Rescuing and monitoring White Sturgeon during drought on the Tuolumne River

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RESEARCH NOTE

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Frequent drought, loss of critical habitat, and warming water conditions threaten one of California's most prehistoric fish. White Sturgeon (*Acipenser transmontanus*) are known to occupy both the Sacramento River (SR) and San Joaquin River (SJR) watersheds and are the largest freshwater fish species in North America. White Sturgeon support a popular recreational fishery in California and, although they are not currently listed under the federal Endangered Species Act, they are considered a state Species of Special Concern (CDFW 2019) and have been petitioned for listing under the California Endangered Species Act. Research shows that increased flows in the spring and early summer increase spawning success and larval recruitment of White sturgeon (Kohlhorst et al. 1991) and if drought continues and low flows persist, sturgeon in California may be impacted by disconnected habitats and intolerable river temperatures (Ficke et al. 2007).

White Sturgeon are found in the San Francisco Estuary (SFE) year-round and spawn primarily in freshwater habitats in the SR (Heublein et al. 2017). Several surveys have monitored spawning behaviors of White Sturgeon in the Sacramento basin (Schaffter 1997; Miller et al. 2020) but there has been a lack of monitoring on the SJR until recently. Researchers previously believed spawning occurred in the SJR only during very high-water years, but recent studies have concluded that White Sturgeon are using the SJR to spawn during high and low flow years. (Jackson et al. 2016).

White Sturgeon rarely exhibit holding behaviors after spawning and the most common strategy is to return to the estuary immediately after spawning (Klimley et al. 2015). If White Sturgeon delay out-migration, they may have difficulty navigating through shallow water habitat after spring runoff flows decrease. In this scenario, any sturgeon occupying the SJR or lower Tuolumne River in the summer may be forced to hold in deep pools until water operators increase river flows or winter precipitation begins and they can move freely throughout the river (Anderson et al. 2018).

Lab studies have shown that White Sturgeon exhibit optimal growth and metabolism up to 25°C (Cech et al. 1984) but research is largely based around juvenile sturgeon in captivity. The maximum temperature tolerated by sexually mature White Sturgeon in natural environments is less studied. The highest summer temperatures documented in the SJR reach 30°C (CDFW 2018) and if adult sturgeon hold in these conditions, rather than migrating to the estuary, they could be subjected to sub-optimal river temperatures. As river discharges decrease and temperatures rise it may be beneficial to capture and relocate any holding sturgeon to more suitable habitat to keep the fish in good health and reduce the chance of poaching.

The Tuolumne River is a main tributary to the SJR and is an important resource for White Sturgeon. The river originates in the Sierra Nevada mountains and the basin drains approximately 173,252 ha. Don Pedro Reservoir and the Old La Grange Dam are the furthest downstream impoundments and the extent of anadromy ends at the base of Old La Grange Dam. From 2020 to 2021 the Tuolumne River experienced a drought, and the water year types were categorized as Median Dry and Critical-Below Normal, respectively (MID and TID 2022). During the same period, the SJR also experienced low flows and the water years were indexed as Dry and Critical year types (DWR 2023). During summer months, California Department of Fish and Wildlife (CDFW) staff experienced shallow water depths, large sand bars and various channel obstructions while navigating the SJR and associated tributaries by motor vessel (A. Dahl, pers. obs.). Multiple years of compounding droughts and low flows may hinder a sturgeon's ability to migrate throughout the SJR watershed and increases the risks associated with elevated water temperatures and poaching.

Water managers of the Tuolumne River released water from Old La Grange Dam between 10 April 2021 and 22 April 2021 (1,400 cfs; USGS 11290000; **Fig. 1**). By 4 June 2021, the Tuolumne River reached base flow (114 cfs; USGS 11290000) for the remainder of the summer. After the flows receded, a landowner noticed several sturgeon in the river near his property (37.576°, –121.114°) located approximately 9.6 rkm from the confluence of the Tuolumne and the SJR. CDFW began monitoring river temperatures at this location to determine what conditions these fish were experiencing and noted that the shallow water habitat downstream of the pool where the sturgeon were holding made it unlikely that they would make a volitional outmigration. River temperatures were expected to reach 30°C in July (**Fig. 1**) which not only exceeds the temperature limit (25°C) for high growth for White Sturgeon (Cech et al. 1984; Israel et al. 2009), it also approaches their critical thermal maximum of 30°C (Weber et al. 2024). Based on this data, CDFW managers decided that relocating these fish was necessary to keep these sturgeon in good health,

reduce the opportunity for poaching, and use this opportunity to tag the first sturgeon in a tributary to the SJR.

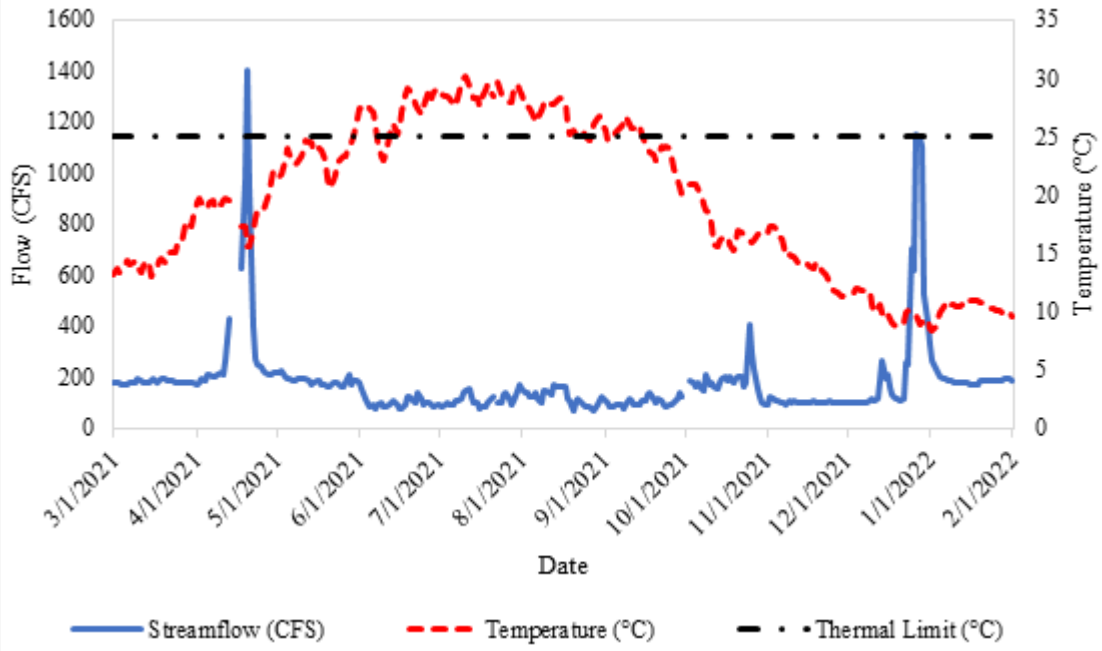


Figure 1. Thermal limit (25°C) for White Sturgeon optimal growth in relation to Tuolumne River mean daily flow and temperature from 1 Mar 2021–1 Feb 2022 in Modesto, CA (rkm 27; USGS 11290000).

CDFW staff conducted a White Sturgeon rescue and tagging effort on 22 and 24 June 2021 due to high river temperatures and low flow conditions creating shallow river depths potentially obstructing migration to suitable habitat. Sturgeon were captured by extending two 30-m trammel nets, parallel with streamflow, along the river bottom. All sturgeon were transported with a V-shaped cradle to shallow water, ventral side up, with the head submerged to have continuous flow of water. CDFW staff measured fork length, total length, and river temperatures (**Table 1**). They then surgically implanted captured sturgeon with an acoustic tag (Vemco V16, 69 kHz) and Passive Integrated Transponder tag (Biomark, HDX23, 23 mm) in the peritoneal adjacent to the midline of the fish and between the third and fourth scute (Miller et al. 2020). The incision was closed with two simple interrupted sutures tied with surgeon's knots. After tagging, each fish was placed in an aerated holding box and transported individually by truck to the release location on the SJR at Mossdale Crossing (SJR rkm 90.1; 37.787°, –121.307°). We later tracked these fish by acoustic receivers (Vemco VR2W, 69 kHz) positioned throughout the basin (**Fig. 2**).

Table 1. White Sturgeon fork length (cm), total length (cm), and river temperatures (°C) during relocation effort in June 2021 on the Tuolumne River (rkm 9.6; 37.576°, –121.114°). (TR = Tuolumne River; SJR = San Joaquin River)

Date Tagged	Length – Fork	Length – Total	Temp – TR	Temp – SJR
22 June 2021	177	181	26.7	23.2
22 June 2021	152	174	26.7	23.2

Date Tagged	Length – Fork	Length – Total	Temp – TR	Temp – SJR
24 June 2021	153	162	25.9	22.3

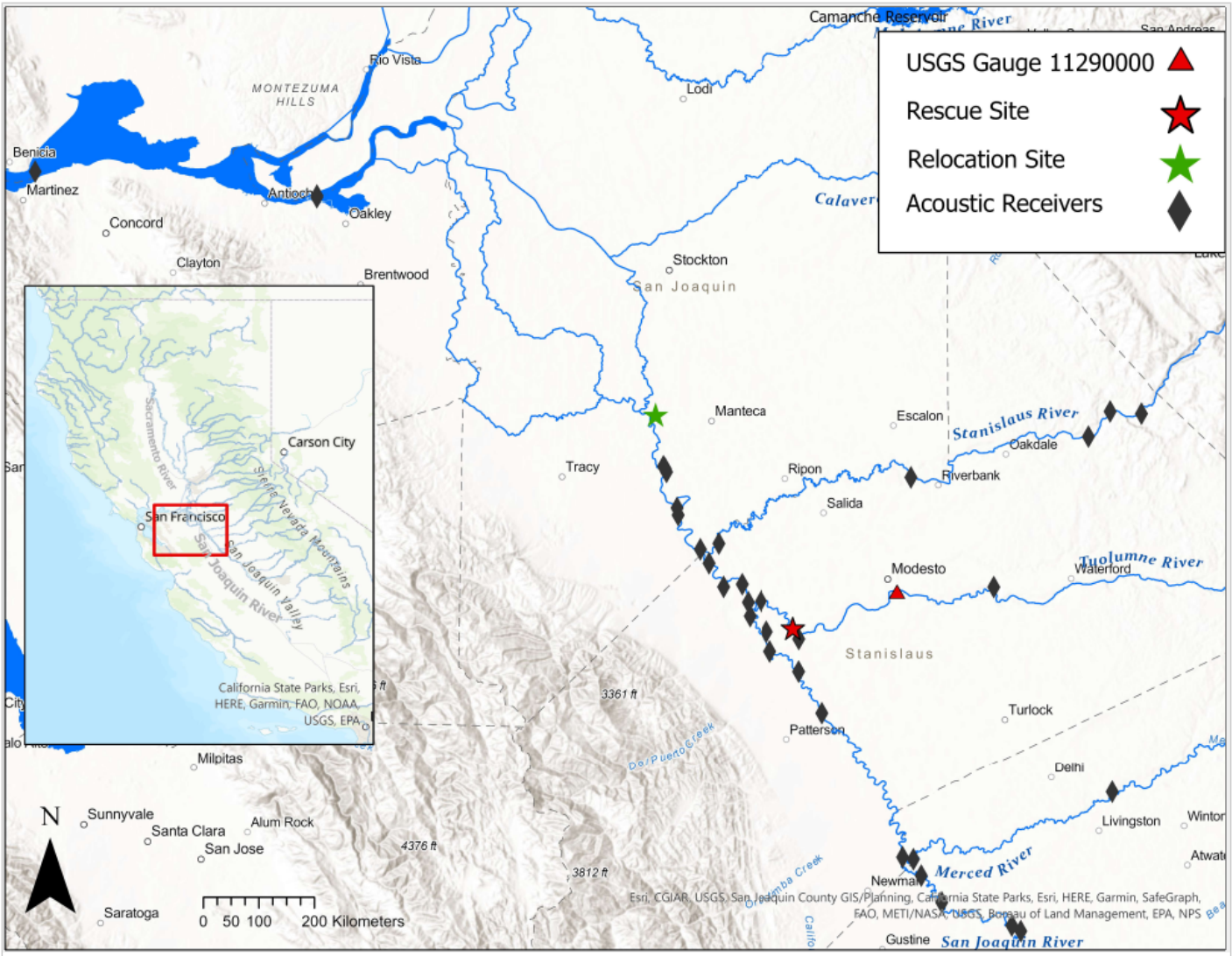


Figure 2. USFWS and CDFW acoustic receiver locations within the SFE and SJR basin, rescue site on the Tuolumne River (rkm 9.6), relocation site at Mossdale Crossing near Lathrop, CA (SJR rkm 90.1), and Tuolumne River flow gauging station in Modesto, CA (rkm 27; USGS 11290000).

Three White Sturgeon were captured, tagged, and relocated to the SJR. Two sturgeon were captured on 22 June and one on 24 June 2021. After the relocation, CDFW monitored the same pool in the Tuolumne River throughout the summer by using an Adaptive Resolution Imaging Sonar (ARIS, Explorer 1800) for the presence of any remaining sturgeon. The ARIS captured images of one sturgeon on 8 August 2021 and another image of two sturgeon three weeks later (Fig. 3). We did not attempt to capture either sturgeon due to increased handling stress related to summer air temperatures and shallow depths at the relocation site. CDFW continued to confirm the presence of these fish until September, when Water Hyacinth (*Eichhornia crassipes*) covered the pool and prevented CDFW from monitoring with a boat and ARIS. CDFW was able to resume monitoring in December after precipitation increased flows, moving the

large patch of vegetation downstream; however, no sturgeon were detected with the ARIS.

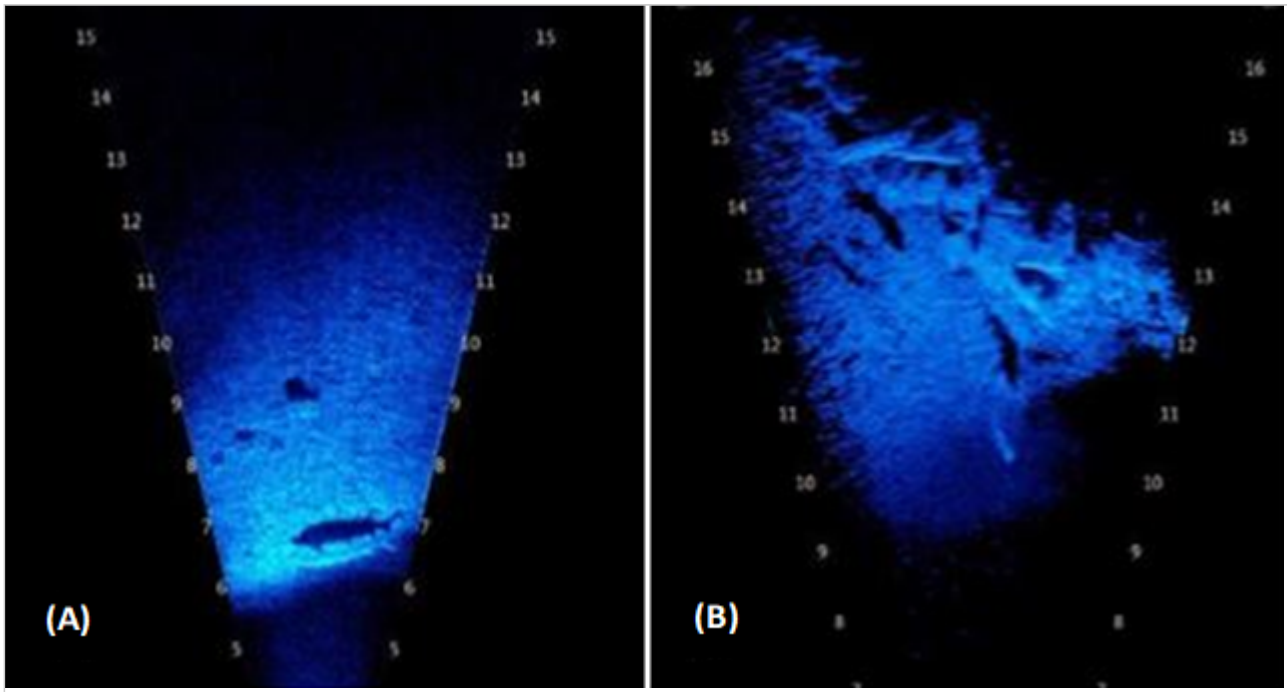


Figure 3. A) Sonar image captured by ARIS on 10 Aug 2021 confirming presence of one additional Sturgeon following tagging and relocation event. B) Image captured on 31 Aug 2021 confirming presence of two sturgeon holding at same location (Tuolumne rkm 9.6).

By using acoustic receivers positioned throughout the SJR and in the SFE, CDFW was able to monitor the sturgeons' movements after relocation. United States Fish and Wildlife Service (USFWS) and CDFW operate and maintain an array of Vemco (VR2W 69 kHz) acoustic receivers ranging from the entrance of the SFE, at Antioch and Benicia Bridge, throughout the SJR and within its tributaries (**Fig. 2**). These arrays assist in observing the migration patterns of sturgeon. Detection histories revealed that one of the three fish migrated downstream directly to the bay where it was detected at Antioch and Benicia receivers in July of 2021. Contrary to the first fish, the second sturgeon migrated 30 rkm upstream from the release site in the SJR and was detected by receivers near this vicinity for the remainder of the summer. The third tagged sturgeon has yet to be detected on any receivers within the SJR or SFE. It is possible that this third sturgeon could have traveled towards the SR without being detected and attempts will be made to gain acoustic data from other surveys within the SR. Currently, there is a lack of acoustic receiver coverage within the delta, between Mossdale Crossing and the Antioch Bridge receivers. Increasing staff and funding will also allow CDFW to fill gaps in current acoustic monitoring and extend coverage between Mossdale Crossing and the SFE.

This monitoring effort documents the first tagging event of White Sturgeon in any tributary to the SJR and increases the knowledge of environmental factors experienced by White Sturgeon in the Tuolumne River. Although no spawning has been documented in the SJR tributaries (Faukner and Jackson 2014), the relocated White Sturgeon likely migrated into the Tuolumne River during the appropriate migratory spawning timeframe for White Sturgeon. Drought stressor monitoring funding made this rescue and monitoring possible, and this effort helps expand the knowledge of White Sturgeon habitat use and migration patterns within the SJR and associated tributaries. Continuous monitoring and resources,

dedicated to better understanding White Sturgeon life history, are needed to properly manage the sturgeon fishery in the lower SJR and its tributaries.

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