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**Post-rescue survival and subsequent spawning migrations of sturgeon rescued
after Sacramento River flood control weir overtopping events**



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CONTENTS

Introduction 2
Methods 6
Results 7
Discussion 21
References 23

LIST OF FIGURES

Figure 1. Yolo Bypass, Fremont Weir, and Rio Vista Bridge Receiver Array 4
Figure 2. Sutter Bypass and Tisdale Weir 5
Figure 3. WS23-04 in the Fremont Weir stilling basin prior to capture and tagging, 2 April 2023. 7
Figure 4. GS19-04 tagging surgery, Tisdale Weir 25 April 2019. 7
Figure 5. Southern DPS Green Sturgeon rescued from the Tisdale Weir stilling basin showing abrasion injuries from contact with concrete infrastructure, 25 April 2019 23
Figure 6. GS19-15 rescued from the Yolo Bypass Deep Pond being released after tagging in the Sacramento River 20 June 2019.. 23

Introduction

Two species of sturgeon occur in California, the White Sturgeon (*Acipenser transmontanus*) a California species of concern that currently supports an important recreational fishery, and the federally threatened southern Distinct Population Segment (sDPS) Green Sturgeon (*Acipenser medirostris*). Both species are long-lived, iteroparous, and typically reach sexual maturity between 10-20 years of age. Populations of both species have been severely reduced due to the construction of impassable dams blocking access to breeding grounds, water diversions, habitat degradation, a legacy commercial fishery, recreational fishery retention, poaching, and in the summer of 2022, an unprecedented harmful algal bloom that occurred over widespread areas of the greater San Francisco Bay which killed at least 16 adult or sub adult Green Sturgeon, 170 adult White Sturgeon and over 630 adult sturgeon that could not be identified to species due to decomposition. Recovery of populations to fisheries management objective levels is a lengthy process due to factors such as the long generational interval and successful recruitment of year-class cohorts which is dependent on high river and delta outflows through from late winter through early summer.

White Sturgeon spend the majority of their lives in the Sacramento-San Joaquin Delta-San Francisco Bay (SFBDE), although acoustic telemetry data and other tagging studies have shown that some individuals tagged in the SFBDE enter the Pacific Ocean and may range as far north as the Columbia River. Spawning adults typically stage in the upper portion of the estuary or lower Sacramento River in late fall through early winter and begin their upstream migration to their spawning grounds from late January through early March (Schaffter 1997). The majority of White Sturgeon appear to spawn in the middle Sacramento River between Knights Landing (river kilometer or rkm 142) and Colusa (rkm 237) (Schaffter 1997, CDFW 2021, 2022, 2023). Spawning also occurs at least periodically in the San Joaquin River between rkm 115 to 145 (Jackson *et. al.* 2016), and sporadically in the Feather and Bear rivers (personal communication with A. Seesholtz). White sturgeon typically migrate back to the SFBDE within several weeks to several months after spawning (Schaffter 1997). Female White Sturgeon typically spawn every three to five years, and males every one to three years, so that in any given year, only a portion of the White Sturgeon make spawning migrations.

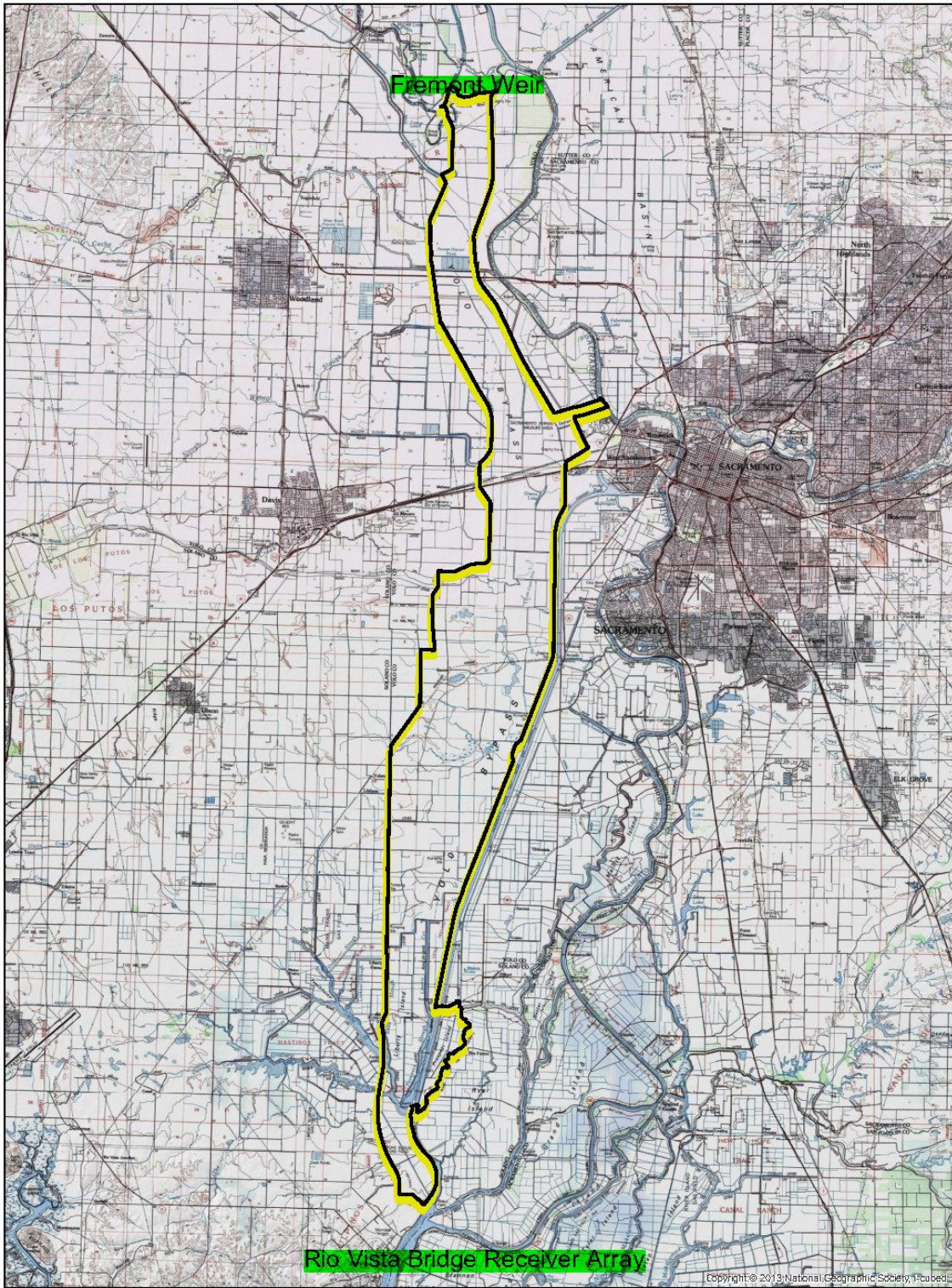
Adult sDPS Green Sturgeon spend the majority of their lives in the nearshore marine environment, ranging from Baja California to the Bering Sea, with some individuals making seasonal forays into larger bays and coastal estuaries, including the SFBDE and Grays Harbor and Willapa Bay in Washington (NMFS 2018). Southern DPS Green Sturgeon typically begin their spawning migration from the Pacific Ocean into the Sacramento River system in late February to early April, making a rapid upstream migration to their spawning grounds. The Sacramento River system is the only river system currently known to support spawning of sDPS Green Sturgeon. Spawning has been documented in a 93 km section of the Sacramento River from Hamilton City (rkm 332.5) upstream to Cottonwood (rkm 426) (Poytress *et. al.* 2015), the Feather River in the vicinity of the Thermalito Bay Outlet (Seesholtz *et al.* 2015), and the Yuba River (CDFW 2018, 2019). Southern DPS Green Sturgeon exhibit two distinct post-spawning


behaviors. Some individuals make a rapid return to the marine environment after spawning, while others will hold near their spawning grounds until late fall or early winter flow increases trigger downstream migration (Heublein *et. al.* 2009). Similar to White Sturgeon, females typically spawn every three to five years, and males typically spawn every one to three years (NMFS 2015).

The approximately 59,000-acre Yolo Bypass is essentially a leveed floodplain designed to convey floodwaters from the Sacramento River and west side streams and drains around the populated regions of the central Sacramento Valley (**Figure 1**). Inundation of the Yolo Bypass occurs when Sacramento River flows overtop the Fremont Weir, located at rkm 226 as measured from the Golden Gate Bridge. Inundation of the Yolo Bypass occurs when Sacramento River flows at the Fremont Weir exceeds a stage height of 32.3 feet above mean sea level which occurs at a flow of approximately 1,622 cubic meters per second (57,290 cubic feet per second) (DWR 2016). Inundation of the Yolo Bypass is augmented by flows from west side tributaries including Cache Creek, Willow Slough, Willow Slough Bypass, Putah Creek, and South Fork Putah Creek. Up to 80 percent of the Sacramento River's floodwaters are conveyed for a distance of approximately 50 km through the Yolo Bypass and returned to the Sacramento River via the Cache Slough Complex approximately two miles upstream of the town of Rio Vista.

The Tisdale Bypass is inundated by overtopping of the Tisdale Weir, located at RKM 286 when Sacramento River flows exceed a stage height of 45.5 feet above mean sea level which occurs at a flow of approximately 595 cubic meters per second (21,012 cfs). The Tisdale Weir capacity is 1,076 cubic meters per second (38,000 cfs) (DWR 2010). The Tisdale Bypass flows east for approximately seven km into the Sutter Bypass (**Figure 2**). Sutter Bypass flows south for approximately 33 km where it joins the Sacramento River and Yolo Bypass near Fremont Weir.

During weir overtopping events, flows within the Yolo Bypass can be much greater than flows within the Sacramento River, attracting migratory anadromous fish including both sDPS Green Sturgeon and White Sturgeon into the Yolo Bypass at the Cache Slough complex. As long as flows within the Yolo and Sutter bypasses are of sufficient magnitude, adult sturgeon migrating up the bypasses can swim over the weirs and return to the Sacramento River. However, as flows over the weirs decrease or end, adult sturgeon become stranded in the weir stilling basins and in scour ponds such as the Tule and Deep ponds and other inundated features downstream of the weirs and would ultimately perish from factors such as poor water quality, desiccation, predation, or illegal harvest in the absence of

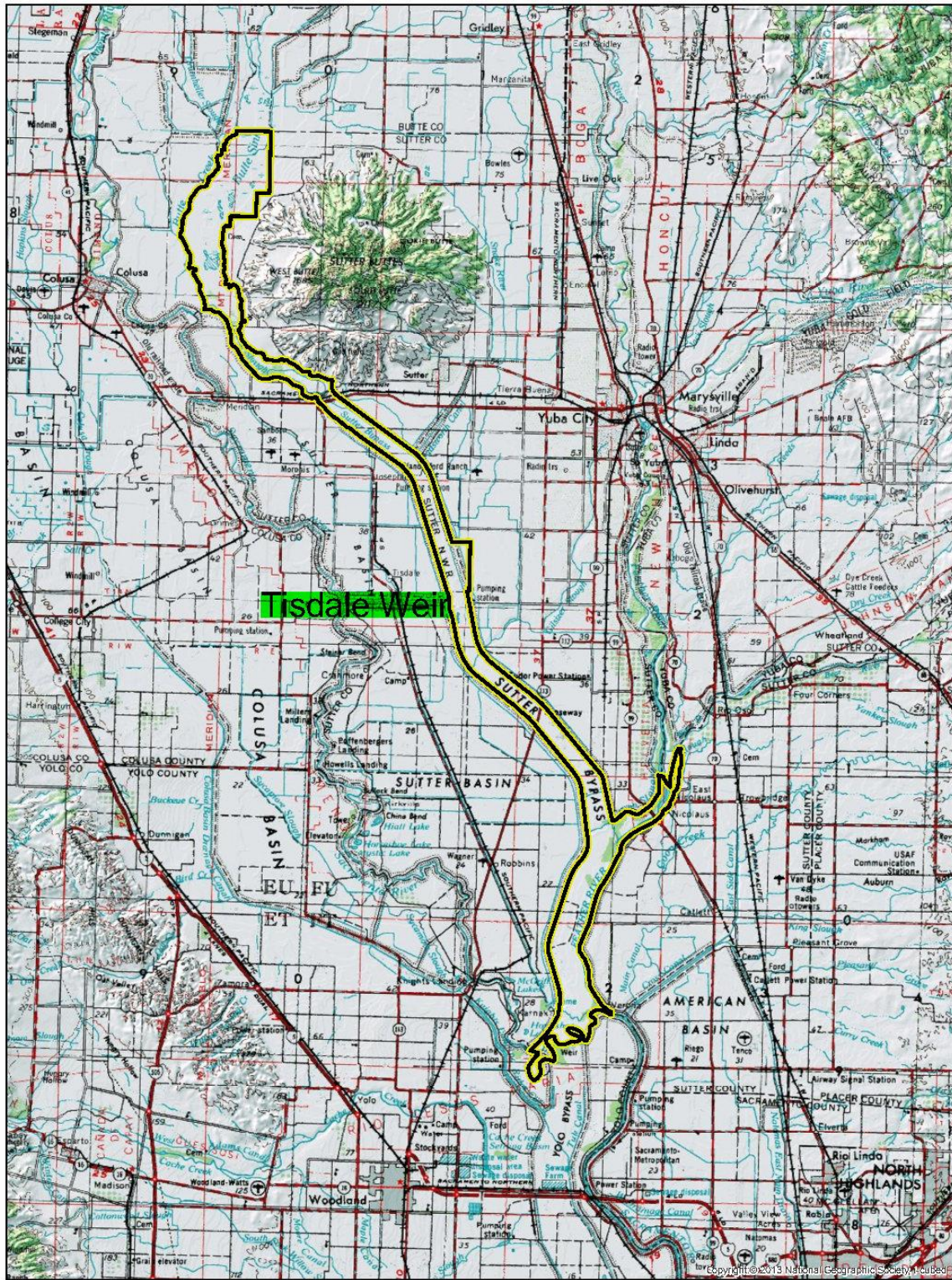


 Yolo Bypass

0 1.25 2.5 5 7.5 10 Miles



Figure 1. Yolo Bypass, Fremont Weir, and Rio Vista Bridge receiver array locations.



 Sutter Bypass

0 1.5 3 6 9 12 Miles



Figure 2. Sutter Bypass and Tisdale Weir.

rescue efforts. CDFW staff have conducted periodic fish rescues for fish stranded in the Fremont and Tisdale weir stilling basins and downstream areas of their respective bypasses since at least 1955 (Beccio 2016). Beginning with fish rescue efforts in April 2011, rescued adult sturgeon were internally tagged with acoustic transmitters which provided telemetry data on post-rescue movement and survival. Thomas *et. al.* (2013) provides insight on post-rescue migration and survival of 24 sDPS Green Sturgeon rescued from Fremont and Tisdale weir stilling basins in 2011, as well as potential long term population level effects if rescue efforts were not undertaken. This report details the post-rescue survival and subsequent spawning migrations of White Sturgeon and sDPS Green Sturgeon rescued from the Fremont and Tisdale weir stilling basins and downstream scour pools within the Yolo and Tisdale bypasses following Sacramento River weir overtopping events in 2016, 2017, 2019, and 2023.

Methods

CDFW staff monitored stage heights at Fremont and Tisdale weirs following overtopping events to determine when Sacramento River flows would recede below weir crest heights so that rescue efforts could be conducted in a safe and efficient manner. Rescue efforts within the Fremont Weir stilling basin were usually conducted one or two days after the cessation of overtopping events, while rescue efforts within the Tisdale Weir stilling basin were typically conducted a week or more after the cessation of overtopping events due to stilling basin water depth. Rescue efforts in the Yolo Bypass ponds were typically initiated several weeks to several months after the cessation of overtopping events to allow for water levels to recede to a point where rescue efforts could be optimized. Methods of capture included dip nets, heavy duty beach seines; and trammel nets for use in Yolo Bypass ponds. Captured sturgeon were identified to species, assessed for overall condition, transferred ventral side up into a cradle to induce a somewhat catatonic state, and measured to the nearest 0.5-cm. Sturgeon determined to be in good or fair condition were tagged with a uniquely coded Innavosea® model V16 69 kHz acoustic transmitter with a 10-year battery life transmitting at a ping rate interval of 90-120 seconds. Acoustic transmitters were surgically implanted into the peritoneal cavity through an incision made approximately 5-mm off the ventral midline between the second and third ventral scutes. The incision was closed with two or three 2/0 interrupted sutures. Tagged sturgeon were monitored for recovery and released into the Sacramento River nearest to the point of capture, although White Sturgeon rescued from the Yolo Bypass Tule Pond were transported in an aerated tank to the Sacramento River Elkhorn Boat Launch for release due to low river stage height which prevented safe access to a release location in the vicinity of the Fremont Weir.

To determine post-rescue movement patterns and survival, I analyzed tag detection dates recorded at the Rio Vista Bridge (RVB) 69 kHz receiver array, as this location serves as a proxy to determine upstream and downstream spawning migrations for both sturgeon species (**Figure 1**). Initial detections of tagged White Sturgeon at RVB two

weeks to two months after rescue were considered to have continued upstream migration to their spawning grounds, while initial detections of tagged sDPS Green Sturgeon at the RVB receiver array one month to one year after rescue were considered to have continued upstream migration to their spawning grounds. Detection of tagged sturgeon of either species at the RVB receiver array within a week after rescue was considered evidence of an aborted spawning migration. Prior to December 2017, the UC Davis Biotelemetry Laboratory maintained 69 kHz receiver arrays that included receiver deployments in the Sacramento River from the Redding area to the Rio Vista Bridge and numerous locations in the SFBDE. Detection data from these arrays were also used to help elucidate sturgeon post-rescue survival and subsequent fate when RVB receiver array detection data was lacking or inconclusive. It is important to note that between early December 2017 and 7 June 2018 and 13 September and 10 December 2019, there were no 69 kHz receivers deployed at RVB, therefore there are two considerable temporal gaps for which detection data is lacking. The RVB receiver array was downloaded two or three times annually, with the last download occurring on 11 May 2023. RVB download data was imported into the Innavosea VUE® database program for analysis of individual transmitter detections to determine post-rescue survival and movement patterns which were then used to infer spawning migration status after rescue as well as subsequent spawning migrations.

An important caveat regarding RVB receiver array detection data for determining subsequent spawning migrations is that upstream or downstream migration is inferred by the detection date range for each species. For White Sturgeon, upstream spawning migration is assumed within the date range of 1 December through 15 March, while the date range for post-spawn downstream migration was assumed to be 16 March through 1 June. For sDPS Green Sturgeon, upstream spawning migration is assumed within the date range of 1 February through 15 May, while the date range for post-spawn downstream migration was assumed to be 16 May through 31 January of the following year. There are a number of detections for White Sturgeon that are either within or outside of the typical spawning migration period that appear to be associated with foraging behavior based on extended residency within the RVB receiver array detection zone. These detections or suites of detections are addressed in the Results section narratives for post-rescue movements of individual fish. Tagged sturgeon that have not been detected as of 11 May 2023 at the RVB receiver array or at any other receiver arrays were considered to be post-rescue mortalities.

Results

CDFW Anadromous Fisheries staff rescued 33 adult White Sturgeon and 32 sDPS Green Sturgeon after Sacramento River flows overtopped the Tisdale and Fremont flood control weirs during the 2016, 2017, 2019, and 2023 water years. Although there were no weir overtopping events in 2020, two White Sturgeon were rescued from a small scour pond in the Tisdale Bypass in May of 2020 after stranding during one of the 2019 weir overtopping events; these two sturgeon survived in the pond for over a year prior to rescue. In total, 32 White Sturgeon and 22 sDPS Green Sturgeon were tagged

with acoustic transmitters. One White Sturgeon rescued from the Fremont Weir stilling basin in 2019 was not tagged due to stressed condition, eight Green Sturgeon rescued from the Tisdale Weir stilling basin in 2019 were not tagged due to an insufficient number of tags on hand, and two Green Sturgeon rescued from the Deep Pond in 2019 were not tagged due to stressed condition. **Table 1** presents species with study identification numbers, rescue dates, rescue locations, transmitter IDs, post-rescue spawning migration status, and subsequent spawning migrations.

Eight of the 33 White Sturgeon (24 percent) that were rescued and tagged with acoustic transmitters were not detected at the RVB receiver array or any other receiver arrays and are presumed to be either post-rescue mortalities or were harvested by recreational anglers or poachers prior to their arrival at a receiver array. Thirteen (39 percent) White Sturgeon were detected at the RVB receiver array within two weeks after rescue which is indicative of them aborting their spawning migration. Of these, four (12 percent) were not detected making subsequent spawning migrations. Six (18 percent) of White Sturgeon that aborted their spawning migration after rescue made one or more subsequent spawning migrations. Seven (21 percent) of the White Sturgeon continued their spawning migrations post-rescue. Of these, four (12 percent) have made one or more subsequent spawning migrations.

Four of the 22 sDPS Green Sturgeon (18 percent) that were rescued and tagged with acoustic transmitters were not detected at the RVB receiver array or any other receiver arrays and are presumed to be either post-rescue mortalities or were harvested by poachers prior to their arrival at a receiver array. Seven (32 percent) Green Sturgeon were detected at the RVB receiver array within two weeks after rescue which is indicative of them aborting their spawning migration. Of these, all seven (100 percent) made at least one subsequent spawning migration. Eleven (50 percent) Green Sturgeon continued their spawning migration after rescue. Of these, nine (41 percent) made at least one subsequent spawning migration. Following Table 1 are narrative paragraphs for each sturgeon rescued describing post-rescue detections at the RVB receiver array and other receiver arrays as applicable.



Figure 3. WS23-04 in the Fremont Weir stilling basin prior to capture and tagging, 2 April 2023.



Figure 3. GS19-04 tagging surgery, Tisdale Weir 25 April 2019.

Table 1. Sturgeon species, study ID, rescue location, rescue date, and transmitter ID. All sturgeon were released into the Sacramento River near their capture location except that White Sturgeon rescued from the Tule Pond were released into the Sacramento River at the Elkhorn Boat Launch.

Study ID	Location	Date rescued	Transmitter ID	Post-rescue spawning migration	Subsequent spawning migrations
WS16-01	Tisdale Weir	2016-03-31	A69-9001-25736	Aborted	2019, 2020, 2021
WS16-02	Tule Pond	2016-07-01	A69-9001-25738	Aborted	None
WS16-03	Tule Pond	2016-07-01	A69-9001-25739	Aborted	2019, 2020, 2023
WS16-04	Tule Pond	2016-07-01	A69-9001-25742	Post-rescue mortality	None
WS16-05	Tule Pond	2016-07-01	A69-9001-25747	Aborted	None
WS16-06	Tule Pond	2016-07-08	A69-9001-25740	Post-rescue mortality	None
WS16-07	Tule Pond	2016-07-08	A69-9001-25743	Aborted	2020, 2021
WS16-08	Tule Pond	2016-07-21	A69-9001-25746	Post-rescue mortality	None
WS16-09	Tule Pond	2016-07-21	A69-9001-25749	Aborted	None
WS16-10	Tule Pond	2016-07-21	A69-9001-25752	Post-rescue mortality	None
WS17-01	Fremont Weir	2017-03-13	A69-9001-25753	Aborted	None
WS17-02	Fremont Weir	2017-04-03	A69-9001-25751	Aborted	2022
WS17-03	Fremont Weir	2017-05-04	A69-9001-25741	Continued	2019, 2022, 2023?
WS17-04	Tule Pond	2017-06-28	A69-9001-15826	Post-rescue mortality	None
WS17-05	Tule Pond	2017-07-20	A69-9001-25745	Post-rescue mortality	None
WS18-01	Tule Pond	2018-04-27	A69-9001-15841	Post-rescue mortality	None
WS18-02	Tule Pond	2018-05-04	A69-9001-15829	Aborted	2020
WS19-01	Fremont Weir	2019-02-21	A69-9001-15827	Continued	None
WS19-02	Fremont Weir	2019-02-21	A69-9001-15828	Aborted	2021, 2023
WS19-03	Fremont Weir	2019-02-21	A69-9001-15831	Continued	2023
WS19-04	Fremont Weir	2019-02-22	A69-9001-15842	Continued	2020, 2023
WS19-05	Fremont Weir	2019-03-22	A69-9001-15830	Continued	2023
WS19-06	Fremont Weir	2019-03-22	A69-9001-15832	Aborted	None
WS20-01	Tisdale Bypass	2020-05-01	A69-9001-5040	Aborted	2021, 2023

Study ID	Location	Date rescued	Transmitter ID	Post-rescue spawning migration	Subsequent spawning migrations
WS20-02	Tisdale Bypass	2020-05-01	A69-9001-5043	Post-rescue mortality	None
WS23-01	Fremont Weir	2023-03-28	A69-9001-5034	Aborted	None
WS23-02	Fremont Weir	2023-03-28	A69-9001-64037	Continued	None
WS23-03	Fremont Weir	2023-04-02	A69-9001-5033	Aborted	None
WS23-04	Fremont Weir	2023-04-02	A69-9001-64040	Continued	None
GS16-01	Fremont Weir	2016-03-29	A69-9001-25735	Continued	2019, 2023
GS17-01	Fremont Weir	2017-03-14	A69-9001-25750	Continued	2021
GS17-02	Fremont Weir	2017-05-04	A69-9001-25755	Aborted	2020
GS17-03	Tisdale Weir	2017-05-12	A69-9001-25748	Aborted	2020
GS17-04	Tisdale Weir	2017-05-12	A69-9001-25756	Aborted	2020
GS17-05	Tisdale Weir	2017-05-12	A69-9001-25758	Post-rescue mortality	None
GS19-01	Fremont Weir	2019-03-22	A69-9001-15833	Continued	None
GS19-02	Fremont Weir	2019-03-22	A69-9001-15836	Continued	2023
GS19-03	Tisdale Weir	2019-04-25	A69-9001-15834	Post-rescue mortality	None
GS19-04	Tisdale Weir	2019-04-25	A69-9001-15835	Continued	2023
GS19-05	Tisdale Weir	2019-04-25	A69-9001-15837	Continued	2023
GS19-06	Tisdale Weir	2019-04-25	A69-9001-15838	Aborted	2020, 2022
GS19-07	Tisdale Weir	2019-04-25	A69-9001-15839	Post-rescue mortality	None
GS19-08	Tisdale Weir	2019-04-25	A69-9001-15840	Continued	2022
GS19-09	Tisdale Weir	2019-04-25	A69-9001-15843	Continued	None
GS19-10	Tisdale Weir	2019-04-26	A69-9001-15847	Continued	2023
GS19-11	Tisdale Weir	2019-04-26	A69-9001-15848	Aborted	None
GS19-12	Tisdale Weir	2019-04-26	A69-9001-15849	Aborted	2022
GS19-13	Tisdale Weir	2019-04-26	A69-9001-15850	Post-rescue mortality	None
GS19-14	Tisdale Weir	2019-05-03	A69-9001-15846	Aborted	2022
GS19-15	Deep Pond	2019-06-20	A69-9001-15844	Continued	2023
GS19-16	Deep Pond	2019-06-20	A69-9001-15845	Aborted	2023

White Sturgeon WS16-01, fork length 185 cm, was rescued from the Tisdale Weir stilling basin 31 March 2016, and was tagged with transmitter ID A69-9001-25736 and released into the Sacramento River at the Tisdale Boat Launch Ramp. WS16-01 was detected at the RVB receiver array eight days later on 7 April 2016, which is indicative of WS16-01 aborting its spawning migration after rescue. The next detection date for WS16-01 at the RVB receiver array was 25 January 2019 which is indicative of an upstream spawning migration. WS16-01 was then detected at the RVB receiver array 91 days later on 26 April 2019 which is indicative of a post-spawn downstream migration. The next detection date at the RVB receiver array for WS16-01 was 1 February 2020 which is indicative of a second post-rescue upstream spawning migration. WS16-01 was then detected at the RVB receiver array 80 days later on 20 April 2020 which is indicative of a post-spawn downstream migration. The last detection for WS16-01 at the RVB receiver array was 19 February 2021, which is indicative of a third post-rescue upstream spawning migration. However, WS16-01 was not detected at the RVB receiver array making a downstream post-spawn migration as of 11 May 2023.

White Sturgeon WS16-02, fork length 172 cm, was rescued from the Tule Pond 1 July 2016, tagged with transmitter ID A69-9001-25738 and released into the Sacramento River at the Elkhorn Boat Launch Facility. WS16-02 was detected at the RVB receiver array four days later on 5 July 2016, is indicative of WS16-02 aborting its spawning migration after rescue. As of 11 May 2023, there are no other detections for WS16-02 at the RVB receiver array. The last detection at any receiver array location for WS16-02 was 6 September 2016 at the Carquinez Bridge receiver array.

White Sturgeon WS16-03, fork length 139 cm, was rescued from the Tule Pond 1 July 2016, tagged with transmitter ID A69-9001-25739 and released into the Sacramento River at the Elkhorn Boat Launch Facility. WS16-03 was detected at the RVB receiver array three days later on 4 July 2016, which is indicative of WS16-03 aborting its spawning migration after rescue. The next detection date for WS16-03 at the RVB receiver array was 17 January 2019 which is indicative of an upstream spawning migration. WS16-03 was then detected at the RVB receiver array 91 days later on 18 April 2019 which is indicative of a post-spawn downstream migration. The next detection date at the RVB receiver array for WS16-03 was 6 February 2020 which is indicative of a second post-rescue upstream spawning migration. WS16-03 was then detected at the RVB receiver array 46 days later on 24 March 2020 which is indicative of a post-spawn downstream migration. WS16-03 was detected again at the RVB receiver array 21 December 2020 and 19-21 December 2022; both date ranges are somewhat earlier than the expected timing for upstream spawning migration and may be more indicative of foraging movements in the vicinity of the RVB receiver array, as no subsequent detections in 2020 and 2022 occurred during the post-spawn migration period. WS16-03 was detected again at the RVB receiver array from 6-8 January 2023 which is indicative of a third post rescue spawning migration. WS16-03 was then detected at the RVB receiver array 95 days later on 13 April 2023 which is indicative of a post-spawn downstream migration.

White Sturgeon WS16-05, fork length 155 cm, was rescued from the Tule Pond 1 July 2016, tagged with transmitter ID A69-9001-25747 and released into the Sacramento River at the Elkhorn Boat Launch Facility. WS16-05 was detected at the RVB receiver array 4 July 2016, or three days after rescue which suggests that WS16-05 likely aborted its spawning migration after rescue. As of 11 May 2023, there are no other detections for WS16-05 at the RVB receiver array. The last detection at any receiver array location for WS16-05 was 7 July 2016 at the Carquinez Bridge receiver array.

White Sturgeon WS16-07, fork length 179.5 cm, was rescued from the Tule Pond 8 July 2016, tagged with transmitter ID A69-9001-25743 and released into the Sacramento River at the Elkhorn Boat Launch Facility. WS16-07 was not detected at the RVB receiver array post rescue release but was detected on 11 July 2016 at Delta Cross Channel receiver array which is approximately 23 km upstream from the RVB receiver array. WS16-07 was subsequently detected at number of other receiver arrays in the Mokelumne and San Joaquin rivers and lower SFBDE that were maintained by the UC Davis Biotelemetry Laboratory until December 2017. The initial detection of WS16-07 at the RVB receiver array was on 18 February 2020, which is indicative of WS16-07's first post rescue spawning migration. WS16-07 was then detected at the RVB receiver array 37 days later on 10 April 2020 which is indicative of a post-spawn downstream migration. The next detection for WS16-07 at the RVB receiver array was 3 November 2021, which is somewhat earlier than expected but not unprecedented for an upstream spawning migration by White Sturgeon. WS16-07 was then detected at the RVB receiver array 157 days later on 27 April 2022 which is indicative of a post-spawn downstream migration.

White Sturgeon WS16-09, fork length 115.5 cm, was rescued from the Tule Pond 21 July 2016, tagged with transmitter ID A69-9001-25749 and released into the Sacramento River at the Elkhorn Boat Launch Facility. WS16-09 was not detected at the RVB receiver array post rescue release but was detected on 24 July 2016 at Delta Cross Channel receiver array which is approximately 23 km upstream from the RVB receiver array. WS16-09 was subsequently at number of other receiver arrays in the Mokelumne and San Joaquin rivers and lower SFBDE. The last detection for WS16-09 was at the Decker Island array on 29 October 2016 which is approximately eight km downstream of the RVB receiver array. There were no detections of WS16-09 at the RVB receiver array as of 11 May 2023.

White Sturgeon WS17-01, fork length 115 cm, was rescued from the Fremont Weir stilling basin on 13 March 2017, tagged with transmitter ID A69-9001-25753, and released into the Sacramento River at Fremont Weir. The only post-rescue detections for WS17-01 were at the Benicia Bridge receiver array 27 May 2017.

White Sturgeon WS17-02, fork length 189 cm, was rescued from the Fremont Weir stilling basin on 3 April 2017, tagged with transmitter ID A69-9001-25751, and released into the Sacramento River at Fremont Weir. The initial detection for WS17-02 at the RVB receiver array was 13 April 2017 or ten days after rescue which suggests that

WS16-05 likely aborted its spawning migration after rescue. The next detections for WS17-02 at the RVB receiver array were 26-29 September 2017, the timing of these detections is suggestive of foraging behavior. WS17-02 was then detected on 29 March 2020 which is about two weeks later than expected for an upstream spawning migration. WS17-02 was then detected at the RVB receiver array 232 days later on 16 November 2020. The timing of the 2020 detections is more suggestive of foraging movements than of spawning migrations. WS-17-02 appeared to make an upstream spawning migration on 11 November 2022 with an apparent corresponding downstream spawning migration 119 days later on 10 March 2022.

White Sturgeon WS17-03, fork length 130 cm, was rescued from the Fremont Weir stilling basin on 4 May 2017, tagged with transmitter ID A69-9001-25741, and released into the Sacramento River at Fremont Weir. The first detection for WS17-03 at the RVB receiver array was 29 May 2017. The UC Davis Biotelemetry Laboratory 69 kHz array recorded detections for WS17-03 as far upstream Butte City on 15 May 2017 which suggests that WS17-03 continued its upstream migration after rescue, although the timing is somewhat later than typical for an upstream spawning migration for White Sturgeon. Several detections for WS17-03 were recorded at the RVB receiver array in the fall of 2017 and the summer of 2018; the timing of these detections is suggestive of foraging behavior. The next series of detections for WS17-03 at the RVB receiver array were 15 January 2019 through 31 January 2019 which appears to be indicative of pre-spawn staging behavior. WS17-03 was then detected at the RVB receiver array almost daily beginning on 14 February 2019 through 27 March 2019. The 14-day absence interval at the RVB receiver array between 31 January and 14 February 2019 may be indicative of a spawning migration, while the relatively long residence time between 14 February and 27 March 2019 may be indicative of foraging behavior. The next suite of detections for WS17-03 at the RVB receiver array was 26-27 June 2020, which again appear to be foraging movements, followed by another suite of detections from 29 October through 3 November 2021 which are also likely indicative of foraging movement behavior. WS17-03 appeared to make another spawning migration beginning with almost daily staging behavior detections at the RVB receiver array from 19 December through 10 January 2022. The next detection for WS17-03 at the RVB receiver array was 64 days later on 15 March 2022, which was likely a post-spawn downstream migration. Several detections for WS17-03 were recorded during the 2022 White Sturgeon spawning survey on a portable receiver approximately 10 km upstream of Colusa on 12 April 2022 which is indicative of WS17-03's presence in a known spawning reach of the Sacramento River. The next suite of detections for WS17-03 at the RVB receiver array began 5 January 2023 with numerous detections daily through 20 February 2023 which may be indicative of pre-spawning staging behavior. No detections suggesting a downstream post-spawn migration were recorded as of the last RVB receiver array download on 11 May 2023.

White Sturgeon WS18-02, fork length 110 cm, was rescued from the Tule Pond on 4 May 2018, tagged with transmitter ID A69-9001-15829, and released into the

Sacramento River at the Elkhorn Boat Launch. There were no post-rescue detections for WS18-02 in 2018 which is likely due to the six-month interval between early December 2017 and 7 June 2018 when the 69 kHz receiver array was not deployed at RVB. The initial detection for WS18-02 at the RVB receiver array was likely an upstream spawning migration on 10 March 2020 followed by what was likely a post-spawning downstream migration 17 days later on 27 March 2020.

White Sturgeon WS19-01, fork length 152.5 cm, was rescued from the Fremont Weir stilling basin on 21 February 2019, tagged with transmitter ID A69-9001-15827, and released into the Sacramento River at Fremont Weir. The first detection for WS19-01 was 51 days later on 13 April 2019 which is indicative of WS19-01 continuing its spawning migration. WS19-01 was detected again at the RVB receiver array on 16, 28, and 29 June 2019 which is indicative of a downstream post-spawning migration. The last detection for WS19-01 was 14 August 2019 is likely indicative of foraging movement behavior.

White Sturgeon WS19-02, fork length 165 cm, was rescued from the Fremont Weir stilling basin on 21 February 2019, tagged with transmitter ID A69-9001-15828, and released into the Sacramento River at Fremont Weir. WS19-02 was not detected at the RVB receiver array until 23-24 January and 3 February 2021, or 702 days post-rescue, which is indicative of an upstream spawning migration. The next detection for WS19-02 at the RVB receiver array was 28 January 2023 which is indicative of an upstream spawning migration. WS19-02 was then detected 72 days later on 10 April 2023 which is indicative of a post-spawning downstream migration.

White Sturgeon WS19-03, fork length 161.5 cm, was rescued from the Fremont Weir stilling basin on 21 February 2019, tagged with transmitter ID A69-9001-15831, and released into the Sacramento River at Fremont Weir. WS19-03 was detected at the RVB receiver array 85 days later on 17 May 2019 which is indicative of a post-spawning downstream migration. The last suite of detections for WS19-03 at the RVB receiver array was between 18 December 2022 and 3 January 2023 which is indicative of staging for an upstream spawning migration.

White Sturgeon WS19-04, fork length 167 cm, was rescued from the Fremont Weir stilling basin on 22 February 2019, tagged with transmitter ID A69-9001-15842, and released into the Sacramento River at Fremont Weir. The first detection for WS19-04 at the RVB receiver array was 58 days later on 21 April 2019 which is indicative of WS19-04 continuing its spawning migration. The next detection for WS19-04 at the RVB receiver array was 15 February 2020 which is indicative of an upstream spawning migration. However, another detection for WS19-04 at the RVB receiver array was not recorded until 764 days later on 20 March 2022, followed by detections on 4 and 26 April 2022. The 2022 detections for WS19-04 at the RVB receiver array do not appear indicative of a spawning migration and are more likely associated with foraging

behavior. The next detection for WS19-04 was 3 January 2023 which is which is indicative of an upstream spawning migration, followed by a detection 116 days later on 29 April 2023 which is indicative of a post-spawning downstream migration.

White Sturgeon WS19-05, fork length 144 cm, was rescued from the Fremont Weir stilling basin on 22 March 2019, tagged with transmitter ID A69-9001-15830, and released into the Sacramento River at Fremont Weir. The first detection for WS19-05 at the RVB receiver array was 40 days later on 1 May 2019 which is indicative of WS19-05 continuing its spawning migration. The next detection for WS19-05 was 668 days later on 27 February 2021, followed by a detection three days later on 2 March 2021. The 2021 detections for WS19-05 at the RVB receiver array do not appear indicative of a spawning migration and are more likely associated with foraging behavior. The next detection for WS19-05 was at the RVB receiver array was 11 January 2023, followed by detections on 13, 18 January and 1 February 2023, which appear to be indicative of pre-spawn staging and eventual upstream spawning migration. The next detection for WS19-05 at the RVB receiver array was 34 days later on 6 March 2023 which is indicative of a post-spawning downstream migration.

White Sturgeon WS19-06, fork length 167 cm, was rescued from the Fremont Weir stilling basin on 22 March 2019, tagged with transmitter ID A69-9001-15830, and released into the Sacramento River at Fremont Weir. The first detection for WS19-05 at the RVB receiver array was four days later on 26 March 2019, which is indicative of WS-19-06 aborting its spawning migration after rescue. There were no other detections for WS19-06 at the RVB receiver array as of 11 May 2023.

White Sturgeon WS20-01, fork length 162 cm, was rescued from a small scour pond in the Tisdale Bypass on 1 May 2020, tagged with transmitter ID A69-9001-5040, and released into the Sacramento River at the Tisdale Boat Launch. The first detection for WS20-01 at the RVB receiver array was four days later on 5 May 2020. The next suite of detections for WS20-01 at the RVB receiver array was between 21 December 2021 and 7 February 2022 which is indicative of pre-spawn staging and an eventual upstream spawning migration. The next detection for WS20-01 at the RVB receiver array was 38 days later on 17 March 2021, which is indicative of a post-spawning downstream migration. WS20-01 was then detected at the RVB receiver array numerous times between 1 April and 13 May 2022 which is likely indicative of foraging behavior. The last detection for WS20-01 was 24 January 2023 which may be indicative of an upstream spawning migration.

White Sturgeon WS23-01, fork length 164 cm, was rescued from the Fremont Weir stilling basin on 28 March 2023, tagged with transmitter ID A69-9001-5034, and released into the Sacramento River at Fremont Weir. WS23-01 was detected at the RVB receiver array 14 days later on 11 April 2023, which is likely indicative of WS23-01 aborting its spawning migration.

White Sturgeon WS23-02, fork length 138 cm, was rescued from the Fremont Weir stilling basin on 28 March 2023, tagged with transmitter ID A69-9001-64037, and released into the Sacramento River at Fremont Weir. WS23-02 was detected at the RVB receiver array 27 days later on 24 April 2023, which is indicative of WS23-02 continuing its spawning migration.

White Sturgeon WS23-03, fork length 142 cm, was rescued from the Fremont Weir stilling basin on 2 April 2023, tagged with transmitter ID A69-9001-5033, and released into the Sacramento River at Fremont Weir. WS23-03 was detected at the RVB receiver array 12 days later on 14 April 2023, which is likely indicative of WS23-03 aborting its spawning migration.

White Sturgeon WS23-04, fork length 184 cm, was rescued from the Fremont Weir stilling basin on 2 April 2023, tagged with transmitter ID A69-9001-64040, and released into the Sacramento River at Fremont Weir. WS23-04 was detected at the RVB receiver array 22 days later on 24 April 2023, which is likely indicative of WS23-03 continuing its spawning migration.

Green Sturgeon GS16-01, fork length 153 cm, was rescued from the Fremont Weir stilling basin on 23 March 2016, tagged with transmitter ID A69-9001-25735, and released into the Sacramento River at Fremont Weir. Detection data from the 69 kHz arrays deployed in the Sacramento River between the Woodson Bridge at rkm 442 and Ben Bridge at rkm 503 recorded numerous detections for GS16-01 between 17 April and 27 June 2016 which is indicative of WS16-01 migrating upstream to known Green Sturgeon spawning habitat. The first detection for GS16-01 at the RVB receiver array was 109 days post-rescue on 10 July 2016, which is indicative of GS16-01 making a post-spawn downstream spawning migration. The next detection for GS16-01 at the RVB receiver array was on 25 February 2019 which is indicative of an upstream spawning migration. However, there were no detections for GS16-01 that are indicative of a post spawning downstream migration in the summer or fall of 2019 or early winter of 2020. The RVB receiver array was not deployed from 13 September through 10 December 2019, so it is likely that GS16-01 made its post-spawn downstream migration during this period. The last detection for GS16-01 as of 11 May 2023 at the RVB receiver array was 12 February 2023 which is indicative of an upstream spawning migration.

Green Sturgeon GS17-01, fork length 172 cm, was rescued from the Fremont Weir stilling basin on 14 March 2017, tagged with transmitter ID A69-9001-25750, and released into the Sacramento River at Fremont Weir. Detection data from the 69 kHz arrays deployed in the Sacramento River between the Woodson Bridge at rkm 442 and Antelope Creek at rkm 466 recorded numerous detections for GS17-01 between 29 April and 18 October 2017 which is indicative of WS17-01 migrating upstream to known Green Sturgeon spawning habitat. However, there were no detections for GS17-01 that are indicative of a post spawning downstream migration in the fall or winter of 2017. The RVB receiver array was not deployed from mid-December through 2017 through 7 June

2018, so it is likely that GS17-01 made its post-spawn downstream migration during this period. The next detection for GS17-01 was 31 October 2021, which is indicative of a post-spawning downstream migration, although there are no detections for GS17-01 in 2020 or 2021 which are indicative of an upstream spawning migration.

Green Sturgeon GS17-02, fork length 172 cm, was rescued from the Fremont Weir stilling basin on 5 May 2017, tagged with transmitter ID A69-9001-25755, and released into the Sacramento River at Fremont Weir. The first detection for GS17-02 at the RVB receiver array was 15 days after rescue on 20 May 2017 which is indicative of GS17-02 aborting its spawning migration. The last detection for GS17-02 was on 8 March 2020 which is indicative of an upstream spawning migration.

Green Sturgeon GS17-03, fork length 159 cm, was rescued from the Tisdale Weir stilling basin on 12 May 2017, tagged with transmitter ID A69-9001-25748, and released into the Sacramento River at the Tisdale Boat Launch. The first detection for GS17-03 at the RVB receiver array was six days after rescue on 18 May 2017 which is indicative of GS17-03 aborting its spawning migration. The last detection for GS17-03 was on 6 March 2020 which is indicative of an upstream spawning migration.

Green Sturgeon GS17-04, fork length 162.5 cm, was rescued from the Tisdale Weir stilling basin on 12 May 2017, tagged with transmitter ID A69-9001-25756, and released into the Sacramento River at the Tisdale Boat Launch. The first detection for GS17-04 at the RVB receiver array was nine days after rescue on 21 May 2017 which is indicative of GS17-04 aborting its spawning migration. The next detection for GS17-04 at the RVB receiver array was 20 February 2020 which is indicative of an upstream spawning migration. GS17-04 was then detected at the RVB receiver array 331 days later on 16 January 2021 which is indicative of a post-spawning downstream migration.

Green Sturgeon GS19-01, fork length 159 cm, was rescued from the Fremont Weir stilling basin on 22 March 2019, tagged with transmitter ID A69-9001-15833, and released into the Sacramento River at the Fremont Weir. The first and only detection for GS19-01 at the RVB receiver array was 266 days after rescue on 13 December 2019 which is indicative of GS19-01 making a post-spawning downstream migration.

Green Sturgeon GS19-02, fork length 160 cm, was rescued from the Fremont Weir stilling basin on 22 March 2019, tagged with transmitter ID A69-9001-15836, and released into the Sacramento River at the Fremont Weir. The first detection for GS19-02 at the RVB receiver array was 79 days later on 9 June 2019, which is likely a post-spawning downstream migration and indicative of GS19-02 continuing its upstream spawning migration after rescue. GS19-02 was detected numerous times at the RVB receiver array in July and August of 2019 which may be indicative of foraging behavior. The last detection for GS19-02 at the RVB receiver array was 5 March 2023 which was indicative of an upstream spawning migration.

Green Sturgeon GS19-04, fork length 147 cm, was rescued from the Tisdale Weir stilling basin on 25 April 2019, tagged with transmitter ID A69-9001-15835, and released

into the Sacramento River at the Tisdale Weir Boat Ramp. The first detection for GS19-04 at the RVB receiver array was 58 days later on 22 June 2019 which is likely a post-spawning downstream migration and indicative of GS19-04 continuing its upstream spawning migration after rescue. The last detection for GS19-02 at the RVB was 7 April 2023 which was indicative of an upstream spawning migration.

Green Sturgeon GS19-05, fork length 189 cm, was rescued from the Tisdale Weir stilling basin on 25 April 2019, tagged with transmitter ID A69-9001-15837, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first detection for GS19-05 at the RVB receiver array was 233 days later on 14 December 2019 which is likely a post-spawning downstream migration and indicative of GS19-04 continuing its upstream spawning migration after rescue. The last detection for GS19-05 at the RVB receiver array 9 March 2022 which was indicative of an upstream spawning migration.

Green Sturgeon GS19-06, fork length 168 cm, was rescued from the Tisdale Weir stilling basin on 25 April 2019, tagged with transmitter ID A69-9001-15838, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first detection for GS19-06 at the RVB receiver array was on 7 February 2020, which was indicative of an upstream spawning migration. However, no detections for WS19-06 indicative of a downstream post-spawning migration were recorded at the RVB receiver array in 2020 or early 2021. The next detection for GS19-06 at the RVB receiver array was 8 March 2022 which was indicative of an upstream spawning migration. The last detection for GS19-06 at the RVB receiver array was 3 January 2023 which is indicative of a downstream post-spawning migration.

Green Sturgeon GS19-08, fork length 168 cm, was rescued from the Tisdale Weir stilling basin on 25 April 2019, tagged with transmitter ID A69-9001-15840, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first detection for GS19-08 at the RVB receiver array was on 25 May 2019, which was indicative a post-spawning downstream migration. The next suite of detections for GS19-08 at the RVB receiver array was 24-30 March 2022 which was indicative of an upstream spawning migration; the six-day detection range with several detections per day appears to be associated with milling behavior prior to the fish continuing its upstream spawning migration. The last detection for GS19-08 at the RVB receiver array was 14 December 2022 which is indicative of a downstream post-spawning migration.

Green Sturgeon GS19-09, fork length 169 cm, was rescued from the Tisdale Weir stilling basin on 25 April 2019, tagged with transmitter ID A69-9001-15843, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first and only detection for GS19-09 at the RVB receiver array was on 25 December 2019, which was indicative a post-spawning downstream migration.

Green Sturgeon GS19-10, fork length 188 cm, was rescued from the Tisdale Weir stilling basin on 26 April 2019, tagged with transmitter ID A69-9001-15847, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first detection for GS19-

10 at the RVB receiver array was 280 days later on 31 January 2020, which is indicative a post-spawning downstream migration. The next and last detection for GS19-10 at the RVB receiver array was 3 February 2023 which was indicative of an upstream spawning migration.

Green Sturgeon GS19-11, fork length 147 cm, was rescued from the Tisdale Weir stilling basin on 26 April 2019, tagged with transmitter ID A69-9001-15848, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first and only detection for GS19-11 at the RVB receiver array was six days later on 2 May 2019 which is indicative of GS19-11 aborting its spawning migration.

Green Sturgeon GS19-12, fork length 169 cm, was rescued from the Tisdale Weir stilling basin on 26 April 2019, tagged with transmitter ID A69-9001-15849, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first detection for GS19-12 at the RVB receiver array was seven days later on 3 May 2019 which is indicative of GS19-12 aborting its spawning migration. The next detection for GS19-12 at the RVB receiver array was 3 March 2022 which is indicative of an upstream spawning migration. The last detection for GS19-12 was on 26 December 2022 which was indicative a post-spawning downstream migration.

Green Sturgeon GS19-14, fork length 147 cm, was rescued from the Tisdale Weir stilling basin on 26 April 2019, tagged with transmitter ID A69-9001-15846, and released into the Sacramento River at the Tisdale Weir Boat Ramp. The first detection for GS19-14 at the RVB receiver array was 12 days later on 8 May 2019 which is indicative of GS19-14 aborting its spawning migration. The next suite of detections for GS19-08 at the RVB receiver array was 11 through 16 February 2022 which is indicative of an upstream spawning migration; the five-day detection range with several detections per day appears to be associated with milling behavior prior to the fish continuing its upstream spawning migration. The last detection for GS19-14 was on 21 January 2023 which is indicative of a post-spawning downstream migration.

Green Sturgeon GS19-15, fork length 171 cm, was rescued from the Yolo Bypass Deep Pond on 20 June 2019, tagged with transmitter ID A69-9001-15844, and released into the Sacramento River near the Fremont Weir. The first detection for GS19-15 at the RVB receiver array was 176 days later on 13 December 2019, which is indicative of GS19-15 making a post-spawning downstream migration. The last detection for GS19-15 at the RVB receiver array was 11 April 2023 which was indicative of an upstream spawning migration.

Green Sturgeon GS19-16, fork length 189 cm, was rescued from the Yolo Bypass Deep Pond on 20 June 2019, tagged with transmitter ID A69-9001-15845, and released into the Sacramento River near the Fremont Weir. The first detection for GS19-16 at the RVB receiver array was 5 days later on 25 June 2019, which is indicative of GS19-16 aborting its migration. The next detection for GS19-16 at the RVB receiver array was 12 April 2022 which was indicative of an upstream spawning migration. The last detection

for GS19-16 at the RVB receiver array was 16 December 2023 which was indicative of a post-spawning downstream migration.

Discussion

Fish rescue operations conducted by CDFW staff following Sacramento River weir overtopping events resulted in the 33 adult White Sturgeon and 32 adult Green Sturgeon being returned to the Sacramento River that would have otherwise perished after becoming stranded in weir stilling basins and bypass scour ponds. As only 22 of 32 of the Green Sturgeon rescued were tagged with acoustic transmitters, the fate of the 10 Green Sturgeon that were not tagged is uncertain. Sturgeon that were apparent post-rescue mortalities may not have survived for several reasons including stress induced by poor water quality in their stranding locations, abrasion injuries from contact with concrete weir infrastructure which could lead to infection, and loss of slime coat or internal injuries suffered during capture and handling (**Figure 3**). Water temperatures in the Tule Pond ranged from 28 to 30 degrees Celsius during the 2016 White Sturgeon rescue effort. While little is known about the thermal maximum for adult White Sturgeon, the White Sturgeon rescued from the Tule Pond in 2016 were extremely lethargic upon capture which was likely a result of thermal stress. Decreased foraging ability may also play a role in post-rescue mortality. Abrasion damage to eyes, barbels and ampullae of Lorenzini were observed in several Green Sturgeon rescued from the Tisdale Bypass stilling basin in 2017 (**Figure 5**). Although telemetry data suggest that post-rescue survival was robust (76 percent for White Sturgeon and 82 percent for Green Sturgeon), a considerable number of sturgeon aborted their spawning migration after rescuing likely due to the migration delay caused by the stranding event, or stress caused by the aforementioned reasons, all of which could result in gamete atresia. Stress caused by capture and handling have been shown to cause White Sturgeon to abort their spawning migration. Schaffter (1997) observed that over 50 percent of White Sturgeon tagged near Freeport and during 1990 and 1991 tagging and spawning surveys migrated downstream after tagging and apparently aborted their spawning migration. However, since sturgeon are long lived iteroparous species, post-rescue survival provided the opportunity for rescued sturgeon to make future spawning migrations. To date, 10 of 32 White Sturgeon and 15 of 22 Green Sturgeon that were rescued made one or more subsequent spawning migrations in the years following rescue and many of these fish have the potential to make several more, therefore rescue efforts to return adult sturgeon to the Sacramento River should be viewed as an overall success, given the Central Valley Project Improvement Act objective of doubling the number of spawning aged fish for both sturgeon species. Thomas *et. al.* (2013) estimated that if Green Sturgeon stranding events continued at their present rate, the population of

spawning age individuals would decrease by 33 percent in 50 years without rescue efforts as opposed to a decrease of seven percent in 50 years if volitional passage through the bypasses are provided in conjunction with rescue efforts. However, while fish rescues do provide benefits in terms of potentially saving fish, there are potential drawbacks associated with fish rescues. The feasibility and likelihood of success of rescue efforts are influenced by such factors as site accessibility, water depth, debris load, and distance to release point. Capture and handling of adult sturgeon also has the potential to result in injury to staff. Fish rescue efforts are costly in terms of staff compensation, equipment, and reallocated time designated to other projects, and therefore should be viewed as a last resort in terms of sturgeon conservation measures within the Yolo and Sutter bypasses.

The Fremont Weir Adult Fish Passage Structure completed in 2019 created volitional passage for numerous sturgeon after overtopping events in the winter and spring of 2019 and 2023 (DWR unpublished data). The Fremont Weir Big Notch Project should be completed by the summer of 2024 which will further facilitate volitional passage of adult sturgeon migrating through the Yolo Bypass back to the Sacramento River. However, it is anticipated that stranding of adult sturgeon is still likely to occur in several sections of the stilling basin and in Yolo Bypass scour ponds, albeit at a much-reduced number. CDFW staff will continue to monitor for sturgeon stranding after weir overtopping events and conduct rescues, as necessary. The Tisdale Weir Rehabilitation and Fish Passage Project is not scheduled for completion until the summer of 2027. Therefore, CDFW will continue to monitor the weir stilling basin after overtopping events and conduct rescue efforts for sturgeon until its completion and evaluate volitional passage when completed to see if rescue efforts will still be necessary.



Figure 5. Southern DPS Green Sturgeon rescued from the Tisdale Weir stilling basin showing abrasion injuries from contact with concrete infrastructure, 25 April 2019.



Figure 6. GS19-15 rescued from the Yolo Bypass Deep Pond being released in the Sacramento River 20 June 2019.

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