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WHITE STURGEON POPULATION CHARACTERISTICS IN THE SACRAMENTO-SAN JOAQUIN ESTUARY AS MEASURED BY TAGGING[1]

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Exploitation rates were 0.073 and 0.065 for 1967 and 1968. These rates empirically seem low enough to provide adequate protection under existing regulations of one 40-inch sturgeon per angler day.

Shedding of tags under the anterior portion of the dorsal fin was negligible, but shedding was significant for tags under the posterior portion of the dorsal fin. Most tag shedding occurred after the first year.

The percentages of total tag returns returned by anglers using private boats, anglers fishing from party boats and shore anglers were 74.1, 20.5 and 5.4% respectively.

The population size was estimated at 114,667 sturgeon. The 95% confidence interval was 72,384 to 212,293.

INTRODUCTION

The white sturgeon (*Acipenser transmontanus*) population declined drastically in the late 19th and early 20th centuries, probably due to excessive commercial fishing. Both the commercial and sport fishery were closed in 1917. The population had recovered by 1954 so that a sport fishery could be initiated. Pycha (1956) and Chadwick (1959) studied white sturgeon to evaluate exploitation rates and describe its life history. Chadwick reported exploitation rates between 2 and 10%. A precise estimate was not obtainable due to tagged fish being taken in commercial gear incidental to salmon and shad fishing. There was also no measure of nonresponse.

From 1954 through 1963 anglers had no effective technique for catching sturgeon, except for snagging which was prohibited in 1956. In 1964, anglers started using bay shrimp (*Crago* sp.) which greatly increased angling efficiency. This tagging study was initiated to determine the impact of the new fishing techniques on the harvest rate. Returns are no longer influenced by commercial fishing as none is permitted in the Sacramento-San Joaquin estuary with gear which could capture sturgeon.

TAGGING METHODS

An 8-inch trammel net was drifted in San Pablo Bay (Figure 1). Drifts lasted 15 min to 1 hr. Sturgeon were removed from the net, placed in cradles and tagged with disc dangler tags using methods described by Chadwick (1963).

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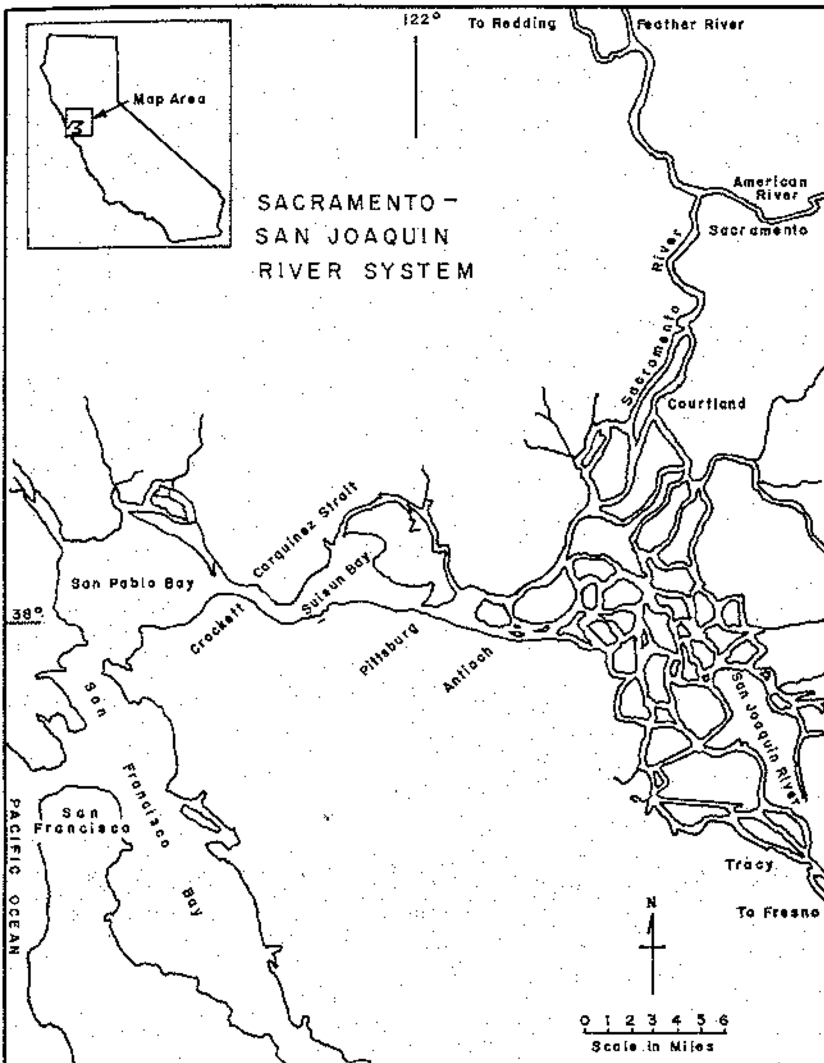

FIGURE 1. Map of the study area. Tagging was done in San Pablo Bay.

Five-dollar reward tags were used exclusively to assure a high response from anglers catching tagged sturgeon. Approximately one-half of the fish were double-tagged to determine tag shedding rates. Tags were placed through the upper back below the anterior and posterior end of the dorsal fin (locations A and B respectively, see Figure 2). Approximately one-fourth of the fish were single-tagged at A only, and one-fourth at location B only. The A location was empirically better because the muscle mass at that location is large and firm.

Only fish longer than the 40-inch TL minimum size limit were tagged.

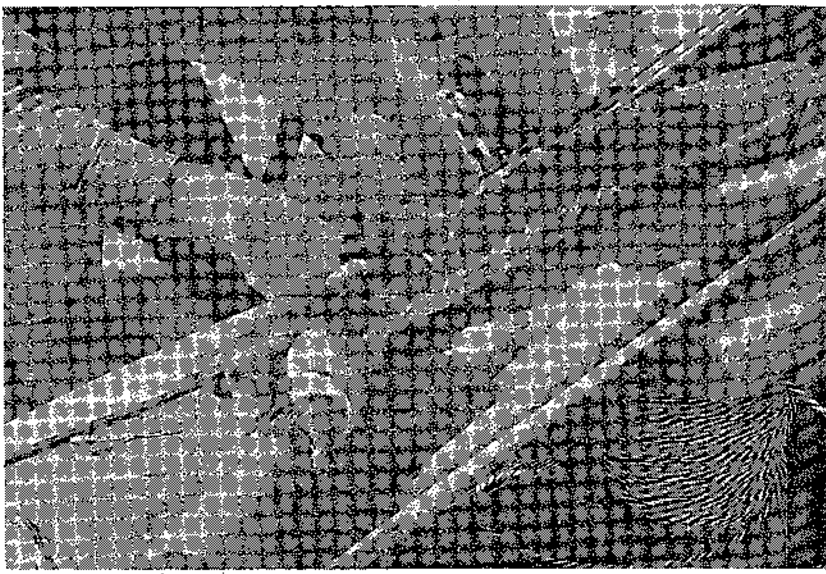

FIGURE 2. White sturgeon being double tagged with disc dangler tags. The anterior tag is designated tag A, the posterior tag B.

RESULTS

In 1967, 1,612 sturgeon were tagged and in 1968, 1,080 sturgeon were tagged. The mean size of sturgeon tagged in 1967 was 47.0 inches and in 1968, 48.8 inches (Figure 3).

Effect of Condition on Returns

To evaluate handling induced mortality, the condition of each sturgeon was classified subjectively as good, fair or poor depending upon the vigor of the sturgeon's swimming efforts upon release.

Surprisingly the fish in fair or poor condition had significantly higher returns than those in good condition.

The only direct evidence of mortality was one tagged sturgeon found dead along the shore of San Pablo Bay. Undoubtedly there were some other mortalities but the general hardy nature of sturgeon is favorable to their withstanding the stress.

Tag Shedding

Returns from double-tagged fish were combined for 1967 and 1968 and revealed significant shedding (Figure 4). A few tags in the B position were shed during the first 360 days. However, during the interval 360–480 days, the shedding rate increased dramatically so that of the 39 double-tagged returns, 18 had shed the B tag. The A tag shedding rate was much less than the B rate and remained at a low rate throughout the study period (Figure 4). Only 6 tags of 198 returns received to date were shed.

Probabilities of tags being shed were calculated using the formulas of Gulland (1963). The probability for A tag shedding was 0.011 for the first 360-day period; 0.017 for the first 720 days and 0.024 for the

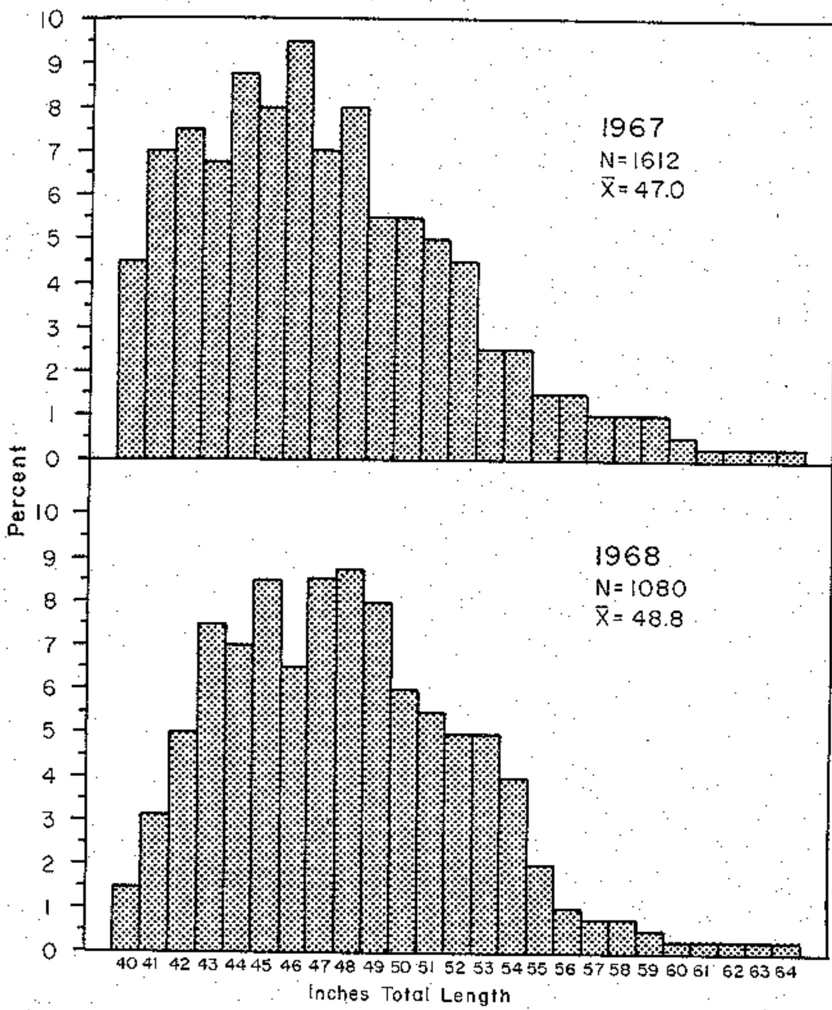

FIGURE 3. Length frequency of sturgeon tagged in 1967 and 1968.

first 1,080 days. The probability of B tag loss was 0.057 for the first 360-day period; 0.314 for the first 720-day period and 0.500 for the 1,080-day period.

The shedding of B tags after 1 year was undoubtedly a function of the time required to wear a hole through the flesh at that location. The A position was at a much thicker cross section of the body. Hence, A tags remained attached fairly well through the first 1,080 days.

The ratio of returns from single A tagged to single B tagged fish generally increased with time, indicating the shedding of the B tags (Table 1). This corroborates the data developed in the double tagging experiment.

A pertinent use of the single tags is to examine the possibility that double-tagged fish suffer an increase in mortality due to the extra stress

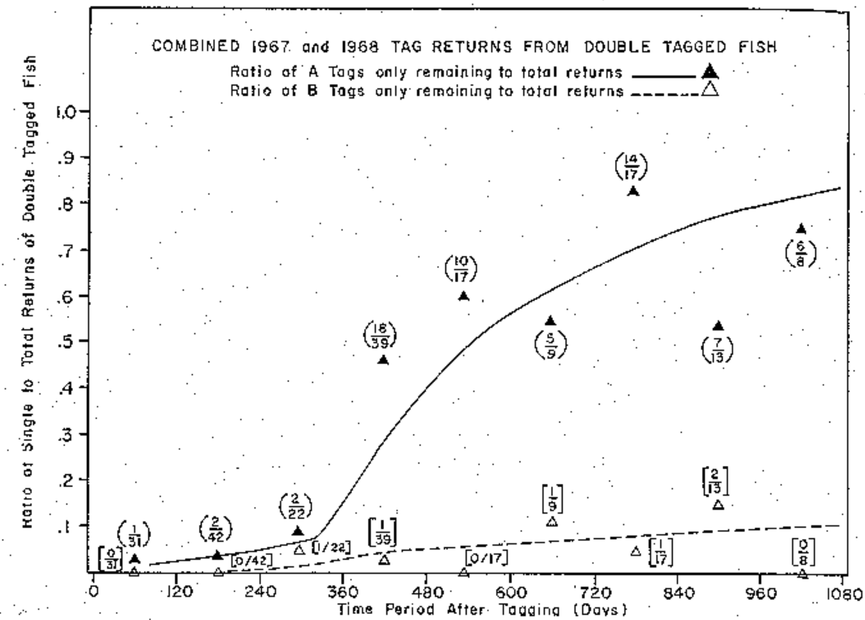

FIGURE 4. Rate of shedding illustrated from returns from fish which were double tagged in 1967 and 1968. Shedding rates during 120-day intervals are indicated by ratios of returns from fish with one tag shed to total returns from double tagged fish regardless of which tags remained. Ratios in parenthesis indicate the number returned.

of having two tags. The returns from single A tags and double-tagged fish with A tags still attached were compared with the expected returns based on the numbers of single and double-tagged fish released. A similar comparison was made for B tags (Table 2). The Chi-square values were not significant indicating that double-tagged fish do not suffer higher mortality than the single-tagged fish.

Exploitation Rate

Only single A and double-tagged fish were used in estimating mortality rates to avoid bias due to the shedding of B tags (Table 3). No correction was made for the slight bias caused by the shedding of A tags. The exploitation rate was 0.073 for 1967 and 0.065 for 1968.

TABLE 1. **Comparison of Single B to Single A Tag Returns from the 1967 and 1968 Tagging Combined.**

	Interval (days)					
	0–240	241–480	481–720	721–960	961–1200	Total
Single A	31	24	18	13	4	90
Single B	34	23	7	6	0	70
Ratio A/B	.91	1.04	2.57	2.17	--	1.29

TABLE 2. **Comparison of Single Tag to Double Tag Returns for A and B Tags from the 1967 Tagging.**

Tags	Tags released	Expected returns	Actual returns	χ^2	Tags	Tags released	Expected returns	Actual returns	χ^2
A	414	69.7	64	--	B	400	45.4	46	--
AB	798	134.3	140	--	AB	798	90.6	90	--
Total	1,212	204	204	0.2457	Total	1,198	136	136	0.0026

Survival in 1967 was estimated to be 0.862 using Ricker's (1958) formula 4.1, so the estimated annual expectation of natural death for 1967 is 0.065.

Mean first year return rates for 1967 and 1968 combined were 7.0% for fish less than 45 inches, 5.8% for fish 46–50 inches, and 7.2% for fish greater than 51 inches long. These percentages do not differ significantly indicating that exploitation rate is not related to fish size.

Characteristics of the Fishery

A postcard questionnaire was sent to each angler returning tags to determine if they were fishing from a party boat, private boat or shore. These tabulations (Table 4) show that anglers fishing from private boats dominated the fishery (74.1%). Party boats are of secondary importance (20.5%), and shore anglers contribute a small portion of the total returns (5.4%).

TABLE 3. **Tabulation of Tag Release and Recapture Data.**

Year	Tag location	Number released	1st year returns	2nd year returns	U	Confidence limits for (U)
1967	Single A	414	25	26		
	AB	798	62	49		
	Total	1,212	87	75	0.073	0.058–0.088
1968	Single A	292	16	--		
	AB	597	37	--		
	Total	810	53	--	.065	0.049–0.083

TABLE 4. **White Sturgeon Returns by Angler Strata.**

	Party boat		Private boat		Shore		
	N	%	N	%	N	%	Total
1967–68	13	11.5	93	82.3	7	6.2	113
1968–69	42	28.6	97	66.0	8	5.4	147
1969–70	12	19.3	49	79.0	1	1.6	62
1970–71*	5	17.2	21	72.4	3	1.0	29
Total	72	20.5	260	74.1	19	5.4	†351

* Includes data received through 8-17-71.
† A total of 366 returns were received, 15 of which (4 %) did not respond to the questionnaire.

Sturgeon Population Estimate

A crude estimate of the number of sturgeon in the population in the fall of 1967 can be made by analyzing tags recaptured during tagging operations in 1968. The following data were used:

$M = 1{,}612$ (number of fish tagged in 1967).
$R = 14$ (number of tagged fish recaptured during 1968 tagging).
$C = 1{,}066$ (number of fish caught in 1968 that were 41 inches or greater in length to adjust for recruitment since sturgeon average about 1 inch of growth per year) (Miller and Orsi, unpublished data).

$$N = \frac{M(C + 1)}{(R + 1)} = 114{,}667$$

The 95% confidence interval for the estimate was calculated using the Poisson Variable Table in Fryer (1966). The confidence interval is 72,384–212,293.

DISCUSSION

Ricker (1958, p. 86) lists a series of conditions which must be met to obtain unbiased estimates of mortality rates and population size from mark and recapture studies. The use of reward tags, the measurement of low tag shedding rates, and the indication that rate of return is not decreased by fatigue suffered during tagging indicate that most conditions are met. The only condition which may not be met is that either tagged fish must become randomly mixed in the population or the distribution of effort must be proportional to the number of fish present in different areas.

The estimated population size in 1967 is much larger than the crude estimate of 11,154 sturgeon in San Pablo Bay in 1954 (Pycha, 1956). The 1954 estimate is almost certainly underestimated by repeated sampling in one place before tagged fish had time to become randomly mixed in the population. However, the general magnitude of the difference suggests an increase in population size since 1954. Vincent Catania, our netman who was involved in both tagging operations, observed that sturgeon were much easier to catch in 1967 than in 1954, supporting the hypothesis that the population was larger.

The exploitation rates empirically do not appear to be excessive although there are many factors which need to be known before estimates of sustained yield can be obtained. It would seem from these data that angling is a relatively inefficient means of harvesting which provides sufficient protection to the population. Hence, present regulations of one 40-inch or larger sturgeon per angler day appear to be adequate to protect the population under existing conditions.

ACKNOWLEDGMENTS

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