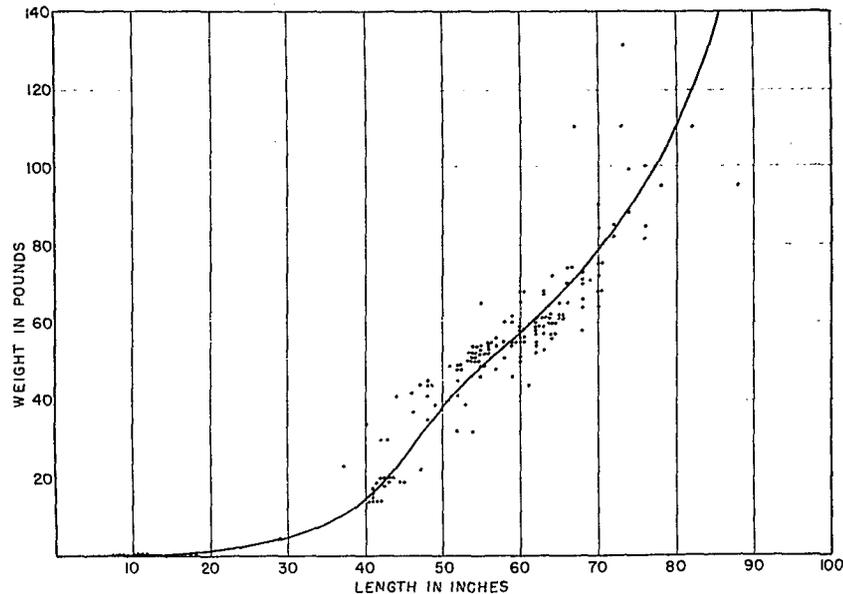


FIGURE 5. Length-weight relationship of white sturgeon.

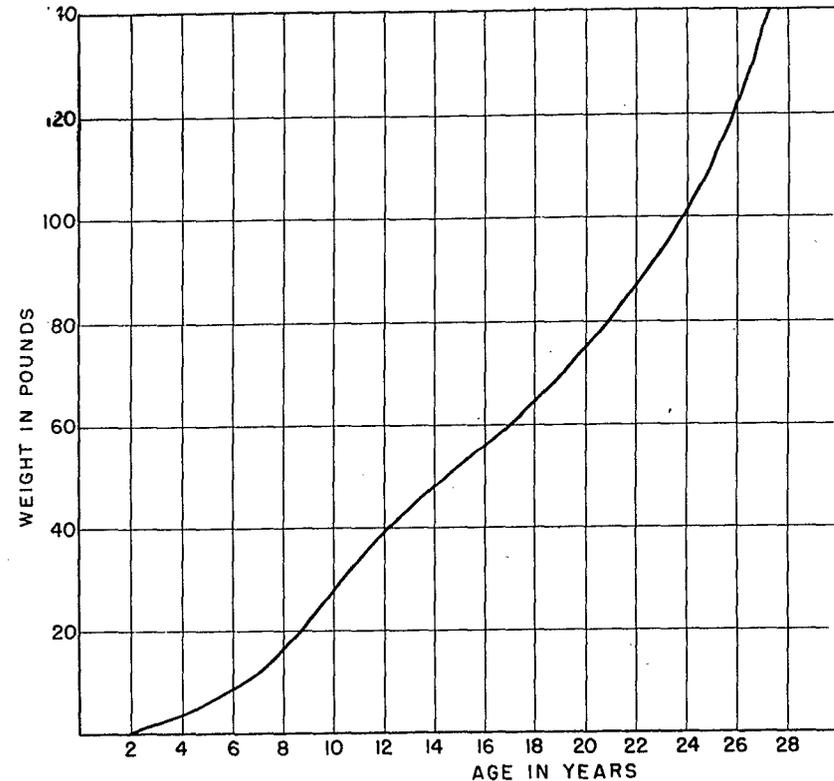


FIGURE 6. Growth in weight of white sturgeon.

A commercial sturgeon fisherman on the Columbia River informed the author that the smallest female sturgeon with ripe eggs he had seen weighed about 35 pounds. It is therefore possible that the inflection in the length-weight regression is connected in some way with sexual maturation.

By combining the data on growth in length and the length-weight relationship, a general curve of growth in weight is obtained (Figure 6). Weight increases slowly during the first 6 years, increases rapidly between 6 and about 12 years, increases more slowly from 12 to about 20 years, and increases very rapidly again past 20 years.

The largest sturgeon weighed in 1954 was 102 inches long and weighed 277 pounds.

#### MANAGEMENT IMPLICATIONS OF THE STUDY

The tagging done in San Pablo Bay indicates that the sturgeon population is large enough to support a small, carefully regulated sport fishery.

The angling catch is still small, but increasing. The large size, game-ness, and excellent table qualities of sturgeon have created much interest among sportsmen, and a few individuals have learned how to catch them in some numbers. The commercial gill net fisheries also

kill an undetermined number of sturgeon each year while fishing for salmon and shad.

The general depletion of most sturgeon fisheries in the western hemisphere is a warning that careful management of these fish is necessary.

The angling regulations established in 1954 were based on the best information available at that time. Results of this present study indicate that they were too liberal in some respects.

Fish of the present 40-inch minimum legal length are about eight years old and weigh only about 15 pounds. A 50-inch fish weighs 38 pounds or more, and is only four or five years older. Moreover, the game qualities of sturgeon are mediocre until they reach 50 inches. A 60-inch fish is a real challenge to the angler.

The sturgeon fishery should be managed so as to maintain a sizable reservoir of large fish both as a spawning stock and a buffer supply for periods of low recruitment. This should also provide maximum recreational benefits. It is particularly important to protect the broodstock of a species such as this which does not begin to spawn until a fairly advanced age, and which appears to produce a strong year class only about every 10 years.

While age at sexual maturity has not yet been determined in California, the available evidence from Columbia River fish suggests that the females are probably not mature before 11 to 12 years.

Since several fish over 100 pounds and one weighing 277 pounds were taken in 1954, and since anglers on the Columbia River take sturgeon weighing well over 300 pounds, it appears that large sturgeon can be harvested by angling.

The present sturgeon sport fishery appears to be supported principally by the 1937 through 1940 year classes, with the 1938 year class making up the greater part of the production. The next strong year class was spawned in 1948 and is just entering the fishery. The fishery is therefore dependent upon a very few widely spaced year classes. Under heavy exploitation, wide fluctuations in abundance of legal-sized fish could be expected. Heavy exploitation is possible, as demonstrated by the taking of 194 sturgeon in San Pablo Bay by one party boat between September 23 and November 28, 1954. An even greater number was taken prior to this period by trolling with snagging gear. Trolling has since been made illegal.

The size of the spawning stock necessary to maintain the California sturgeon fishery is not known. The 40-inch size limit could possibly lead to reduction below the optimal level.

It is therefore recommended that the minimum size limit be raised to 50 inches. The fishery depends, at present, primarily on fish larger than 50 inches, so little immediate reduction in total catch is to be expected. However, the large existing crop of fish under about 45 inches would be protected and allowed to grow to a size worth catching.

In order to fully utilize the growth potentialities of the species, the average size of the catch should be maintained well above 50 inches. A decrease in average size to a point near 50 inches will indicate over-exploitation. The angling catch should therefore be sampled regularly in the future to follow trends in average size.

Under proper management, the California sturgeon population should provide recreation for considerable numbers of fishermen, along with the rare opportunity of catching a really large fish in inland waters.

#### ACKNOWLEDGMENT

The invaluable assistance of Vincent Catania, Net Man and Boatswain, in carrying out the field work is gratefully acknowledged.

#### SUMMARY

After 35 years of complete closure, a sport fishery for sturgeon (*Acipenser transmontanus* and *A. medirostris*) was established in California in 1954. A life history study of the former was begun to evaluate the one-fish-per-day-bag limit, 40-inch size limit, and the no closed season regulations.

A total of 1,003 sturgeon ranging in size from 31 to 94 inches was captured with trammel nets in San Pablo Bay, tagged, and released. Pectoral spine sections were collected from the fish tagged and from fish taken by anglers for age studies.

The recapture of 45 fish while tagging gave a total population estimate of 11,154 fish in San Pablo Bay. In the first five months after tagging, only six tags were turned in by anglers and five by commercial fishermen. Only two fish were recaptured upstream in the Sacramento River. The frequency of angler catches suggests a winter or spring upstream migration and summer downstream migration of large fish. Small fish appear to be nonmigratory.

The fin ray method of age determination appears to be valid. Fish from 0 to 30 years old were aged, with age groups VI and XVI comprising about half of all fish taken. Recruitment was very poor prior to 1936 and from 1940 to 1947. Another large group of young fish is just entering the fishery.

Sturgeon attain a length of 40 inches in the eighth year, 50 inches in the 13th year, and 94 inches in the 30th year. Weight increases slowly with length up to 35 inches, increases rapidly between 35 and 45 inches, slackens somewhat between 50 and 60 inches, and increases rapidly beyond that length.

Exploitation of sturgeon is still at a low level, but is increasing. Because of the great increase in weight between 40 and 50 inches, and because of the wide year class fluctuations, a 50-inch size limit is recommended to provide a buffer stock of large fish for anglers and to insure maintenance of an adequate spawning stock.

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