Interagency Ecological Program for the San Francisco Estuary

# IEP NEWSLETTER

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# Bias in Estimated Annual Harvest Rates for White Sturgeon of the San Francisco Estuary


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## Introduction

Estimated annual White Sturgeon, *Acipenser transmontanus*, harvest rate is one of many metrics produced by the California Department of Fish and Wildlife (CDFW) sturgeon population study (the study). Defined as the fraction of a demographic (e.g., fish in a given size range) harvested in a given year, estimated annual harvest rates have been reported or alluded to at intervals since 1959 (Chadwick 1959; Skinner 1962; Miller 1972; Kohlhorst 1979; Kohlhorst 1980; Kohlhorst and others 1991; Schaffter and Kohlhorst 1999; Kohlhorst and Cech 2001; DuBois and Gingras 2011; DuBois and others 2012) and have been used to monitor the impact of fishing regulations, to estimate natural mortality rate, and to estimate abundance (DuBois and Gingras 2011). Calculated from tagging data and information provided voluntarily (for example, by mail) by sport anglers on their capture of tagged fish, the rates can be biased and — because White Sturgeon is (like most sturgeons are) particularly sensitive to harvest — it is important to understand the direction and magnitude of any bias.

The estimated annual harvest rates reported to date have not accounted for possible biases due to mixing of tagged fish with un-tagged fish, tag shedding, delayed mortality attributable to tagging, or angler willingness to voluntarily contact CDFW about capture of tagged fish. Of those issues, only the level of mixing might cause estimated rates to be biased high and we plan to look into the potential for bias attributable to the level of mixing. Miller

(1972) used a double-tagging study to assess tag shedding and characterized shedding as “negligible.” Delayed mortality attributable to tagging has not been assessed, but survival of tagged fish is a top priority of the study and we suspect mortality is quite low. Angler willingness to voluntarily contact CDFW about capture of tagged fish (hereinafter we will call that “angler willingness”) stands out as a potentially-substantial downward bias.

Angler willingness was first addressed in 1967 by placing a prominently-labeled $5 reward tag on each fish (Miller 1972) and was addressed in the 1980s by increasing the reward value to $20. Starting in 1998, angler willingness was further addressed — and the groundwork for an assessment was laid — by placing a $20, $50, or $100 reward tag on each fish. In an effort (in part) to better assess angler willingness, Sturgeon Fishing Report Cards (Sturgeon Cards) since 2010 have required anglers to record the harvest or release of fish tagged by the study. In the present investigation, we use reward value and Sturgeon Card data to briefly investigate angler willingness to voluntarily contact CDFW about capture of tagged fish in 1998, 2001, 2002, and 2005-2012.

## Investigation

We hypothesized that anglers returning Sturgeon Cards since 2010 would report having caught approximately equal proportions of fish bearing $20, $50, or $100 reward tags, because (1) the study released approximately the same number of tags with each of the 3 rewards, (2) anglers who returned Sturgeon Cards have noted the annual capture of many White Sturgeon (approximately 3000-5000), and (3) documenting capture of tagged fish is required for Sturgeon Card holders. We also hypothesized that anglers returning Sturgeon Cards would report a substantially different proportion of fish bearing $20, $50, or $100 reward tags than would anglers reporting voluntarily, and that anglers would report voluntarily in rough proportion to reward value. To look into (if not test) those hypotheses, we did a few simple summaries of reported capture of tagged fish.

The proportion of tags reported by Sturgeon Cards during 2010-2012 was 45% at $20, 21% at $50, and 34% at $100, which is not equal proportions but is substantially different than the proportion of tags — 23% at $20, 23% at $50, and 54% at $100 — reported voluntarily during the same period. Having seen that the 2010-2012 proportions were a bit “noisy,” we looked at the much larger 1998-2012 dataset on tags reported voluntarily and found the proportions to be 22% at $20, 33% at $50, and 45% at $100. These summaries demonstrate that reward value affected the willingness of many anglers to voluntarily contact CDFW about capture of tagged fish and suggest that estimated annual harvest rates calculated without consideration of reward value were likely biased low.

To get a sense of the magnitude of bias attributable to angler willingness, we estimated annual harvest rates using the below formula and the following permutations of data: (1) Recaptured fish without regard to the fish’s reported fate or to reward value, which is the study’s longtime “conventional” algorithm, (2) recaptured fish reported (voluntarily or by Sturgeon Card) as kept, but without regard to reward value, and (3) recaptured fish reported (voluntarily or by Sturgeon Card) as kept by reward value.

$$\mu_Y = \frac{\left(\Sigma [\![ Tags\ Returned - \Sigma Tags\ Returned_{ra}) ]\!]_{fy} + \left(\Sigma Tags\ Returned_{c}\right)_{fy}}{\Sigma Tags\ Released}$$

Where:
μ = Harvest Rate
Y = Year
fy = First-year (that is, tag returned within 365 days of being released)
ra = Fish reported by angler as being released alive
c = Tag return reported on Sturgeon Card only

We found that harvest rates calculated using only $100 tags were almost always substantially higher than harvest rates calculated otherwise and there was an increasing trend in harvest rate over time (Figure 1). These results strongly suggest that harvest rates calculated from $100 tags were closest to accurate but were likely still biased somewhat low.

## Discussion

This brief investigation describes and (to a degree) quantifies a downward bias in estimated annual White Sturgeon harvest rates attributable to a lack of angler willingness to voluntarily contact CDFW about capture of tagged fish. As follows, this finding suggests that it is important to improve and continue assessing angler willingness, prompts a reinterpretation of the relative impact of fishing mortality on the population and fishery, and suggests that management actions may have contributed to an increase in annual harvest rate.

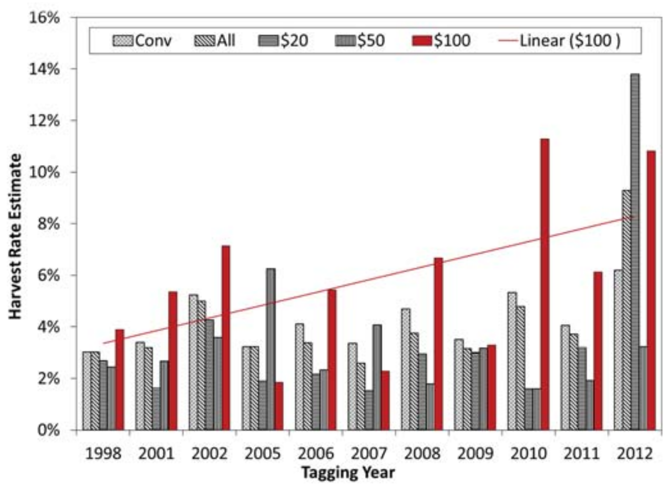


**Figure 1 Estimated annual harvest rates (1998, 2001, 2002, and 2005-2012) for San Francisco Estuary White Sturgeon from the following permutations of data: (1) recaptured fish without regard to the fish's reported fate or tag reward value (Conv), (2) recaptured fish reported (voluntarily or by Report Card) as kept but without regard to tag reward value (All), and (3) recaptured fish reported (voluntarily or by Report Card) as kept by tag reward value ($20, $50, $100). Solid line indicates linear regression on harvest rates estimated using only data on $100 tags.**

The downward bias is attributable to lack of angler willingness and is influenced by the reward paid by CDFW for contacting us. To improve and further assess angler willingness, we plan additional outreach and will modify aspects of study protocol. Additional outreach will include promoting the sturgeon population study through more-frequent distribution of informational fliers, use of social media and Press Releases, and (if possible) improved use of CDFW's web site. Study protocol modifications will include a minor reformatting of tags and the application of tags with rewards of $50, $100, and $150. We are also considering regulatory approaches to increase voluntary reporting of captured tagged fish.

Having seen from the present investigation that estimated annual harvest rates calculated without regard to reward value tended to be biased substantially low from 1998-2012 due to lack of angler willingness, we suspect that the rates calculated prior to that period — when no information on angler willingness was available — were also biased low. If so, harvest contributed more than previously thought to observed declines in the White Sturgeon fishery and population. Estimated annual harvest rates for fish ≥ 102 centimeters total length were approximately 7% in the late 1960s (Miller 1972) and increased to 11.5% in the 1980s (Kohlhorst and others 1991). Given that annual total mortality rates have rarely been more than 20% and have frequently been much less than that (Miller 1972; Kohlhorst 1979; Kohlhorst 1980; Kohlhorst and others 1991; Schaffter and Kohlhorst 1999; DuBois and others 2012), it is likely that harvest has typically been the largest part of total mortality.

White Sturgeon catch-per-unit-effort (CPUE) declined substantially from 1964 to 1974 (Kohlhorst 1980), while White Sturgeon CPUE (DuBois and others 2012) and estimated abundance collapsed through the 1980s (Schaffter and Kohlhorst 1999; DuBois and others 2012). In response to the 1980s collapses, in 1990 the California Fish and Game Commission (Commission) increased the minimum size limit and established a first-ever maximum size limit but made no change to the bag limit of 1 fish per day. The Commission also implemented a suite of fishing regulations in 2007 — including a 3-fish annual bag limit, a reduction in the maximum size limit, and establishment of the Sturgeon Card — that was expected to improve fishing for and the resiliency of White Sturgeon over time as well as provide useful information on the population and patterns in sturgeon fishing. White Sturgeon fishing effort and harvest from Commercial Passenger Fishing Vessels the decade before and the decade after implementation of the maximum size limit were similar, and fishing interest since 2007 has been very high (e.g., 41,000-112,000 Sturgeon Cards issued annually), which suggests that implementation of and later reduction in the maximum size limit focused substantial fishing effort on substantially fewer White Sturgeon cohorts.

We suspect the recent trend of increased estimated annual harvest rates was due the combination of: (1) The economic downturn, which increased angler willingness to contact CDFW to receive rewards for recapturing tagged fish, (2) additional outreach by the CDFW in support of the 2007-present fishing regulations, which increased angler interest about contacting CDFW to receive rewards for the capture of tagged fish, and (3) the 2007-present reduction in the maximum size of White Sturgeon that may be harvested legally, which focused substantial fishing effort on a narrower demographic.

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