Tagging and Monitoring of Juvenile Sturgeon in the Lower Sacramento River and Sacramento-San Joaquin Delta: 2017 Report of Findings

Purpose

Currently there is very little known about the movement patterns, foraging habitat, and overall behavior of juvenile sDPS green sturgeon (*Acipenser medirostris*) and juvenile white sturgeon (*Acipenser transmontanus*) in the lower Sacramento River and Sacramento-San Joaquin Delta-San Francisco Bay (SFBDE). The purpose of this study is to document juvenile sturgeon movement and emigration patterns in the lower Sacramento River and the SFBDE and timing of ocean entry. This study is being conducted by California Department of Fish and Wildlife (CDFW). We are proposing to capture and tag 100 juvenile green sturgeon and 100 juvenile white sturgeon per year with acoustic transmitters and monitor their spatial and temporal movement patterns with an existing array of 69 kHz transmitters deployed throughout the lower Sacramento River and SFBDE. Better understanding of movement patterns is essential to inform management, restoration, and conservation efforts for both sturgeon species.

Background

The southern Distinct Population Segment (sDPS) green sturgeon is one of two sympatric sturgeon species found in river systems of California's Central Valley. The sDPS green sturgeon was listed as threatened on 16 April 2006 by the National Marine Fisheries Service (NMFS 2006). One of the principle criteria for the listing status was the general lack of information available at the time of the status review (NMFS 2006). Since ESA listing there have been several advancements in understanding the biology of green sturgeon. However, research has largely been directed at understanding the behaviors, habitat preferences, and population dynamics of adult green sturgeon within the main-stem Sacramento River. However, there have been very few studies targeting the spatial and temporal components of juvenile sturgeon presence in the lower Sacramento River and SFBDE. There is virtually no information on size, age, or potential environmental cues contributing to movements in the SFBDE and outmigration to the Pacific Ocean. Juvenile green sturgeon are considered to be ubiquitous throughout both the delta and bay, spending up to three years throughout the lower watershed before making an ocean entry (Moyle 2002). Preliminary telemetry detections for laboratory reared and tagged juvenile green sturgeon released in the SFBDE Bay have shown that ocean entry is not necessarily linear, in that individuals may move back into the delta after having already reached the bay (CDFW 2015, 2016, Thomas *et. al.* 2015). Information on timing, survival, and transition rates through the SFBDE region for both sturgeon species is necessary for understanding potential impacts from water diversions, dredging operations, and other projects affecting the lower Sacramento River and SFBDE.

The white sturgeon (*Acipenser transmontanus*) population, while greatly reduced in numbers from historical levels, still supports an important recreational fishery. However, this species is currently considered a Species of Special Concern by CDFW (Musick et al. 2001). Like the green sturgeon, there is relatively little information on the movements and behavior of juvenile white sturgeon in the SFBDE. Dubois (2010) and Radtke (1966) provide the only published work on juvenile white sturgeon distribution within the SFBDE. Results of this study suggest that juveniles are distributed within the lower Sacramento River and parts of the delta. Unlike green sturgeon, white sturgeon spend the majority of their life within the SFBDE, although some individuals enter the Pacific Ocean as adults and migrate up or down the coast in the nearshore marine environment. Additional work is necessary to develop a greater understanding of how white sturgeon are distributed between the lower watersheds and which habitat features are most desirable to sustain future production.

Fisheries researchers have always been challenged by the difficulty in capturing juvenile sturgeon. There are currently many monitoring programs targeting juvenile salmonids throughout the Central Valley. However, most have had little or no success capturing juvenile sturgeon. The gear and sampling methods typically utilized for salmonid monitoring are not effective for targeting benthic species such as juvenile sturgeon. Limited past acoustic tagging and monitoring studies of juvenile green sturgeon include the years 2015 and 2016 of this project and a study involving the capture of larvae or early-stage juveniles near the spawning grounds and rearing them in captivity for up to ten months until they were large enough to receive an acoustic transmitter (Thomas et al. 2015). Otter trawls, set lines, trammel, and gill nets have all been shown to be effective methods for capturing juvenile pallid sturgeon in the Missouri River system (Spindler et al. 2009). Additionally, gill nets have been utilized for the capture of juvenile green sturgeon in the Sacramento-San Joaquin delta (Radtke 1966). Developing a protocol to capture and monitor juvenile sturgeon is essential for the implementation of a long-term monitoring program which is critical for determining population level trends and potential stressors affecting the decline of these species. Findings from this study can then be used to implement species specific management strategies.

2017 is the third year of tagging and monitoring efforts supporting this long-term study. CDFW and UC Davis Biotelemetry staff captured one Age-1+ juvenile sDPS green sturgeon over 33 sampling events during 2015 for a catch per unit effort (CPUE) of 0.0033 per hour of gill net set time. The 2016 sampling season was somewhat more successful, as CDFW staff captured and tagged seven juvenile green sturgeon and 11 juvenile white sturgeon for a CPUE of 0.0081 for green sturgeon and a CPUE 0.0128 for white sturgeon. The 2013, 2014 and 2015 water years were dry, critically dry and critically dry, respectively. White sturgeon recruitment to juvenile life stage is markedly less in critically dry or dry years compared to wet or above normal water years with resulting high delta outflows during late winter through late spring (Fish 2010). It appears that green sturgeon recruitment to the juvenile life stage is similar. Analysis of telemetry data showed that the juveniles of both sturgeon species ranged both upstream and downstream in the SFBDE after tagging, with juvenile green sturgeon exhibiting at least two distinct movement patterns.

Methods

CDFW applied for and received NMFS Section 10(A)(1)(a) Permit Number 17551 that authorized the capture and tagging of up to 100 juvenile green sturgeon annually. A Section 10(A)(1)(a) permit is not required for take of white sturgeon, as they are not a federally listed species. The permit authorizes the use of gill or trammel nets to capture juvenile green sturgeon in the Sacramento River between Tisdale and Rio Vista, the San Joaquin River in the vicinity of Santa Clara Shoal, and the SFBDE in the vicinity of Grizzly Bay at Montezuma Slough. The 2017 sampling effort involved deployment of one or two 100-ft long by 10-ft height variable mesh gill nets with individual panels consisting of 7-cm (2 ¾-inch), 7.6-cm (3.0-inch), and 10.2-cm (4.0-inch) mesh sizes anchored with 18-kg (40-lb) pyramid weights affixed to the ends of the lead line to minimize drift. Site selection was determined by river or delta bathometry, current velocity, absence of large woody or anthropogenic debris, absence of submerged aquatic vegetation, and minimal quantities of drifting aquatic vegetation. Net soak times varied from 60 minutes to 240 minutes with deployment duration being dependent on water temperature and dissolved oxygen concentration (**Table 1**).

CDFW staff conducted 44 days of sampling events in 2017 between 5 January and 14 December. Data collected during sampling events included water temperature, dissolved oxygen, water depth, net set and retrieval times, and number of each fish species captured. Sampling locations and number of sampling events per location are presented in **Figure 1.** We concentrated the 2017 sampling season effort (31 of 44 sampling events) in the main channel of the Sacramento River north of Sherman Lake (rkm 82) at an average depth of 9 m, as this site had the highest CPUE for juvenile green sturgeon 2016. Substrate in this area is dominated by fine sediment interspersed with peat hummocks. This site also typically has considerably less drifting aquatic vegetation than upstream sampling sites. Heavy loading of drifting aquatic vegetation in the gill nets decreases capture efficacy and under periods of large tidal swings and associated strong currents causes the gill net to drift which can result in it snagging on large woody or anthropogenic debris.

Table 1. Temperature and dissolved oxygen parameters for gill netting juvenile green sturgeon from Kahn and Mohead (2010).

Temperature at sampling depth	Minimum DO at sampling depth	% oxygen saturation at sampling depth	Net deployment time (hours)
Up to 19°C	5 mg/l	58%	4
19° to 23°C	5 mg/l	58%	2
23° to 25°	5 mg/l	58%	1
Over 25°	5 mg/l	58%	No netting

Captured juvenile sturgeon were identified to species, assessed for condition, and measured prior to tagging. Juvenile sturgeon were tagged with uniquely coded 69 kHz acoustic transmitters (Innovasea®) via surgical implantation into the peritoneal cavity. The tag size used for juvenile sturgeon in 2017 was either a V7 or V13, which have typical battery lives of 173 days and 911 days, respectively at ping rate intervals of 90-120 seconds. Attachment A includes a detailed standard operating procedure for tagging juvenile sturgeon with acoustic transmitters. Tagged juvenile sturgeon were assigned a study number (year of capture and number, *e.g.*, GS17-01) and released near the point of capture. Brood year assignments for juvenile green sturgeon were made by extrapolating the fork length of young-of-year juveniles captured during late-summer through mid-fall in the Sacramento River near Red Bluff by U.S. Fish and Wildlife-Red Bluff and growth rates of juvenile northern DPS green sturgeon from the Klamath River (USFWS 1995).

The U.C. Davis Biotelemetry Laboratory (UCDBL) deployed and maintained arrays of autonomous 69 kHz receivers throughout the Sacramento River and SFBDE which recorded detections of 69 kHz transmitters. Each receiver array has a variable number of receivers depending on factors such as channel width, deployment mooring availability, and access for maintenance and downloading. The detection range of each array is also variable and dependent on factors such as tag transmission power, signal absorption, line of sight, reflection and refraction, and man-made and natural environmental noise. Typically, areas that have clear water, sand or silt flat bottoms and low current exhibit the greatest detection ranges. For V7 tags, Innovasea® states that reception range under ideal conditions is around 500 m. UCDBL conducts periodic receiver downloads, and the detection data is uploaded to the HYDRA database maintained by UCDBL. CDFW staff uploaded tag identification codes and metadata associated with the tagged sturgeon to the HYDRA database. CDFW staff queried the HYDRA database for each tag code; then downloaded and analyzed the detection data to determine movement patterns and residency time at each receiver location. However, In 2017, funding for UCDBL to maintain the Sacramento River and SFBDE receiver arrays was discontinued and UCDBL staff decommissioned the receiver arrays in November and December 2017. CDFW staff deployed receiver arrays at the Rio Vista, Antioch, and Benicia bridges in the summer of 2018 to provide minimal broad scale detection data for tagged juvenile sturgeon. Therefore, there are considerable gaps in telemetry detection data for juvenile green sturgeon tagged during 2017 through mid-2018. NMFS maintained an array of 69 kHz acoustic release receivers at the Golden Gate after UCDBL removed the core receiver arrays in the Sacramento River. While the primary function of the acoustic release receivers was to deploy and retrieve 417 kHz receivers used to detect juvenile salmonid acoustic tags (JSATS), they also recorded detections of 69 kHz tags and therefore provided detection data for juvenile green sturgeon tagged with 69 kHz transmitters.

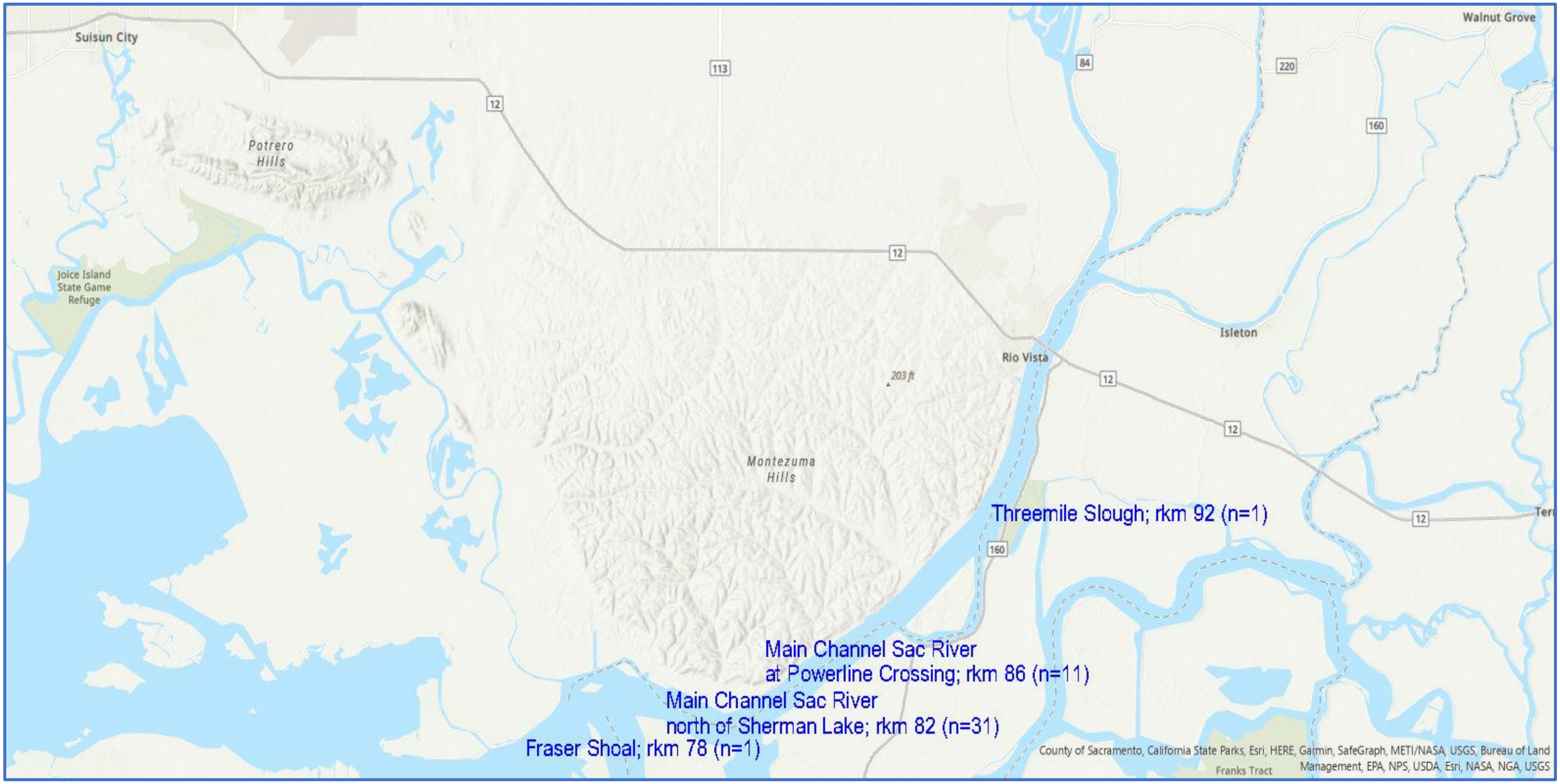


Figure 1. Juvenile sturgeon sampling locations and number of sampling events per location, 2017.

Figure 2. 2017 receiver array location map. **Note**: All receiver arrays except for the Golden Gate array were removed at the end of 2017; receiver arrays redeployed at Rio Vista Bridge by CDFW on 7 June 2018 and at Antioch and Benicia bridges on 12 October 2018.

Results

Water temperatures and dissolved oxygen concentrations remained within the sampling thresholds through the entire sampling season **(Figure 3).** CDFW staff captured and tagged seven juvenile green sturgeon during the 2017 sampling season for a catch per unit effort (CPUE) of 0.0145 per hour of net set time. The juvenile green sturgeon were from three brood year cohorts: one from brood year 2014, two from brood year 2015, and four from brood year 2016 (**Table 1**). All seven green sturgeon were captured and tagged in the main channel of the Sacramento River north of Sherman Lake at a depth of approximately nine meters. No juvenile white sturgeon were captured or tagged during the 2017 sampling season. **Tables 2 through 8** present the detection summaries for juvenile green sturgeon tagged during the 2017 sampling season. Note that the detection interval or residency period at each receiver array shown in the summary tables is not necessarily continuous for that location, rather it is a temporal interval in which the tag code was not detected at any other receiver array during the period. For example, a tag code ID detected at the Rio Vista receiver array on 1, 4, 24, and 31 October but at no other receiver locations would have a residency period of 31 days at the Rio Vista receiver array. The removal of the 69 kHz receiver arrays from the lower Sacramento River and the SFBDE at the end of 2017 and early 2018 resulted in a greatly reduced spatial and temporal range of detections for juvenile green sturgeon tagged in 2017, particularly for the five individuals tagged November. However, CDFW staff's deployment of 69 kHz receiver arrays at Rio Vista, Antioch, and Benicia bridges in the summer of 2018 provided the majority of detection data presented in this report.

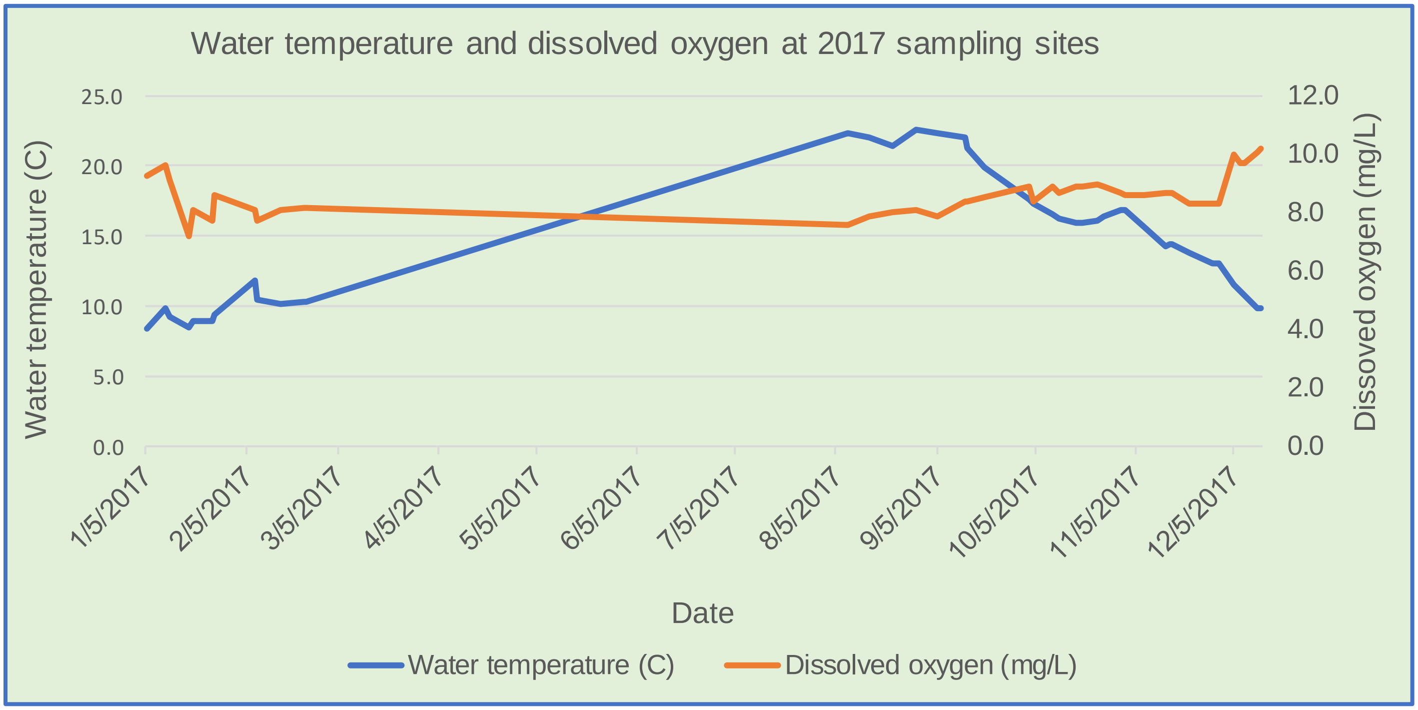


Figure 3. Water temperature and dissolved oxygen at 2017 sampling sites.

Other native fish species captured during sampling included fall-run Chinook salmon (*Oncorhynchus tshawytscha*); n=1, Central Valley steelhead (hatchery origin; *Oncorhynchus mykiss*) n=6, Sacramento splittail (*Pogonichthys macrolepidotus*)**;** n=109, Sacramento pikeminnow (*Ptychocheilus grandis*); n=23, hitch (*Lavinia exilicauda*)**;** n=28, starry flounder (*Platichthys stellatus*); n=4, and tule perch (*Hysterocarpus traskii*); n=10. Non-native fish species captured during sampling included striped bass (*Morone saxatilis*); n=262, American shad (*Alosa sapidissima*); n=1, black crappie (*Pomoxis nigromaculatus*); n=1, and brown bullhead (*Ameiurus nebulosus*); n=3.

Table 1. Study ID, date tagged, capture site, fork length, brood year assignment, and tag code for juvenile sturgeon tagged during 2017. See **Figure 1** for capture site locations.

Study ID[1]	Date tagged	Fork length (cm)	Brood year	Tag code
GS17-01	1/11/2017	74.7	2014	A69-1601-36729
GS17-02	1/11/2017	39	2016	A69-1601-36728
GS17-03	11/1/2017	58.5	2015	A69-1602-1473
GS17-04	11/7/2017	63	2015	A69-1602-1472
GS17-05	11/16/2017	62	2016	A69-1602-1471
GS17-06	11/21/2017	59	2016	A69-1602-1474
GS17-07	11/28/2017	62.5	2016	A69-1602-1475

[1] GS is green sturgeon.

Table 2. GS17-01 Detection Summary. Brood year 2014; Tag code A69-1601-36729; tagged 11 January 2017.

Tagging site (rkm 92)	Rio Vista Bridge (rkm 97)	Benicia Bridge (rkm 52)	Carquinez Bridge (rkm 41)	Richmond Bridge (rkm 15)
1/11/2017; 6/5 to 6/7/17	No detections	1/15/17; 3/24 to 4/1/17; 4/18 to 5/24/17; 6/9/17; 6/10 to 6/13/17; 6/16/17; 6/23 to 6/27/17; 6/28/17; 6/29 to 7/2/17	1/15 to 3/21/17; 4/2 to 4/10/17; 6/9/17; 6/13 to 6/15/17; 6/16 to 6/22/17; 6/23/17; 6/27/17; 6/28/17; 7/2/17	8/31/17 to 1/8/18

Initial tagging site residency: 1 days. Departure from the tagging site to initial detection at the Benicia Bridge: 4 days. Initial Benicia Bridge residency: <1 day. Departure from the Benicia Bridge to initial detection at the Carquinez Bridge: <1 day. Initial Carquinez Bridge residency: 65 days. Departure from the Carquinez Bridge to next detection at the Benicia Bridge: 3 days. Second Benicia Bridge residency: 8 days. Departure from the Benicia Bridge to next detection at the Carquinez Bridge: 1 day. Second Carquinez Bridge residency: 8 days. Departure from the Carquinez Bridge to next detection at the Benicia Bridge: 8 days. Third Benicia Bridge residency: 36 days. Departure from the Benicia Bridge to next detection at the tagging site: 12 days. Second tagging site residency: 2 days. Departure from the tagging site to next detection at the Benicia Bridge: 2 days. Fourth Benicia Bridge residency: 1 day. Departure from the Benicia

Bridge to next detection at the Carquinez Bridge: <1 day. Third Carquinez Bridge residency: 1 day. Departure from the Carquinez Bridge to next detection at the Benicia Bridge: 1 day. Fifth Benicia Bridge residency: 3 days. Departure from the Benicia Bridge to next detection at the Carquinez Bridge: 1 day. Fourth Carquinez Bridge residency; 2 days. Departure from the Carquinez Bridge to next detection at the Benicia Bridge: 1 day. Sixth Benicia Bridge residency: <1 day. Departure from the Benicia Bridge to next detection at the Carquinez Bridge: <1 day. Fifth Carquinez Bridge residency: 6 days. Departure from the Carquinez Bridge to next detection at the Benicia Bridge: 1 day. Sixth Benicia Bridge residency: <1 day. Departure from the Benicia Bridge to next detection at the Carquinez Bridge: <1 day. Sixth Carquinez Bridge residency: <1 day. Departure from the Carquinez Bridge to next detection at the Benicia Bridge: <1 day. Seventh Benicia Bridge residency: 4 days. Departure from the Benicia Bridge to next detection at the Carquinez Bridge: <1 day. Seventh Carquinez Bridge residency: <1 day. Departure from the Carquinez Bridge to next detection at the Benicia Bridge: 1 day. Eighth Benicia Bridge residency: 3 days. Departure from the Benicia Bridge to next detection at the Carquinez Bridge: <1 day. Eight Carquinez Bridge residency: 1 day. Departure from the Carquinez Bridge to initial detection at the Richmond Bridge: 60 days. Richmond Bridge residency: 140 days.

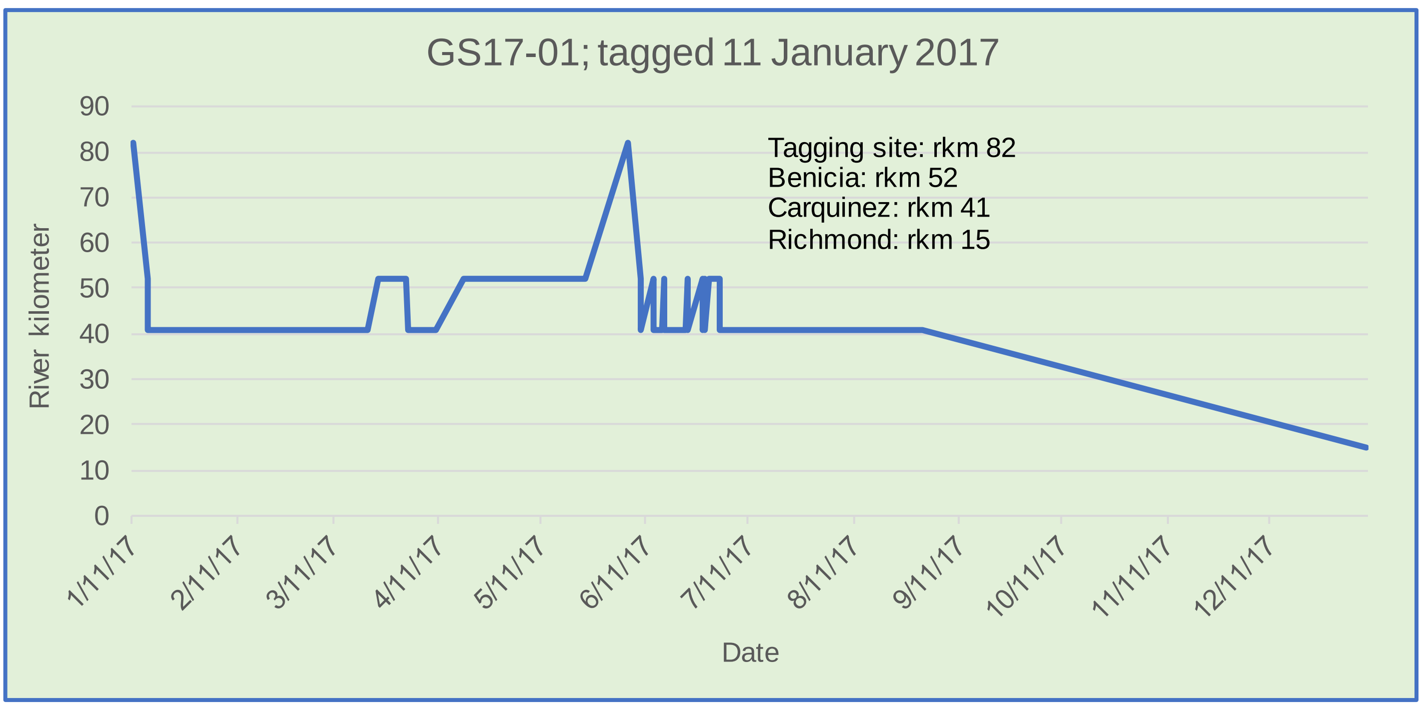


Figure 4. Detection plot for GS17-01; tagged 11 January 2017.

Table 3. GS17-02 Detection Summary. Brood year 2016; Tag code A69-1601-36728; tagged 11 January 2017.

Tagging site (rkm 92)	Rio Vista Bridge (rkm 97)	Benicia Bridge (rkm 52)	Carquinez Bridge (rkm 41)	Richmond Bridge (rkm 15)
No detections	No detections	No detections	No detections	No detections

Note: Possible defective tag or early post-release mortality. Also, all receiver arrays except for the Golden Gate array were removed at the end of 2017.

Table 4. GS17-03 Detection Summary. Brood year 2015; Tag code A69-1602-1473; tagged 1 November 2017.

Tagging site (rkm 92)	Rio Vista Bridge (rkm 97)	Benicia Bridge (rkm 52)	Carquinez Bridge (rkm 41)	Golden Gate (rkm 0.8)
11/1 to 12/8/17	No detections	No detections	No detections	3/4 to 6/12/19

Initial tagging site residency: 37 days. Departure from the tagging site to initial detection at the Golden Gate: 451 days. **Note**: All receiver arrays except for the Golden Gate array were removed at the end of 2017; receiver arrays redeployed at Rio Vista Bridge by CDFW on 7 June 2018 and at Antioch and Benicia bridges on 12 October 2018; GS-17-03 likely migrated past the Benicia, Carquinez and Richmond Bridge arrays between the end of 2017 and mid 2018 prior to detection at the Golden Gate.

Table 5. GS17-04 Detection Summary. Brood year 2014; Tag code A69-1602-1472; tagged 7 November 2017.

Tagging site (rkm 86)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Carquinez Bridge (rkm 41)	Golden Gate (rkm 0.8)
11/7 to 11/11/17	2/6/19	11/12 to 11/13/18	No detections	4/17 to 8/24/19

Tagging site residency: 4 days. Departure from the tagging site to initial detection at the Benicia Bridge: 366 days. Benicia Bridge residency: 1 day. Departure from the Benicia Bridge to initial detection at the Antioch Bridge: 85 days. Antioch Bridge residency: 1 day. Departure from the Antioch Bridge to initial detection at the Golden Gate: 70 days. Golden Gate residency: 129 days. **Note**: All receiver arrays except for the Golden Gate array were removed at the end of 2017; receiver arrays redeployed at Rio Vista Bridge by CDFW on 7 June 2018 and at Antioch and Benicia bridges on 12 October 2018.

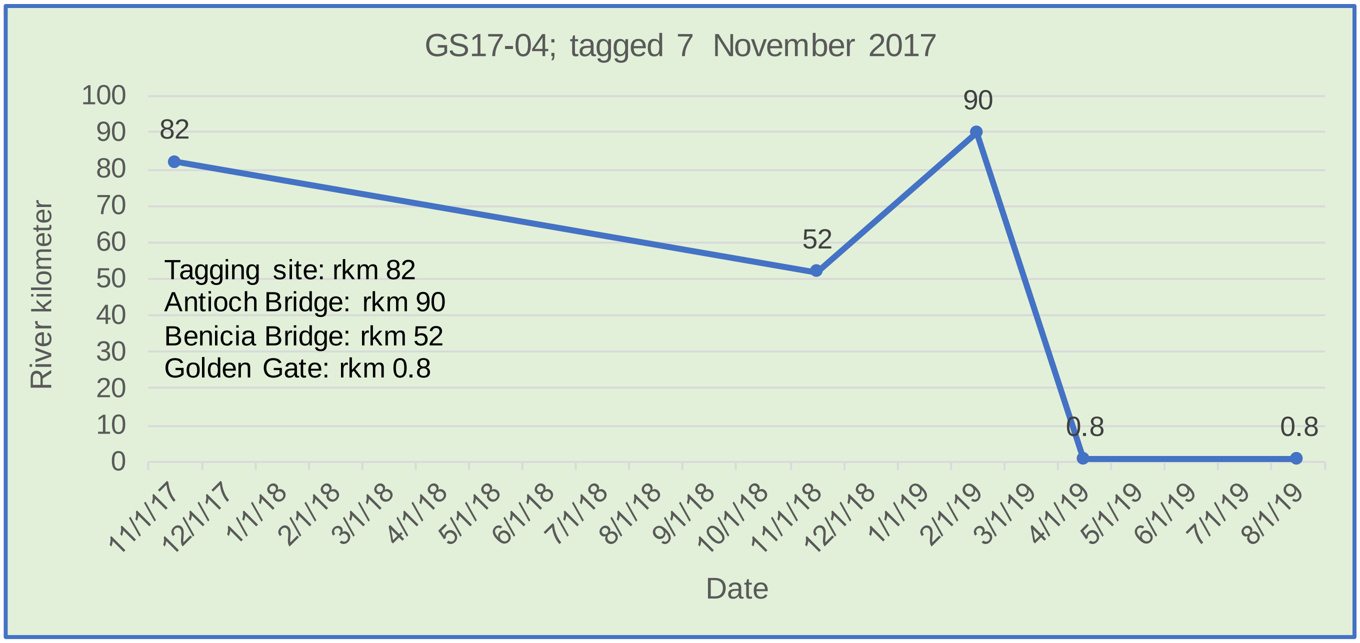


Figure 5. Detection plot for GS17-04; tagged 7 November 2017.

Table 6. GS17-05 Detection Summary. Brood year 2016; Tag code A69-1602-1471; tagged 16 November 2017.

Tagging site (rkm 92)	Benicia Bridge (rkm 52)	Carquinez Bridge (rkm 41)	Richmond Bridge (rkm 15)	Golden Gate (rkm 0.8)
11/17 to 11/22/17	No detections	No detections	No detections	1/18/18

Tagging site residency: 5 days. Departure from the tagging site to initial detection at the Golden Gate: 57 days. Golden Gate residency: 1 day. **Note**: All receiver arrays except for the Golden Gate array were removed at the end of 2017; receiver arrays redeployed at Rio Vista Bridge by CDFW on 7 June 2018 and at Antioch and Benicia bridges on 12 October 2018.

Table 7. GS17-06 Detection Summary. Brood year 201; Tag code A69-1602-1474; tagged 21 November 2017.

Tagging site (rkm 82)	Benicia Bridge (rkm 52)	Carquinez Bridge (rkm 41)	Richmond Bridge (rkm 15)	Golden Gate (rkm 0.8)
11/22/17	7/13 to 7/29/18	No detections	No detections	12/28/18 to 6/2/19

Tagging site residency: 1 day. Departure from the tagging site to initial detection at the Benicia Bridge: 233 days. Benicia Bridge residency: 16 days. Departure from the Benicia Bridge to initial detection at the Golden Gate: 152 days. Golden Gate residency: 156 days. **Note**: All receiver arrays except for the Golden Gate array were removed at the end of 2017; receiver arrays redeployed at Rio Vista Bridge by CDFW on 7 June 2018 and at Antioch and Benicia bridges on 12 October 2018.

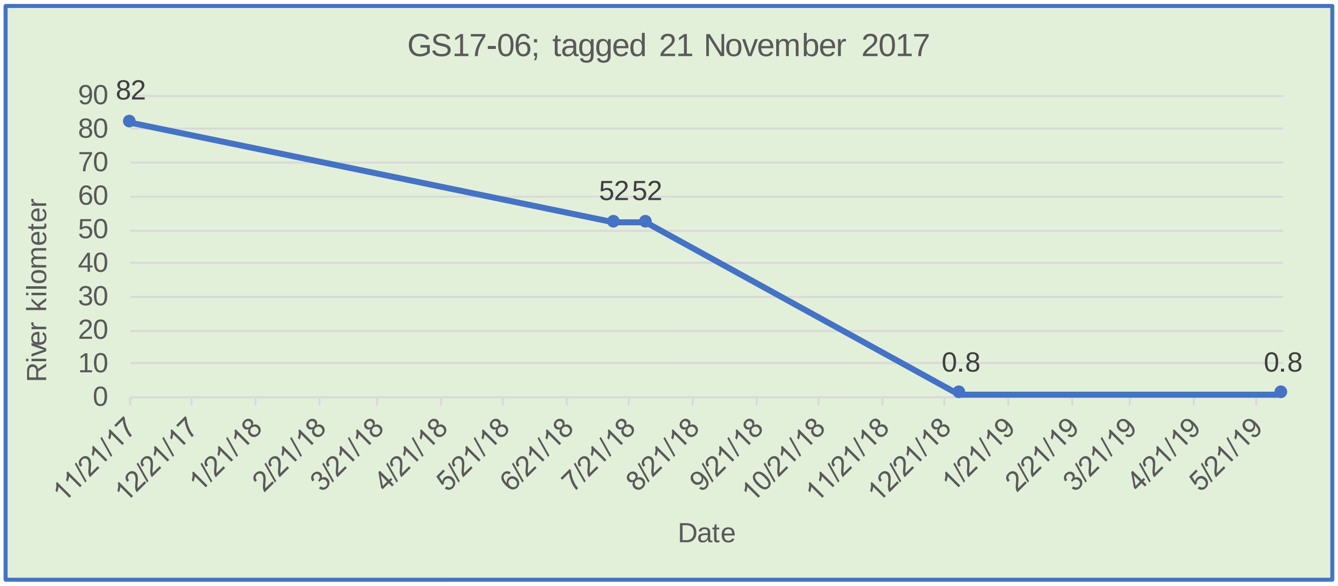


Figure 6. Detection plot for GS17-06; tagged 21 November 2017

Table 8. GS17-07 Detection Summary. Brood year 2016; Tag code A69-1602-1475; tagged 28 November 2017.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Benicia Bridge (rkm 52)	Carquinez Bridge (rkm 41)	Richmond Bridge (rkm 15)
11/29 to 11/30/17	No detections	No detections	No detections	No detections

Tagging site residency: 1 day. **Note**: All receiver arrays except for the Golden Gate array were removed at the end of 2017; receiver arrays redeployed at Rio Vista Bridge by CDFW on 7 June 2018 and at Antioch and Benicia bridges on 12 October 2018.

Table 9. Initial residency periods at receiver locations for juvenile green sturgeon tagged in 2017; range and mean in days; number of fish detected per receiver location (*n*=*x*).

Tagging site (n=6)		Antioch (n=1)		Benicia (n=3)		Carquinez (n=1)		Richmond (n=1)		Golden Gate (n=4)	
range	mean	range	mean	range	mean	range	mean	range	mean	range	mean
1-37	8.2	1	1	1-16	7	65	65	140	140	1-156	95

Table 10. Travel time from tagging site to initial detection at other receiver array locations for juvenile green sturgeon tagged in 2017; range and mean in days; number of fish detected per receiver location (*n*=*x*).

Antioch (n=1)		**Benicia (n=3)**		**Carquinez (n=1)**		**Richmond (n=1)**		**Golden Gate (n=4)**	
range	mean	range	mean	range	mean	range	mean	range	mean
452	452	4-366	201	4	4	233	233	57-522	327

Green sturgeon movement trends. Note: All receiver arrays except for the Golden Gate array were removed by the Uc Davis Biotelemetry Lab at the end of 2017. CDFW staff redeployed receiver arrays at Rio Vista Bridge on 7 June 2018 and at Antioch and Benicia bridges on 12 October 2018. Therefore, there are likely considerable gaps in detections for the first 10 months of 2018, in particular for the five juvenile green sturgeon captured and tagged in November. GS17-02 was not detected at the tagging site or any other receiver arrays, which may be indicative of a defective acoustic transmitter or post-release mortality. GS17-07 was detected at the tagging site receiver array but no other receiver arrays.

The residency of juvenile green sturgeon at the tagging site receiver array ranged from one (GS17-06 and GS17-07) to 37 days (GS17-03), with a mean residency time of 8.4 days. No juvenile green sturgeon tagged in 2017 were detected at Rio Vista Bride and Cache Slough complex receiver arrays which are 15 and 24 km upstream, respectively, from the tagging site. GS17-04 was the only juvenile green sturgeon detected in the San Joaquin River at the Antioch Bridge receiver array. Three juvenile green sturgeon tagged in 2017 were detected at the Benicia Bridge. Departure from the tagging site to initial detection at the Benicia Bridge ranged from four to 366 days with a mean of 201 days. Four of seven juvenile green sturgeon tagged in 2016 were detected at the Benicia Bridge. Departure from the tagging site to initial detection at the Benicia Bridge ranged from three to 49 days with a mean of 15 days. The difference in the time to initial detection at the Benicia Bridge between 2016 and 2017 is likely due to the absence of a receiver array during the first 10 months of 2018; it is likely that at least some of the juvenile green sturgeon tagged in November of 2017 had moved downstream to the Benicia Bridge prior to the redeployment of the receiver array in October, as the initial detections for these fish were recorded after the Benicia Bridge receiver array was redeployed on 12 October 2018; presence at the Benicia Bridge would not have been detected prior to this date.

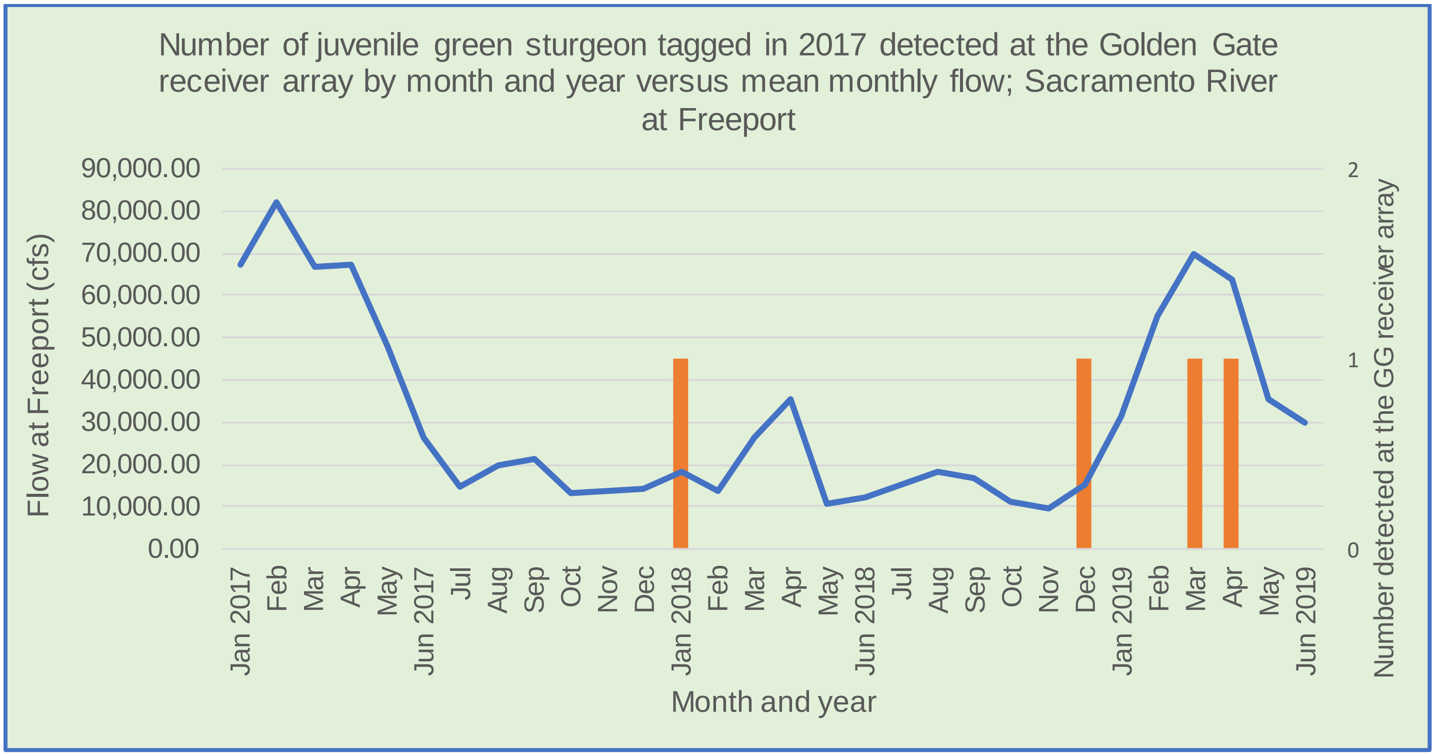
GS17-01 made numerous forays between the Benicia Bridge and Carquinez Bridge receiver arrays between 9 June and 2 July 2017. Downstream (Benicia to Carquinez) forays were typically initiated after the onset of outgoing tides (east to west current flow), while upstream forays were initiated after the onset of incoming tides (west to east current flow). The tidal current changes approximately 50 minutes after low or high tide, as there is a lag in directional change following peak high and low tide events. The average downstream travel time between the Benicia and Carquinez receiver arrays was 2 hours and 48 minutes, for an average speed of 3.9 km per hour, and the average upstream travel time between the Carquinez and Benicia receiver arrays was 8 hours and 12 minutes, for an average speed of 1.4 km per hour (**Table 11**). Two of the upstream forays lasted through more than one tidal cycle.

Four juvenile green sturgeon tagged in 2017 were detected at the Golden Gate receiver array, with the time from departure from the tagging site to initial detection at the Golden Gate receiver array ranging from 63 days for GS17-05 to 552 days for GS17-06 with a mean of 409 days. GS17-03, GS17-04, and GS17-06 were detected over two or more temporal periods ranging from one to six days at the Golden Gate receiver array with absence periods ranging from four to 149 days, while GS17-05 was detected for only one day at the Golden Gate receiver array. Although there were no detections for GS17-03, GS17-04, GS17-05, and GS17-06 on receiver arrays deployed in nearshore Pacific Ocean locations, it is possible that some or all of these juvenile green sturgeon made short duration ocean forays.

Table 9. GS17-01 Forays between the Benicia and Carquinez Bridge receiver arrays.

Foray direction	Last detection	First detection	Low tide (time)	High tide (time)	Travel Time (hours:min)
Benicia-Carquinez	2017-06-09 13:24	2017-06-09 17:15	13:26	19:58	3:51
Carquinez-Benicia	2017-06-09 20:00	2017-06-10 23:22	19:58 (6/9)	1:39 (6/10)	27:22
Benicia-Carquinez	2017-06-13 14:50	2017-06-13 17:13	11:13	18:16	2:23
Carquinez-Benicia	2017-06-15 23:31	2017-06-16 02:07	0:53 (6/16)	6:12 (6/16)	2:36
Benicia-Carquinez	2017-06-16 17:07	2017-06-16 19:46	13:06	20:07	2:35
Carquinez-Benicia	2017-06-22 19:10	2017-06-23 04:50	18:24	0:28 (6/23)	9:40
Benicia-Carquinez	2017-06-23 13:31	2017-06-23 16:43	19:22	14:37	3:12
Carquinez-Benicia	2017-06-23 18:52	2017-06-23 23:52	19:22	1:15	5:00
Benicia-Carquinez	2017-06-27 15:38	2017-06-27 18:04	11:28	18:08	2:26
Carquinez-Benicia	2017-06-27 22:36	2017-06-28 01:16	23:24	4:49	2:30
Benicia-Carquinez	2017-06-28 16:29	2017-06-28 19:11	18:58	0:29	2:42
Carquinez-Benicia	2017-06-28 23:37	2017-06-29 01:38	0:29	5:55	2:01

Foray direction	Last detection	First detection	Low tide (time)	High tide (time)	Travel Time (hours:min)
Benicia-Carquinez	2017-07-02 09:08	2017-07-02 11:41	15:14	9:41	2:33



While the timing of initial detection for juvenile green sturgeon at the Golden Gate receiver array is highly variable (**Figure 7**), increases in delta outflows may provide a queue for outmigration from the SFBDE. The first juvenile green sturgeon to arrive at the Golden Gate receiver array, GS17-05, was detected 18 January 2018 during a slight outflow increase. The other three juvenile green sturgeon detected at the Golden Gate receiver array had initial detections during a prolonged delta outflow increase beginning in December 2018, although the last individual to be detected at the Golden Gate receiver array was not detected until April 2018 when flows began to recede. Therefore, increases in Delta outflow may not be the only parameter influencing outmigration.

Discussion

2017 was the third year of this study, and although the CPUE for juvenile green sturgeon was relatively low, it was not unexpected given that the 2016, 2015, and 2014, were below normal, critically dry, and critically dry, respectively. Recruitment of white sturgeon to the juvenile life stage is significantly greater during wet or above normal water years with resulting high delta outflows during late winter through late spring as compared to recruitment during dry or critically dry years with minimal delta outflows (Fish 2010). While data for recruitment green sturgeon to the juvenile life stage is lacking, it is likely that green sturgeon exhibit similar recruitment patterns.

Unlike juvenile salmonids that enter the delta and typically migrate downstream to the Pacific Ocean, juvenile green sturgeon ranged throughout the SFBDE, making both upstream and downstream migrations or foraging forays. Similar to juvenile green sturgeon tagged in 2016, juvenile green sturgeon tagged during 2017 exhibited at least two distinct movement patterns, with some making a more or less direct net downstream migration with possible forays into the Pacific Ocean, while others tended to move more ubiquitously throughout the delta and rear for a longer period. The variation in movement and rearing patterns may represent alternate life history strategies which could serve to increase overall survival and recruitment to the adult life stage if rearing conditions in either the SFBDE or ocean are unfavorable.

Interestingly, no juvenile white sturgeon were captured or tagged during the 2017 sampling season. In 2016, CDFW staff captured and tagged 11 juvenile white sturgeon over 81 days of sampling effort compared to 44 days of sampling effort in 2017. However, all 11 juvenile white sturgeon were captured at sampling sites four and 10 km upstream from the primary sampling site in 2017. It appears likely that the two sturgeon species may utilize different rearing habitats. The depth at sites where juvenile white sturgeon were captured in 2016 range from five to seven meters, while the 2017 sampling site depth at rkm 82 averages around 10 meters.

The removal of the 69 kHz extensive receiver array in the lower Sacramento River and SFBDE at the end of 2017 resulted in a seven month period with a complete lack of detections for juvenile sturgeon tagged in 2016 and 2017. Although CDFW staff deployed receiver arrays at Rio Vista on 7 June 2018 and at the Antioch and Benicia bridges on 12 October 2018, receiver coverage in the lower Sacramento River and SFBDE was greatly reduced compared to when UCDBL maintained to core 69 kHz receiver array, making it difficult to determine habitat utilization and fine scale movement patterns. Redeployment of a robust 69 kHz receiver array is critical to provide a better understanding of juvenile sturgeon utilization of the lower Sacramento River and SFBDE.

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Attachment A:

JUVENILE STURGEON TAGGING STANDARD OPERATIONAL PROCEDURES

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Region 2 Anadromous Fisheries
February 2022

PREPARATION:

1. Prior to conducting field sampling, perform an inventory check on the juvenile sturgeon tagging kit and ensure there everything necessary to conduct tagging is in the surgery kit.

COLLECTION:

1. Upon capture immediately move fish to holding bucket or cooler and place air bubbler in holding tank.

2. Identify species, observe fish condition upon placement in holding container; record capture time and capture location.

SURGERY SET UP:

1. Everything needed to perform the surgery should be included in the juvenile sturgeon tagging kit (see above PREPARATION section).
2. Set up surgery table on a stable platform (e.g., boat deck or captain seat).
3. Fill one five-gallon bucket half-full (10 liters) of river water and add the contents of one pre-weighed vial of MS-222 and mix thoroughly.
4. Fill a second bucket with river water to be used for gravity-feed gill irrigation during surgery.
5. Remove surgery trays and place on surgery bench, collect necessary tools (scalpel, tissue forceps, suture forceps, suture, scissors) and place in trays
6. Weigh and measure sturgeon to determine the appropriate tag size. Record the tag ID and serial number on the data sheet, remove magnet from tag to activate. Check to make sure the identification sticker has been removed from the tag and is taped to the Juvenile Sturgeon Tagging Form

7. Use the PIT tag reader to scan the tag ID and record the ID number on the data sheet.

SURGERY:

1. Place the sturgeon in the anesthesia bucket and monitor the fish for loss of muscle function (torpor). Time to torpor ranges from 45 to 90 seconds.
2. Place the sturgeon on the surgery table and start gravity-feed gill irrigation by placing one end of the 10-mm tube in the sturgeon's mouth. Record total length (TL), fork length (FL), and weight measurements. Measurements can also be made after the completion of surgery. Plan the incision location which should be between the 3-4 ventral scutes off the midline.
3. Make the incision and insert the PIT tag and then the acoustic tag.
4. Use two sutures to close the incision.
5. Make sure all data is recorded on the Juvenile Sturgeon Tagging Form
6. Record surgery end time and place the sturgeon in the holding bucket or tank for recovery. Recovery usually takes less than five minutes, however; the fish should be held in the holding tank until it shows complete recovery (e.g., strong swimming response when held by the caudal peduncle).

7. **Before release, ensure all required data has been recorded on the Juvenile Sturgeon Tagging Form**. The identification sticker that comes with the tag should be attached to the data form as additional insurance that the correct tag identification was recorded on the Juvenile Sturgeon Tagging Form

8. Record the condition of the sturgeon prior to release. The fish should be completely recovered **(see step 6)**

RELEASE:

1. Release the sturgeon either upstream or downstream of the fishing area, considering the direction of current to prevent recapture. Record the release time on the data sheet.