Tagging and Monitoring of Juvenile Sturgeon in the Lower Sacramento River and Sacramento-San Joaquin Delta: 2019 Report of Findings

Purpose

The purpose of this study is to document juvenile sDPS green sturgeon (*Acipenser medirostris*) sturgeon and juvenile white sturgeon (*Acipenser transmontanus*) movements 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 will serve to inform management, restoration, and conservation efforts for both sturgeon species. Catch per unit effort (CPUE) also serves to provide a general idea of the previous year's cohorts recruitment to the juvenile life stage for both 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. Until this study, there has been virtually no research conducted regarding the size, age, or potential environmental cues contributing to juvenile sturgeon 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). Findings from the 2015 through 2018 sampling seasons shown that ocean entry is not necessarily linear, in that individuals may move back into the delta after having already reached the bay (CDFW 2024a-d), 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 these studies 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 and migrate up or down the coast in the nearshore 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. Gill nets have been shown to be effective for capturing juvenile sturgeon during the first four years of this study. Gill nets were also utilized for the capture of juvenile green sturgeon in the Sacramento-San Joaquin delta (Radtke 1966). Limited past telemetric studies of juvenile green sturgeon include the first four years of this study and by capturing larvae or early-stage juveniles near the spawning grounds, rearing them in captivity for up to ten months until juveniles were sufficiently large enough to receive an acoustic tag, and releasing them in the SFBDE at Santa Clara Shoal on the San Joaquin River (Thomas et al. 2015). The success of developing a protocol to capture and monitor juvenile sturgeon is important for the implementation of a long-term monitoring program. Such a program is critical for determining population level trends and potential stressors affecting the decline of these species and for implementation of species specific management strategies.

2019 is the fourth 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. The 2016 and 2017 sampling seasons were somewhat more successful, as CDFW staff captured and tagged seven juvenile green sturgeon and 11 juvenile white sturgeon in 2016 and seven juvenile green sturgeon in 2017. The 2018 sampling season was the most successful to date for

capture and tagging of juvenile green sturgeon, as CDFW staff tagged 35 juvenile green sturgeon in addition to five juvenile white sturgeon The CPUE for juvenile green sturgeon was over ten-fold higher than in any of the previous three years of sampling. 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, including outmigration to the Pacific Ocean, and in some instances, a return to the SFBDE after several months. Juvenile white sturgeon tended to range more widely throughout the SFBDE than juvenile green sturgeon, although none were detected at the Golden Gate receiver array.

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 2019 sampling effort involved deployment of one 300-ft long by 8-ft height by 2-inch mesh gill 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**).

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

CDFW staff conducted 38 days of sampling events in 2019 between 3 January and 19 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. All sampling efforts were conducted in the main channel of the at one of two sites on the Sacramento River: north of Sherman Lake (rkm 82) or at Marsh Island (rkm 80) **(Figure 1).** Both sites have an average depth of 9 m. Substrate in this area is dominated by fine sediment interspersed with peat hummocks. These sites also typically have 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 with associated strong currents causes the gill net to drift which can result in it snagging on large woody or anthropogenic debris.

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 2019 was either a V9 or V13, which have typical battery lives of 274 days and 911 days, respectively at ping rate intervals of 90-120 seconds. Juvenile sturgeon were also tagged with passive integrated transponder (PIT) tags. 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.*, GS19-01) and released near the point of capture. Brood year assignments for juvenile green sturgeon were assigned 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 the U.S. Fish and Wildlife juvenile green sturgeon trawl capture and tagging project to when young-of-year individuals are first encountered at the sampling sites in the SFBDE, and from documented growth rates of juvenile northern DPS green sturgeon rearing in the Klamath River (USFWS 1995).

The Sacramento River-SFBDE 69 kHz autonomous receiver array was decommissioned by the UC Davis Biotelemetry Lab (UCDBL) at the end of 2017. CDFW staff deployed receiver arrays at the Rio Vista Bridge on 7 June 2018 and at the Antioch and Benicia bridges on 12 October of 2018 to provide minimal broad scale detection data for tagged juvenile sturgeon. However, 69 kHz autonomous receivers were not redeployed at sampling site, rather a portable VR100-200 receiver (Innovasea®) was deployed only during sampling events, which were typically six hours a day twice a week. Therefore, there are considerable temporal gaps in detection data at the sampling site. However, National Marine Fisheries Service staff did maintain 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. Site residency at the Rio Vista, Antioch, Benicia, and Golden Gate receiver arrays is defined as the temporal period between the first and last detections at each receiver array without detections at any other receiver array rather than detections over a continuous period. For example, a tag ID code detected at the Rio Vista Bridge receiver array on 4, 6, 10, and 31 October was considered to have a residency period of 27 days (the temporal period between 4 to 31 October) if the tag ID code was not detected at any other receiver array between 4 and 31 October. 69 kHz receivers deployed at Point Reyes, Point San Pedro, Ano Nuevo, and at the Cement Ship in north Monterey Bay for white shark research provided opportunistic detections for juvenile green sturgeon entering the nearshore marine environment. Receiver array locations are shown in **Figures 2 and 3.**

Results

Water temperatures and dissolved oxygen concentrations remained within the sampling thresholds through the entire sampling season **(Figure 4).** CDFW staff captured and tagged 14 juvenile green sturgeon during the 2019 sampling season for a catch per unit effort (CPUE) of 0.053 per hour of net set time, and three juvenile white sturgeon for a CPUE of 0.011 per hour of net set time. All juvenile sturgeon were captured and tagged in the main channel of the Sacramento River at depth of approximately nine meters at rkm 82 (n=8) or rkm 80 (n=6).

The juvenile green sturgeon were from two brood year cohorts: eight from brood year 2018 and six from brood year 2017. The three juvenile white sturgeon were from brood year 2017 (**Table 1**). **Tables 2 through 18** present the detection summaries for juvenile sturgeon tagged during the 2019 sampling season, and **Figure 3** shows receiver locations and river kilometer of the receiver locations as measured from Golden Gate Bridge.

Other native fish species captured during sampling included Central Valley steelhead (hatchery origin; *Oncorhynchus mykiss*) n=1, Sacramento splittail (*Pogonichthys macrolepidotus*)**;** n=2, Sacramento pikeminnow (*Ptychocheilus grandis*); n=5, starry flounder (*Platichthys stellatus*); n=4 and tule perch (*Hysterocarpus traskii*); n=2. Non-native fish species captured during sampling included striped bass (*Morone saxatilis*); n=187 and American shad (*Alosa sapidissima*); n=3.

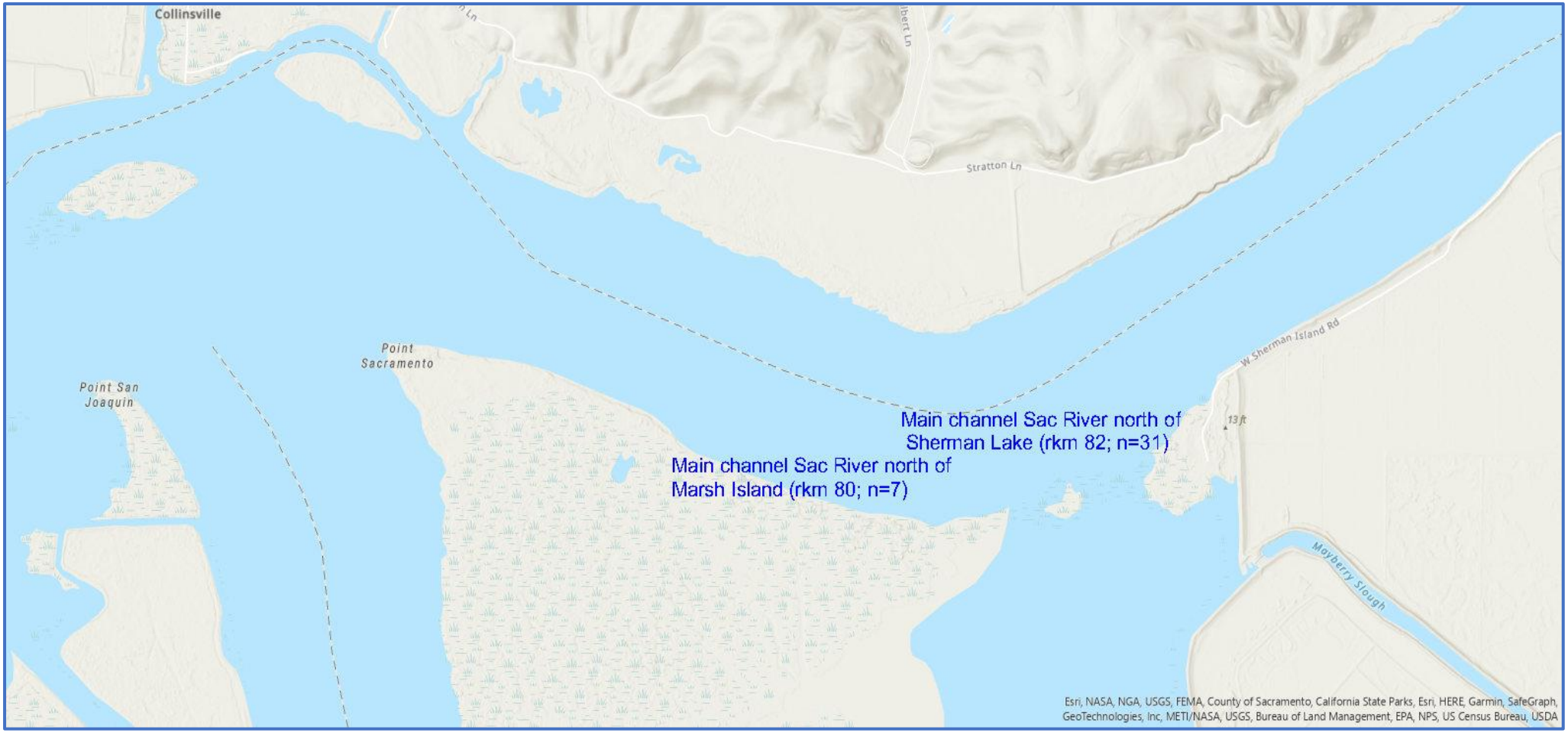

Figure 1. Juvenile sturgeon sampling locations and number of sampling events per location, 2019.

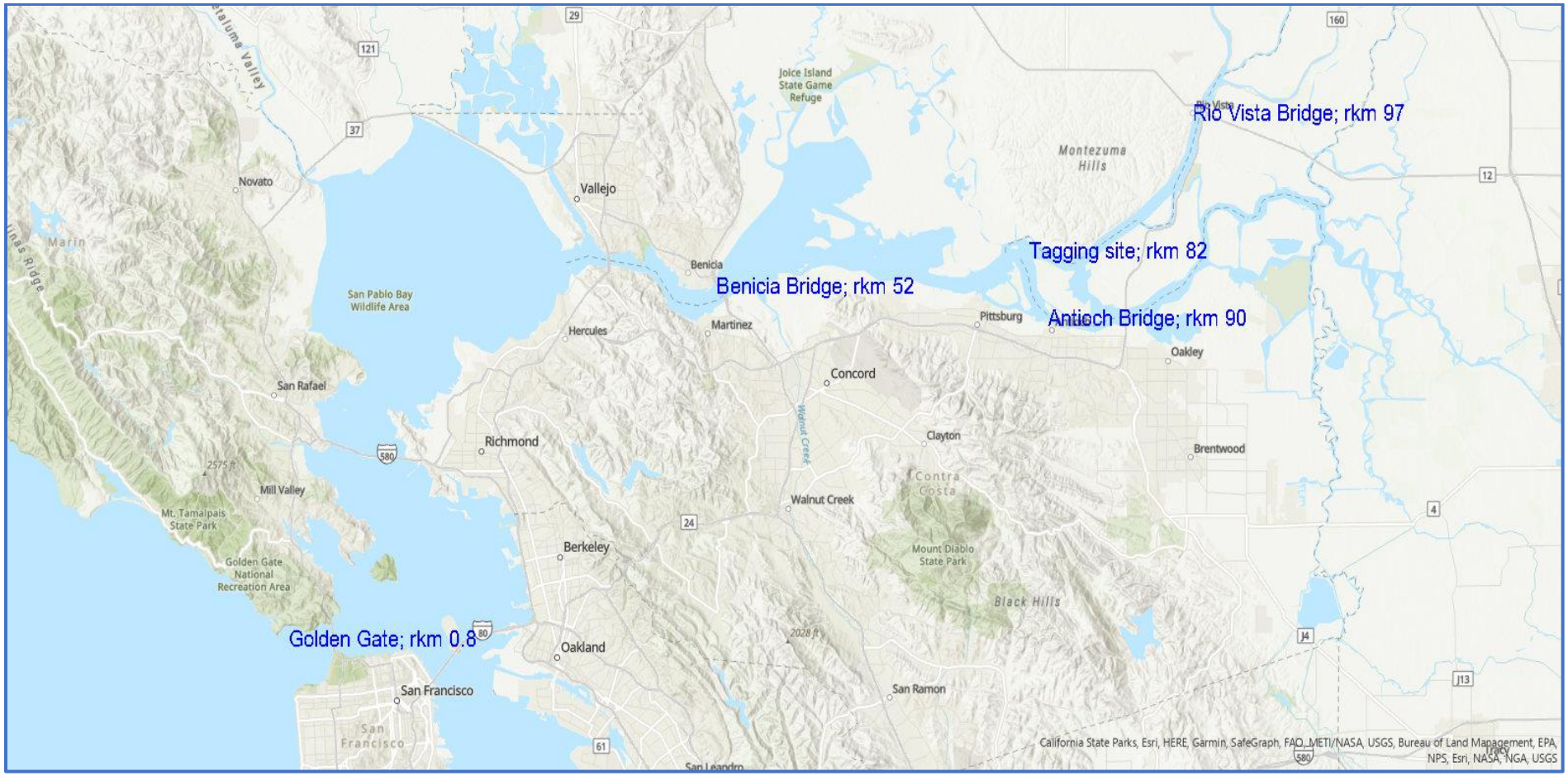

Figure 2. 2019 receiver array location map. Note that CDFW staff deployed a portable VR100-200 receiver at the sampling site only while sampling, typically six hours a day twice weekly.

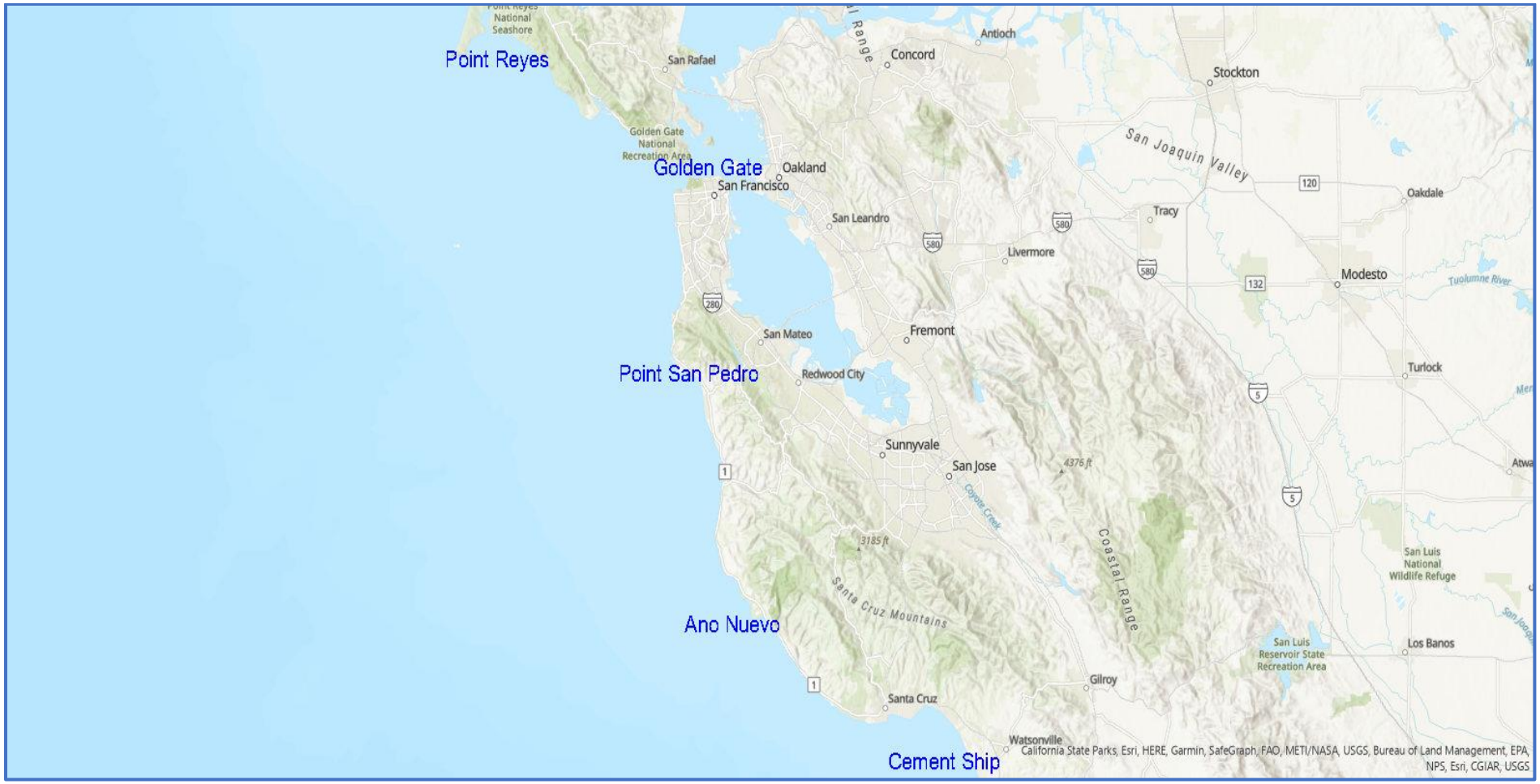

Figure 3. Pacific Ocean 69 kHz receiver array location map. Note that receivers were deployed for white shark research.

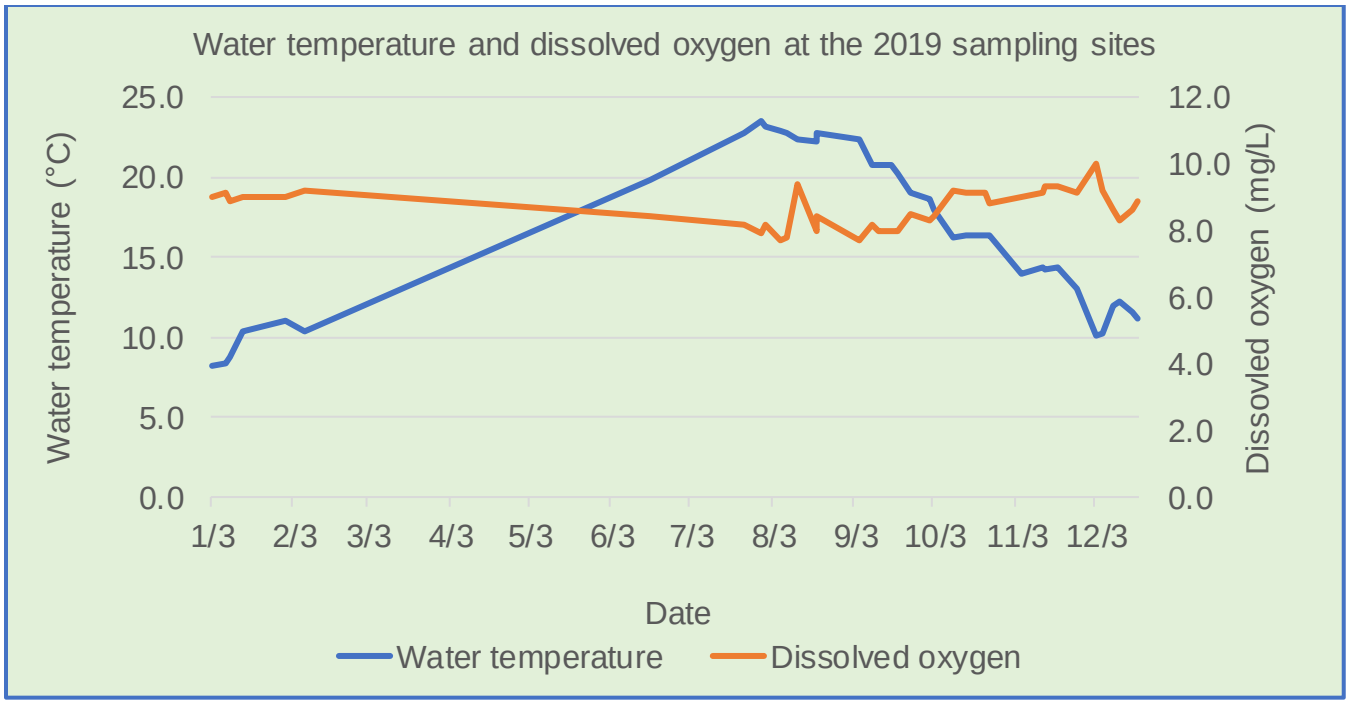

Figure 4. Water temperature and dissolved oxygen at the 2019 sampling sites.

Table 1. Study ID, date tagged, fork length, brood year, and tag codes for juvenile sturgeon tagged during 2019.

Study ID[1]	Date tagged	Fork length (cm)	Brood year	Tag code
GS19-01	2/7/2019	55	2017	A69-1602-12236
GS19-02	2/7/2019	40	2018	A69-1602-11442
GS19-03	2/7/2019	40.5	2018	A69-1602-11446
GS19-04	2/7/2019	61	2017	A69-1602-12239
GS19-05	2/7/2019	53	2017	A69-1602-12238
GS19-06	2/7/2019	53	2017	A69-1602-12234
GS19-07	10/1/2019	58	2018	A69-9001-13356
GS19-08	10/3/2019	57	2018	A69-1602-12237
GS19-09	10/3/2019	53.5	2018	A69-1602-12228
GS19-10	10/3/2019	55	2018	A69-1602-12235
GS19-11	11/5/2019	53	2018	A69-1602-12219
GS19-12	12/10/2019	67.5	2017	A69-1602-12221
GS19-13	12/12/2019	69.5	2017	A69-1602-12220
GS19-14	12/12/2019	48	2018	A69-1602-12230
WS19-01	7/23/2019	56	2017	A69-1602-12225
WS19-02	8/6/2019	53	2017	A69-1602-12229
WS19-03	9/10/2019	55	2017	A69-1602-12224

Green sturgeon detection summaries.

Table 2. GS19-01 Detection Summary. Brood year 2017; Tag code A69-1602-12236; tagged 7 February 2019.

Tagging site (rkm 92)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
2/7/19	No detections	2/14/19	2/16/19	No detections

Tagging site residency: 1 day. Departure from the tagging site to initial detection at the Antioch Bridge: 7 days. Antioch Bridge residency: 1 day. Departure from the Antioch Bridge to initial detection at the Benicia Bridge: 2 days. Benicia Bridge residency: 1 day.

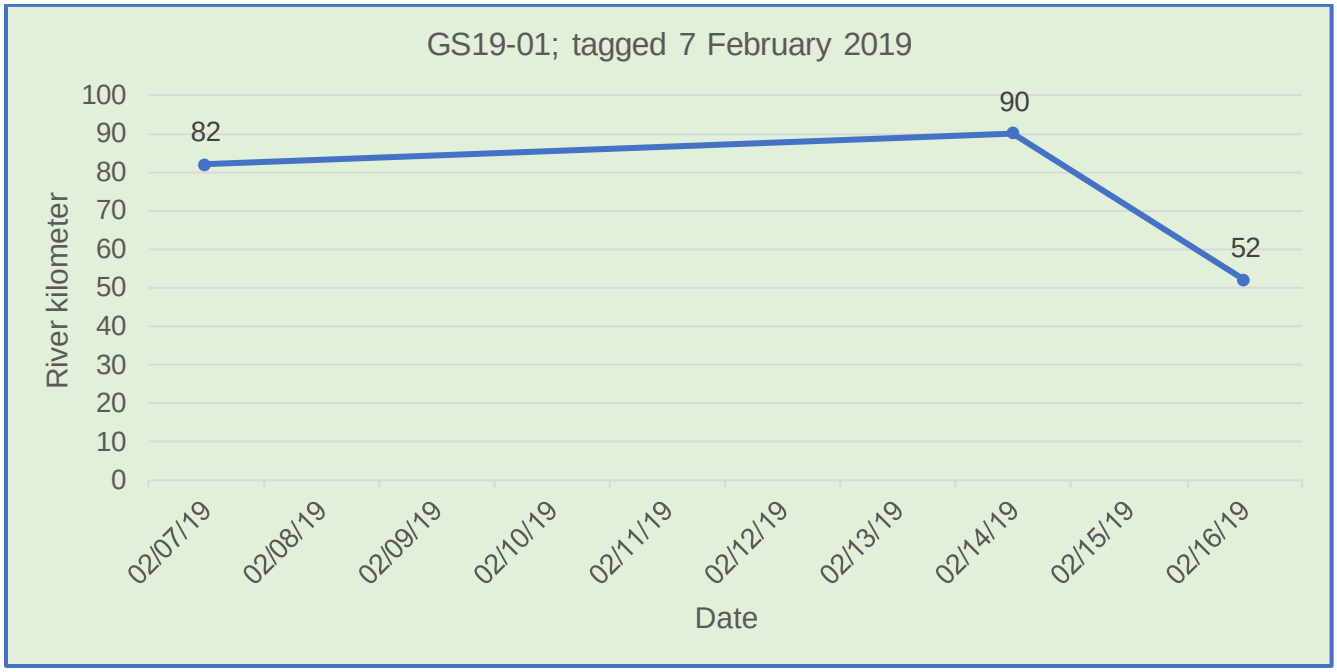

Figure 3. Detection plot for GS19-01; tagged 7 February 2019. Brood year 2017, 55 cm fork length.

Table 3. GS19-02 Detection Summary. Brood year 2018; Tag code A69-1602-11442; tagged 7 February 2019.

Tagging site (rkm 92)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
2/7/19	No detections	No detections	12/24/19 to 1/1/20	1/9 to 1/24/20

Tagging site residency: 1 day. Departure from the tagging site to initial detection at the Benicia Bridge: 320 days. Benicia Bridge residency: 8 days. Departure from the Benicia Bridge to initial detection at the Golden Gate: 8 days. Golden Gate residency: 15 days.

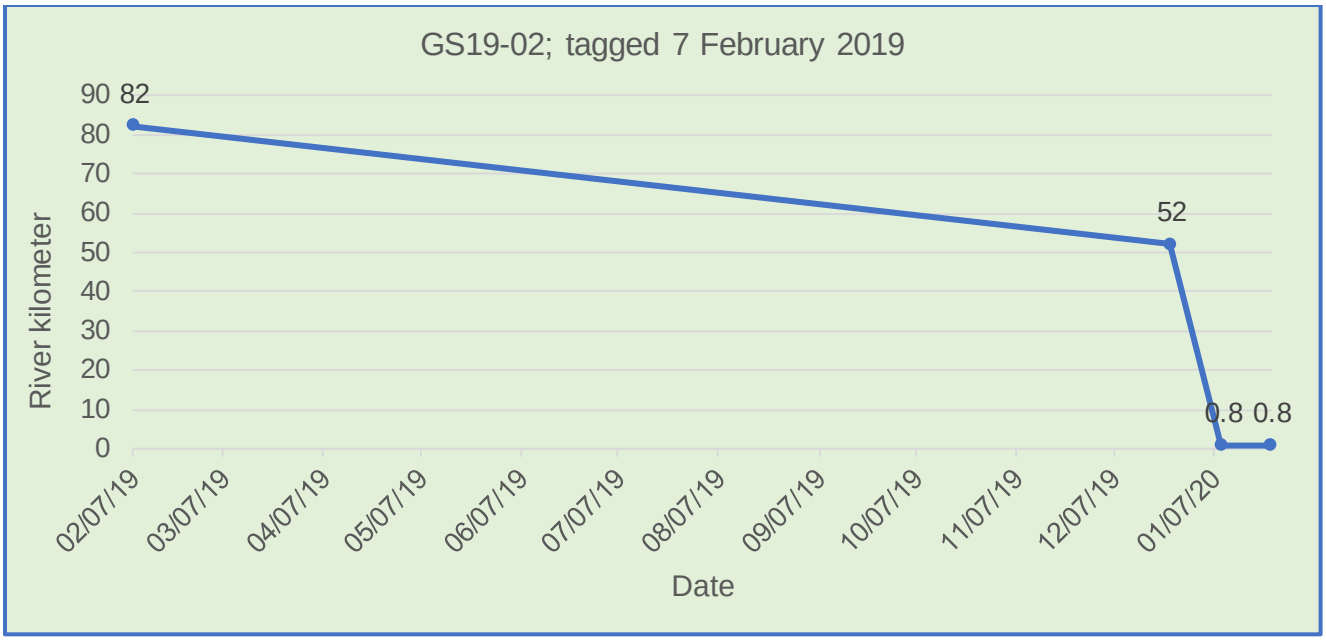

Figure 4. Detection plot for GS19-02; tagged 7 February 2019. Brood year 2018, 40 cm fork length.

Table 4. GS19-03 Detection Summary. Brood year 2018; Tag code A69-1602-11446; tagged 7 February 2019.

Tagging site (rkm 92)	**Rio Vista Bridge (rkm 97)**	**Antioch Bridge (rkm 90)**	**Benicia Bridge (rkm 52)**	**Golden Gate (rkm 0.8)**
2/7/19; 12/10/19	No detections	7/20/19	7/6 to 7/8/19; 7/21/19 12/25 to 12/28/20	No detections

Initial tagging site residency: 1 day. Departure from the tagging site to initial detection at the Benicia Bridge: 149 days. Initial Benicia Bridge residency: 3 days. Departure from the Benicia Benica Bridge to initial detection at the Antioch Bridge: 12 days. Antioch Bridge residency: 1 day. Departure from the Antioch Bridge to next detection at the Benicia Bridge: 1 day. Second Benicia Bridge residency: 1 day. Departure from the Benicia Bridge to next detection at the tagging site: 142 days. Second tagging site residency: 1 day. Departure from the tagging site to next detection at the Benicia Bridge: 15 days. Third Benicia Bridge residency: 3 days.

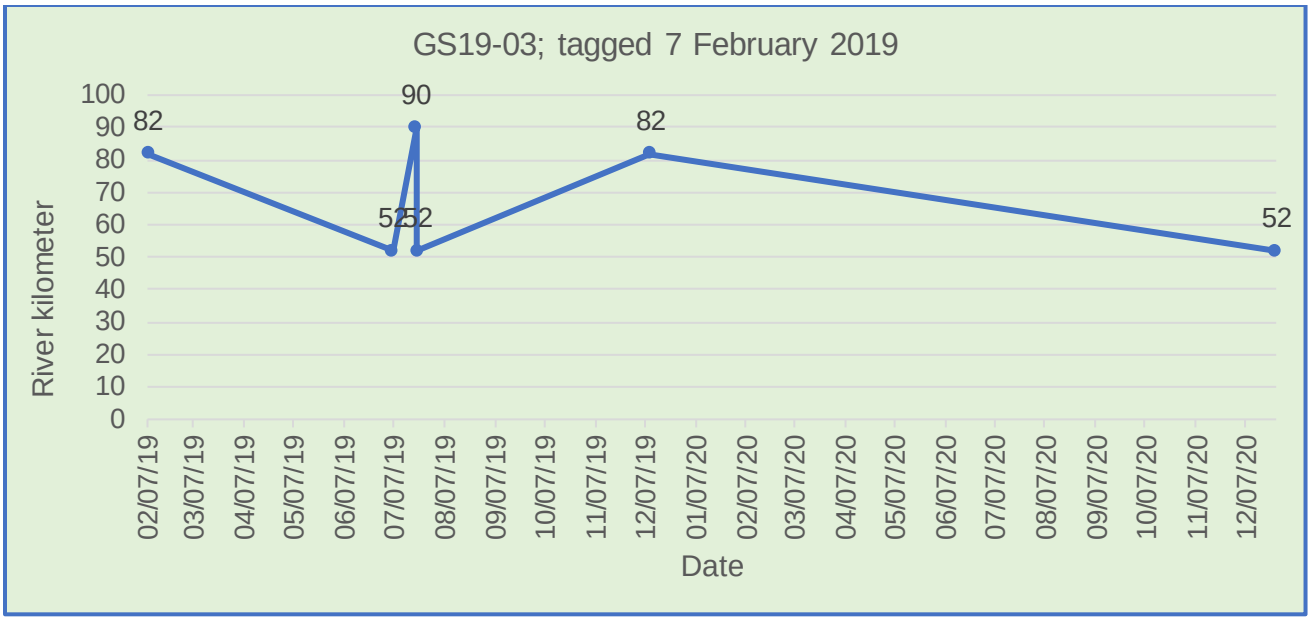

Figure 5. Detection plot for GS19-03; tagged 7 February 2019. Brood year 2018, 40.5 cm fork length.

Table 5. GS19-04 Detection Summary. Brood year 2017; Tag code A69-1602-12239; tagged 7 February 2019.

Tagging site (rkm 86)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
2/7/19	No detections	No detections	2/17/19	9/3/19 to 10/2/20

Tagging site residency: 1 day. Departure from the tagging site to initial detection at the Benicia Bridge: 10 days. Benicia Bridge residency: 1 day. Departure from the Benicia Bridge to initial detection at the Golden Gate: 198 days. Golden Gate residency: 395 days.

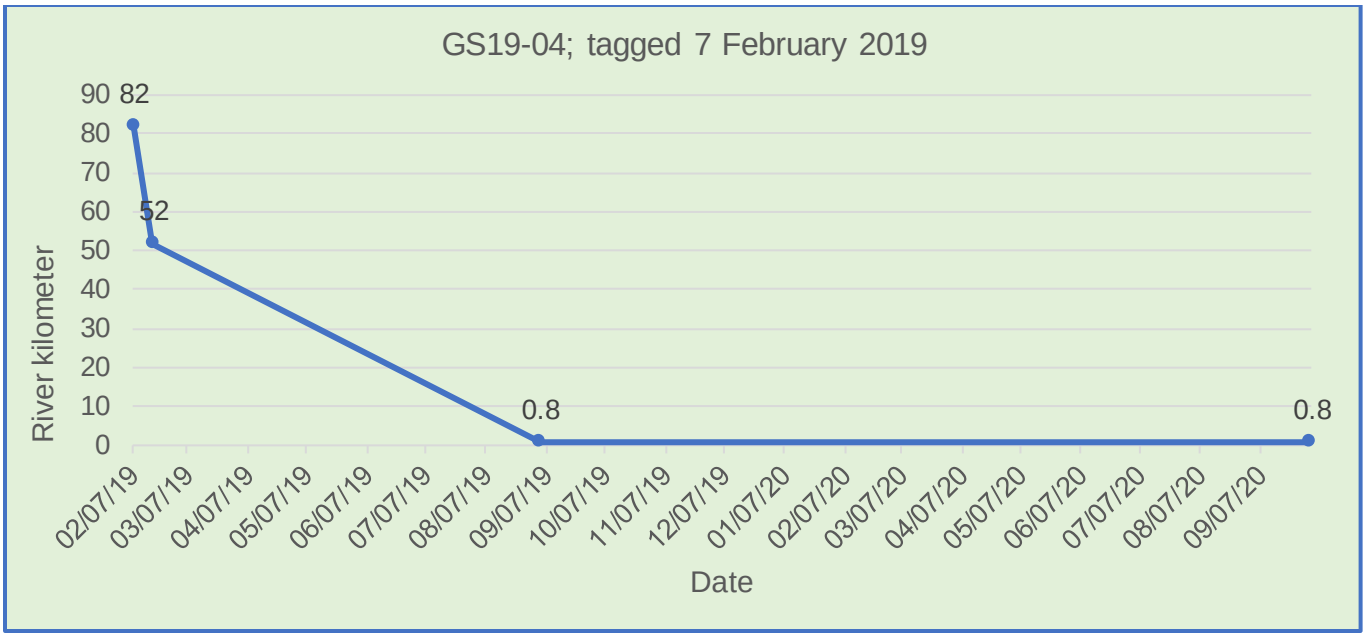

Figure 6. Detection plot for GS19-04; tagged 7 February 2019. Brood year 2017, 61 cm fork length.

Table 6. GS19-05 Detection Summary. Brood year 2017; Tag code A69-1602-12238; tagged 7 February 2019.

Tagging site (rkm 92)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
2/7/19	No detections	No detections	3/30 to 4/17/19	8/12/19 to 8/28/20

Tagging site residency: 1 day. Tagging site departure to initial detection at the Benicia Bridge: 51 days: Benicia Bridge residency: 19 days. Benicia Bridge to initial detection at the Golden Gate: 117 days: Golden Gate residency: 382 days.

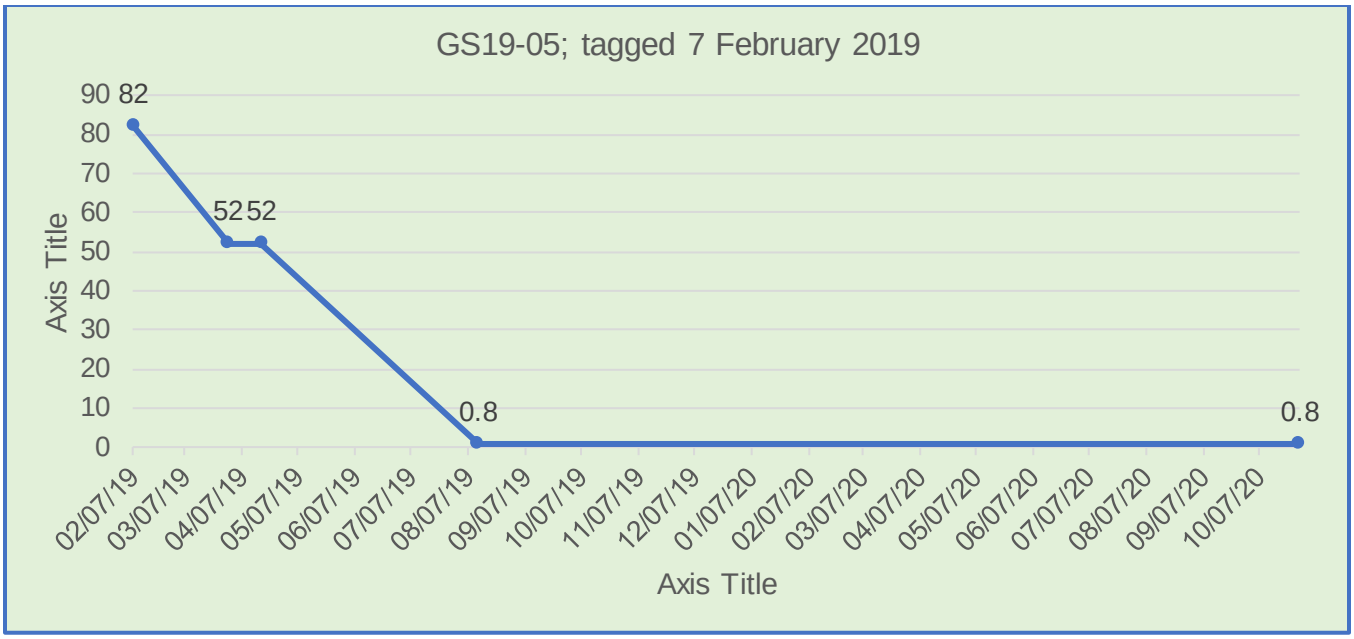

Figure 7. Detection plot for GS19-05; tagged 7 February 2019. Brood year 2017, 53 cm fork length.

Table 7. GS19-06 Detection Summary. Brood year 2017; Tag code A69-1602-12234; tagged 7 February 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
2/7/19	No detections	No detections	2/19/19	8/28/19 to 10/6/20

Tagging site residency: 1 day. Tagging site departure to initial detection at the Benicia Bridge: 12 days. Benicia Bridge residency: 1 day. Benicia Bridge to initial detection at the Golden Gate: 190 days: Golden Gate residency: 405 days.

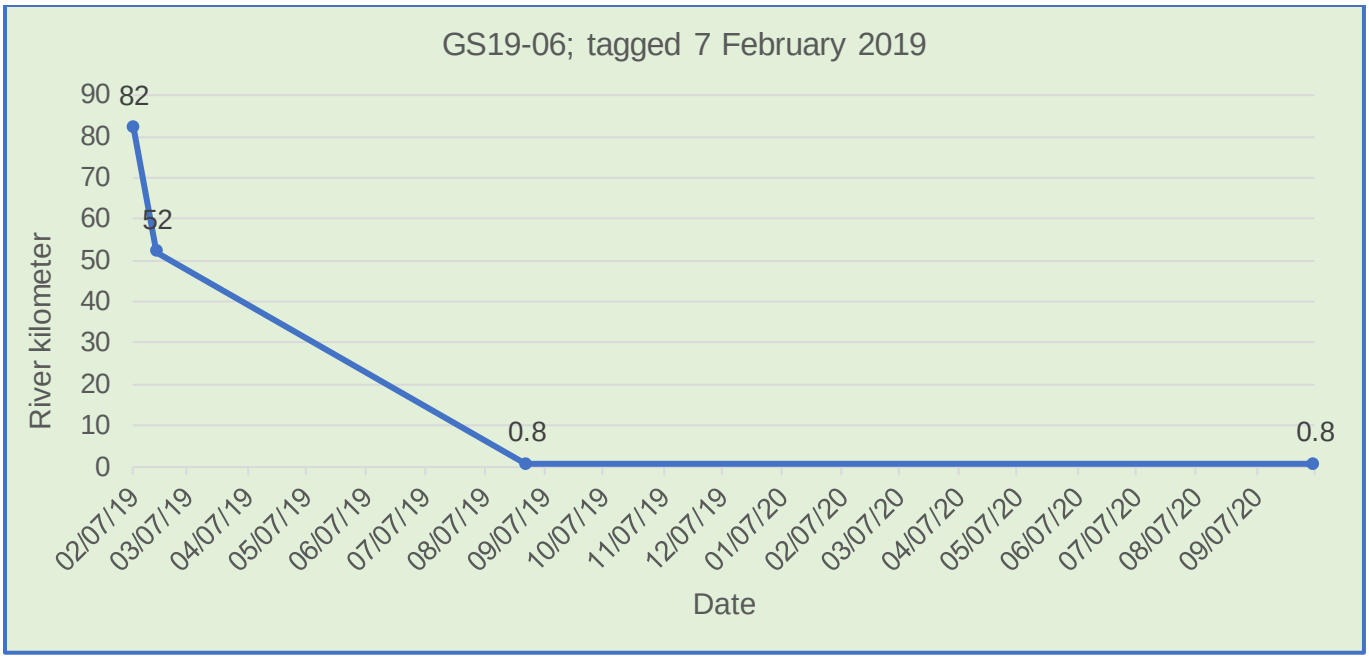

Figure 8. Detection plot for GS19-06; tagged 7 February 2019. Brood year 2017, 53 cm fork length.

Table 8. GS19-07 Detection Summary. Brood year 2018; Tag code A69-1602-13356; tagged 1 October 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
10/1 to 10/15/19	No detections	No detections	No detections	No detections

Tagging site residency: 14 days.

Table 9. GS19-08 Detection Summary. Brood year 2018; Tag code A69-1602-12237; tagged 3 October 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
10/3 to 11/13/19	6/4/20	No detections	6/6/20	1/30 to 5/15/21

Tagging site residency: 29 days. Tagging site departure to initial detection at the Rio Vista Bridge: 204 days. Rio Vista Bridge residency: 1 day. Departure from Rio Vista Bridge to initial detection at the Benicia Bridge: 2 days. Benicia Bridge residency: 1 day. Benicia Bridge to initial detection at the Golden Gate: 224 days: Golden Gate residency: 105 days.

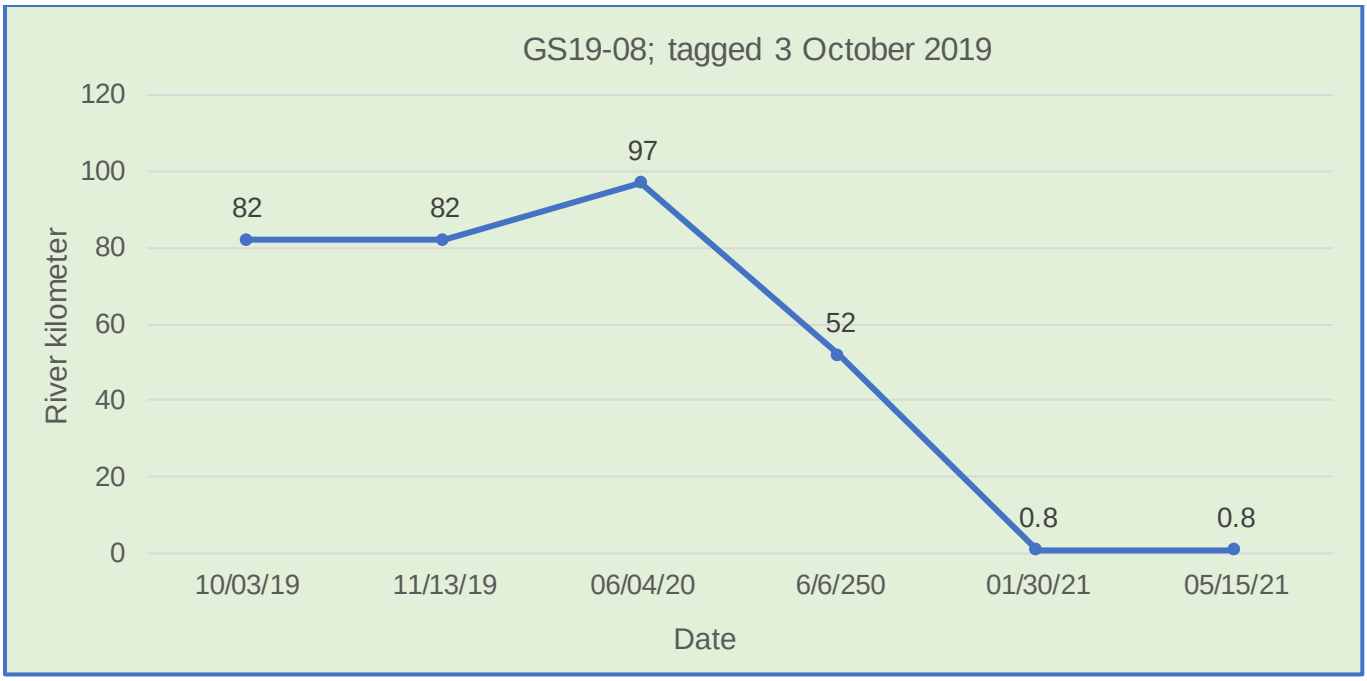

Figure 9. Detection plot for GS19-08; tagged 3 October 2019. Brood year 2018, 57 cm fork length.

Table 10. GS19-09 Detection Summary. Brood year 2018; Tag code A69-1602-12228; tagged 3 October 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
10/3/19	No detections	No detections	11/25/19 to 2/9/20	12/21 to 12/26/20

Tagging site residency: 1 day. Tagging site departure to initial detection at the Benicia Bridge: 53 days. Benicia Bridge residency: 76 days. Benicia Bridge to initial detection at the Golden Gate: 316 days: Golden Gate residency: 5 days.

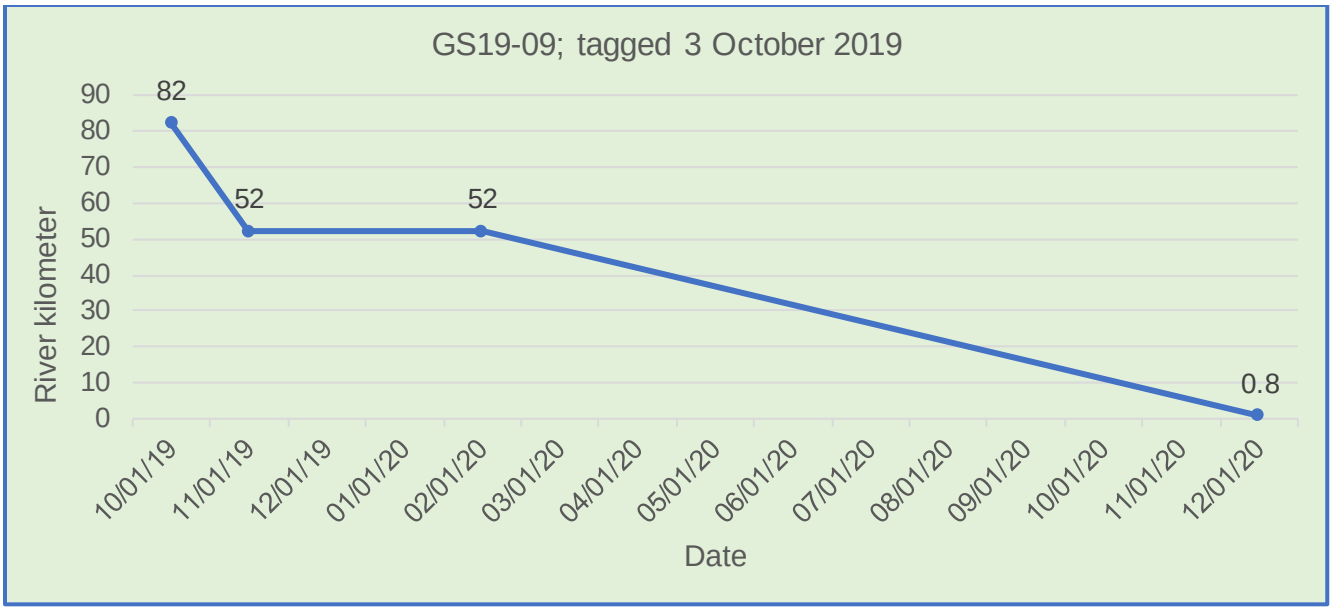

Figure 10. Detection plot for GS19-09; tagged 3 October 2019. Brood year 2018, 53.5 cm fork length.

Table 11. GS19-10 Detection Summary. Brood year 2018; Tag code A69-1602-12235; tagged 3 October 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
10/3 to 11/26/19	No detections	No detections	12/16/19 to 1/18/20	No detections

Tagging site residency: 54 days. Tagging site departure to initial detection at the Benicia Bridge: 20 days. Benicia Bridge residency: 33 days.

Table 12. GS19-11 Detection Summary. Brood year 2018; Tag code A69-1602-12219; tagged 5 November 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
11/5 to 12/3/19	No detections	No detections	No detections	No detections

Tagging site residency: 28 days.

Table 13. GS19-12 Detection Summary. Brood year 2017; Tag code A69-1602-12221; tagged 10 December 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
12/10/19	No detections	No detections	12/15/19 to 6/12/20	11/15/20 to 5/13/21

Tagging site residency: 1 day. Tagging site departure to initial detection at the Benicia Bridge: 5 days. Benicia Bridge residency: 180 days. Benicia Bridge to initial detection at the Golden Gate: 156 days: Golden Gate residency: 197 days.

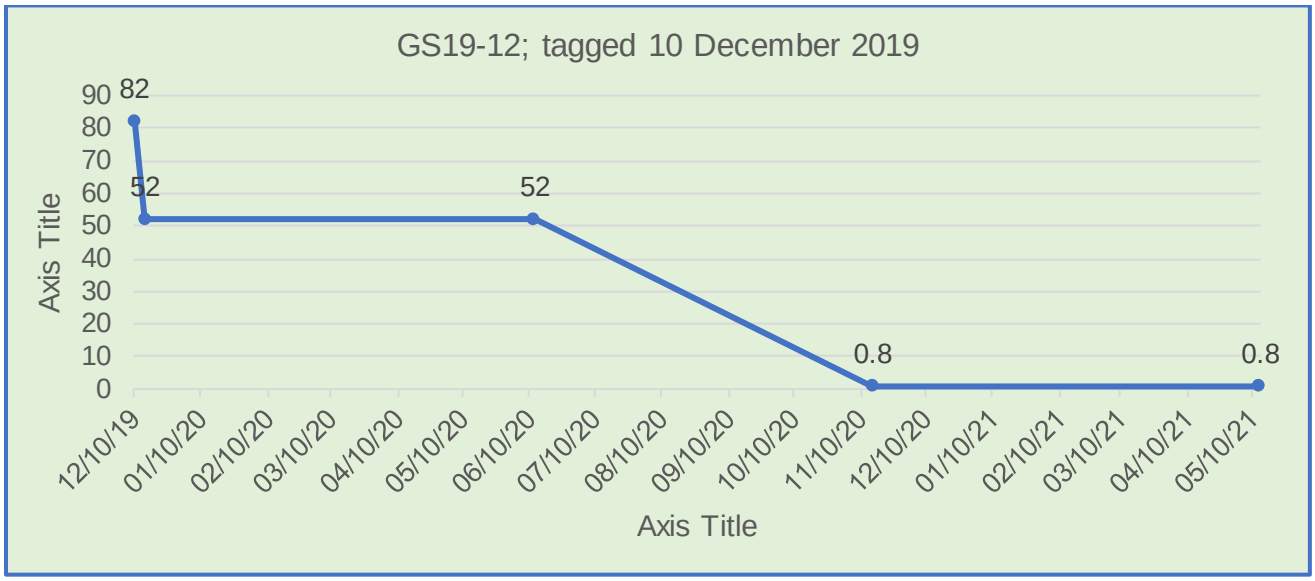

Figure 11. Detection plot for GS19-12; tagged 10 December 2019. Brood year 2017, 67.5 cm fork length.

Table 14. GS19-13 Detection Summary. Brood year 2017; Tag code A69-1602-12222; tagged 12 December 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
12/12/19; 1/23 to 5/12/20	12/30/19	5/14 to 10/29/20; 4/5 to 9/15/21	12/17/20 to 1/19/21	No detections

Initial tagging site residency: 1 day. Tagging site departure to initial detection at the Rio Vista Bridge: 18 days. Rio Vista Bridge residency: 1 day. Departure from Rio Vista Bridge to next detection at tagging site: 24 days. Second tagging site residency: 110 days. Departure from tagging site to initial detection at the Antioch Bridge: 2 days. Initial Antioch Bridge residency: 168 days. Departure from the Antioch Bridge to initial detection at the Benicia Bridge: 49 days. Benicia Bridge residency: 33 days.

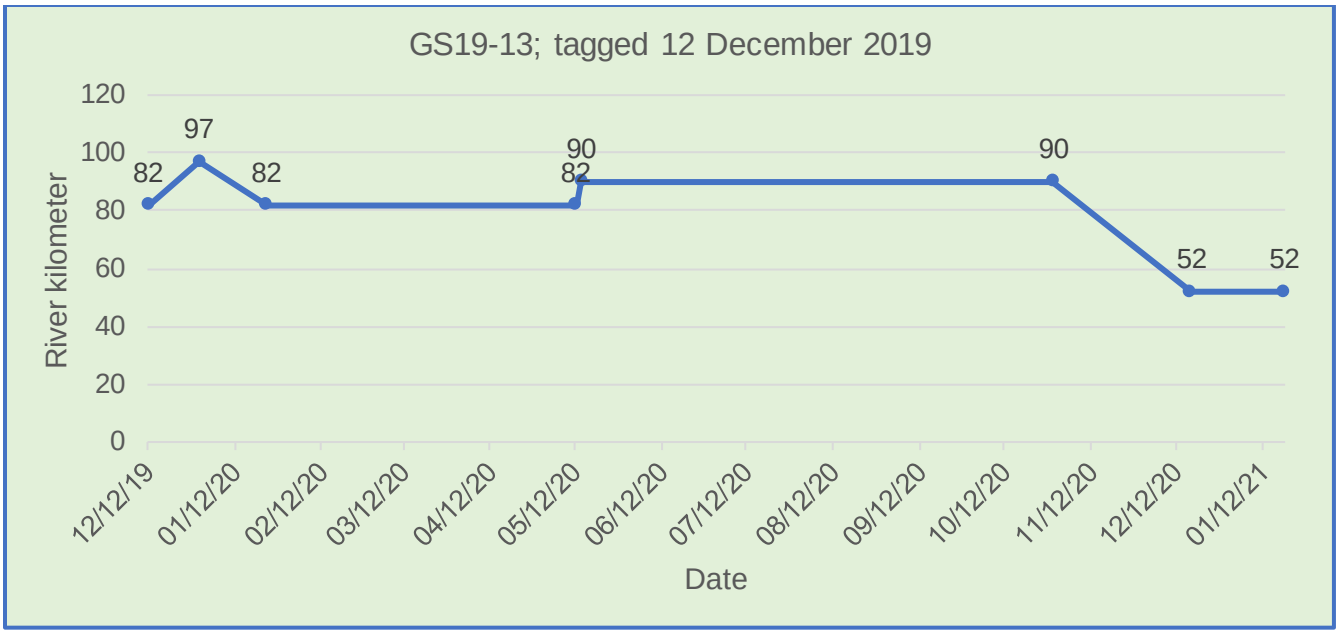

Figure 12. Detection plot for GS19-13; tagged 12 December 2019. Brood year 2017, 69.5 cm fork length.

Table 15. GS19-14 Detection Summary. Brood year 2018; Tag code A69-1602-12230; tagged 12 December 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
12/12 to 12/19/19	No detections	No detections	No detections	No detections

Tagging site residency: 7 days.

Green sturgeon detections and movement trends. Table 19 presents a summary of residency periods and travel times between receiver arrays for juvenile green sturgeon tagged in 2019. It is important to note that 69 kHz autonomous receivers were not deployed at the sampling site in 2019, and therefore it is likely that there are considerable temporal gaps in detection data for the sampling site. However, CDFW staff deployed a portable VR100-200 receiver during sampling events, typically for periods of 5-6 hours two days a week. All 14 juvenile green sturgeon tagged with acoustic transmitters were detected for at least one day at the sampling sites. One of juvenile green sturgeon was not detected at any other receiver arrays, which is likely indicative of a defective acoustic tag, post-release mortality, or long residency periods in areas not covered by acoustic receivers. Initial residency at the sampling site ranged from one to 54 days, with a mean residency time of 10 days (**Table 19**). Two juvenile green sturgeon returned to the tagging site after their initial departure. Absence periods between departure and the next detection at the sampling site ranged from 42 to 306 days with a mean of 174 days.

Table 19. Tagging site, Rio Vista Bridge, Antioch Bridge, Benicia Bridge, and Golden Gate initial residency periods and travel times between receiver locations for juvenile green sturgeon tagged in 2019.

Residency (days)									
Tagging site (n=12)		Rio Vista (n=2)		Antioch (n=3)		Benicia (n=11)		Golden Gate (n=7)	
range	Mean	range	mean	range	mean	range	mean	range	mean
1 to 54	10	1	1	1 to 168	57	1 to 180	32	5 to 405	215

Travel time from tagging site (days)							
Rio Vista (n=2)		Antioch (n=3)		Benicia (n=11)		Golden Gate (n=7)	
range	mean	range	mean	range	mean	range	mean
18 to 204	111	2 to 163	57	5 to 320	96	186 to 485	315

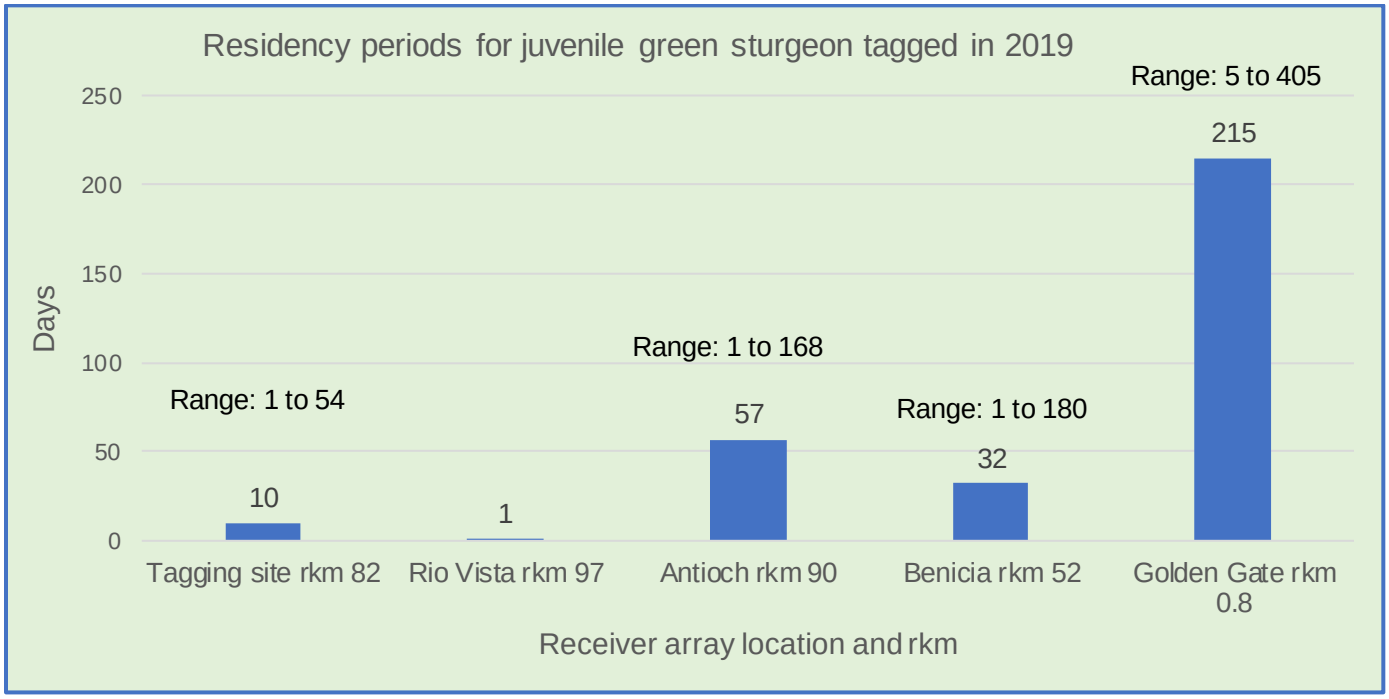

Figure 13. Residency periods at the tagging site; and Rio Vista Bridge, Antioch Bridge, Benicia Bridge, and Golden Gate receiver arrays for juvenile green sturgeon tagged in 2019.

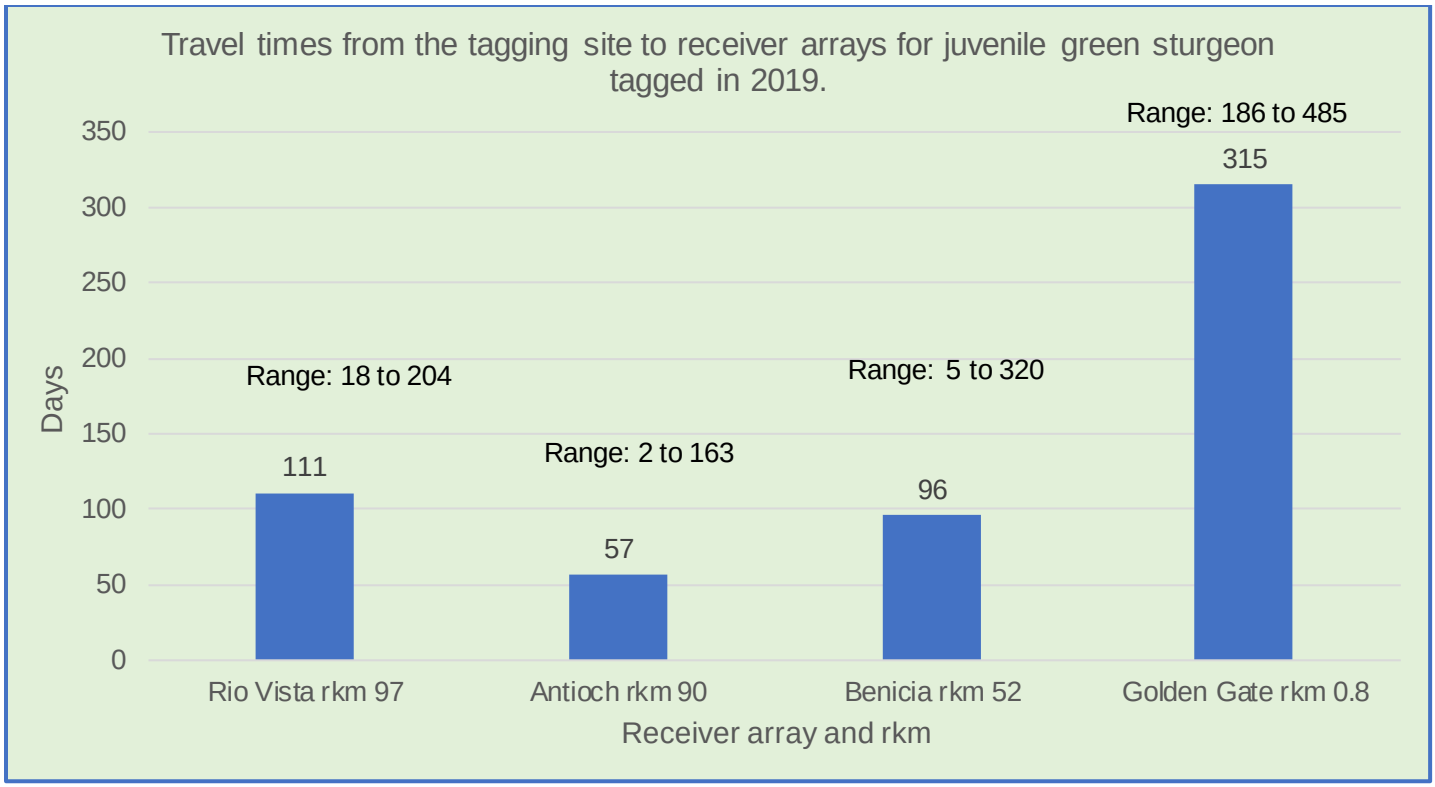

Figure 14. Travel time in days from the tagging site to the Rio Vista Bridge, Antioch Bridge, Benicia Bridge, and Golden Gate receiver arrays for juvenile green sturgeon tagged in 2019.

Two of 14 (14.3 percent) juvenile green sturgeon tagged in 2019 were detected at the Rio Vista Bridge receiver array, a distance of 15 km upstream from the sampling site. Travel time from tagging site departure to initial detection at the Rio Vista Bridge ranged from 18 to 204 days with a mean of 11 days. The residency period at the Rio Vista Bridge receiver array for both juvenile green sturgeon was one day. No juvenile green sturgeon tagged in 2019 were detected at the Antioch Bridge receiver array on the San Joaquin River.

Eleven of 14 (78.5 percent) of juvenile green sturgeon tagged in 2019 were detected at the Benicia Bridge receiver array. Days from sampling site departure to the initial detection at the Benicia Bridge receiver array ranged from five to 320 days, with a mean of 96 days. Initial residency at the Benica Bridge receiver array ranged from one to 180 days, with a mean of 32 days. Two juvenile green sturgeon tagged in 2019 had multiple residency periods at the Benicia Bridge receiver array, meaning they were detected at one or more receiver arrays after their initial departure from the Benicia Bridge receiver array. Subsequent residency periods ranged from three to 122 days, with a mean of 63 days.

Seven of 14 (50 percent) of juvenile green sturgeon tagged in 2019 were detected at the Golden Gate receiver array. Days from Benicia Bridge departure to the initial detection at the Golden Gate receiver array ranged from 186 to 485 days, with a mean of 315 days. Residency at the Golden Gate receiver array ranged from five to 405 days, with a mean of 215 days. Three juvenile white sturgeon tagged in 2019 were detected in the Pacific Ocean at Point San Pedro by 69 kHz receiver arrays deployed for white shark research. GS19-04 was detected at Point San Pedro on 17-18 March 2020; the last detection at the Golden Gate prior to detections at Point San Pedro was 105 days earlier on 3 December 2019. GS19-04 was detected again at the Goden Gate on 11 April 2020. GS19-05 was detected at Point Reyes on 23 and 29 February 2020; the last detection at the Golden Gate prior to detections at Point Reyes was 5 days earlier on 18 February 2020. GS19-05 was detected again at the Golden Gate on 3 March 2020. GS19-06 was detected at Point Reyes on 8 and 30 March 2020 and at Point San Pedro on 4, 8 and 9 April 2020; the last detection at the Golden Gate prior to detections at Point Reyes and Point San Pedro was 126 days earlier on 3 November 2019. GS19-06 was detected again at the Golden Gate on 8 June 2020.

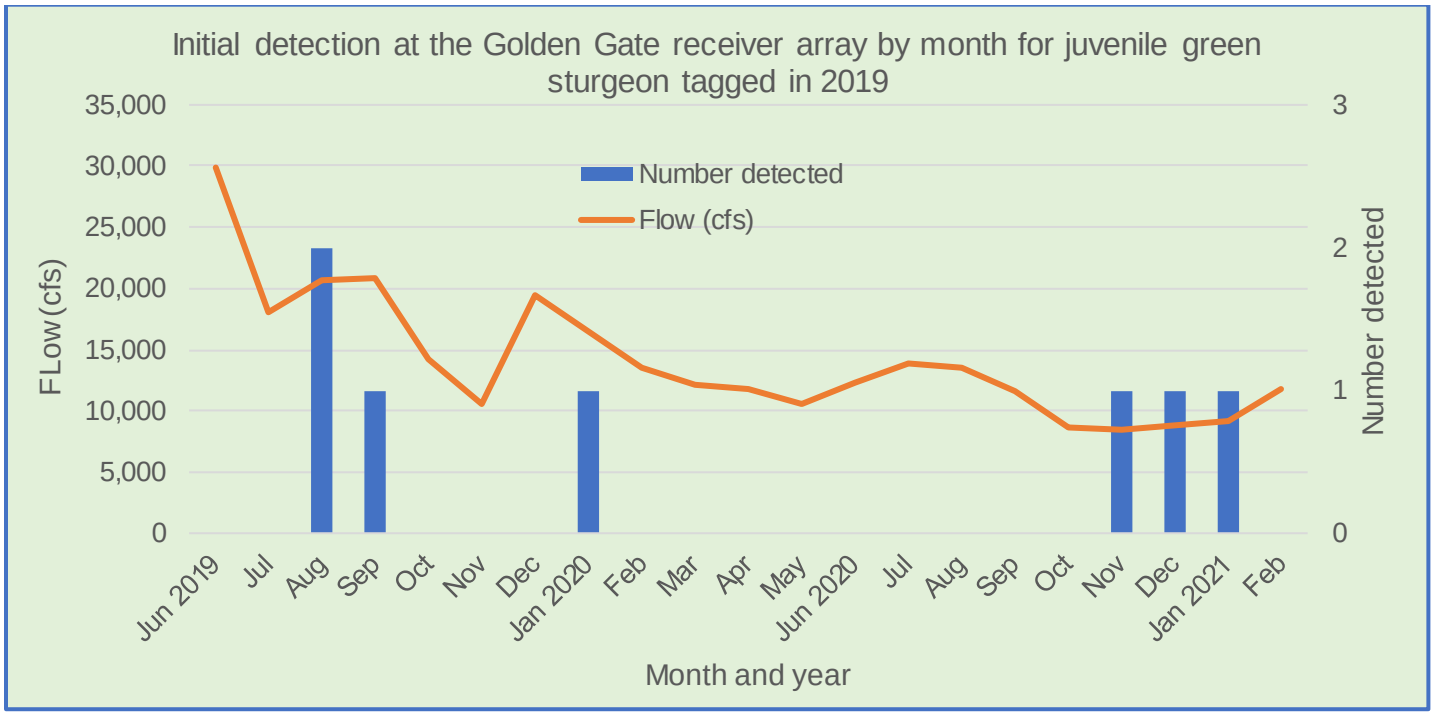

Figure 15. Initial detection at the Golden Gate receiver array by month and delta outflow (Sacramento River at Freeport) for juvenile green sturgeon tagged in 2019.

There may be a relationship between delta outflows as measured by Sacramento River flow at Freeport and initial detection followed by ocean entry for juvenile green sturgeon tagged in 2019. Three juvenile green sturgeon tagged in 2019 were initially detected at the Golden Gate receiver array in August and September 2019 following a 2,000 cfs increase in delta outflow (**Figure 15**). Initial detections for four other juvenile green sturgeon with detections at the Golden Gate receiver array occurred during periods of stable or slightly decreasing outflow. Therefore, there may be other environmental queues influencing outmigration from the SFBDE to the marine environment.

There were no differences in tagging site residency time, travel time from the tagging site to Benicia Bridge receiver array, Benicia Bridge receiver array residency time, travel time from the tagging site to the Golden Gate receiver array time based on brood year class. However, the Golden Gate residency period was significantly greater for 2017 brood year juvenile green sturgeon **(Table 20**).

Table 20. Juvenile green sturgeon brood year, number tagged; and means in days for tagging site residency, travel time from tagging site to the Benicia Bridge (BB), Benicia Bridge residency, travel time from Benicia Bridge to the Golden Gate (GG) receiver array, and Golden Gate receiver array residency with P-values from ANOVA.

Brood year	tagging site residency (days)	tagging site to BB (days)	BB residency (days)	BB site to GG (days)	GG residency (days)
2017	1	72	58	168	344
2018	19	150	24	270	55
P-value	0.064	0.34	0.42	0.068	*0.022*

White Sturgeon detection summaries.

Table 16. WS19-01 Detection Summary. Brood year 2018; Tag code A69-1602-12225; tagged 23 July 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
7/23/19	No detections	No detections	7/25/19 to 3/14/21	No detections

Tagging site residency: 1 day. Departure from tagging site to initial detection at the Benicia Bridge: 2 days. Benicia Bridge residency: 598 days.

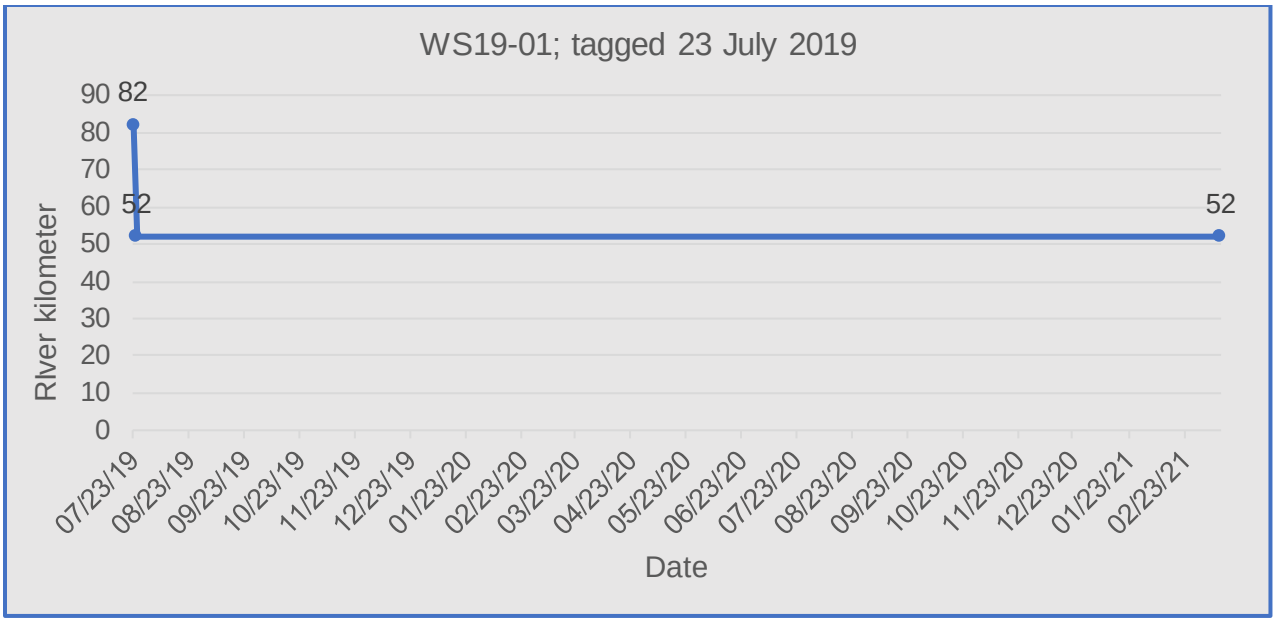

Figure 13. Detection plot for WS19-01; tagged 23 July 2019. Brood year 2017, 56 cm fork length.

Table 17. WS19-02 Detection Summary. Brood year 2017; Tag code A69-1602-12229; tagged 6 August 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
8/6/19; 4/14 to 7/2/20	8/13 to 8/26/19	No detections	8/11/19; 9/1/19 to 1/1/20	No detections

Initial tagging site residency: 1 day. Departure from tagging site to initial detection at the Benicia Bridge: 5 days. Initial Benicia Bridge residency: 1 day. Benicia Bridge to initial detection at the Rio Vista Bridge: 2 days. Rio Vista Bridge residency: 13 days. Departure from Rio Vista Bridge to next detection at the Benicia Bridge: 6 days. Second Benicia Bridge residency: 122 days. Departure from Benicia Bridge to next detection at tagging site: 104 days. Second tagging site residency: 79 days.

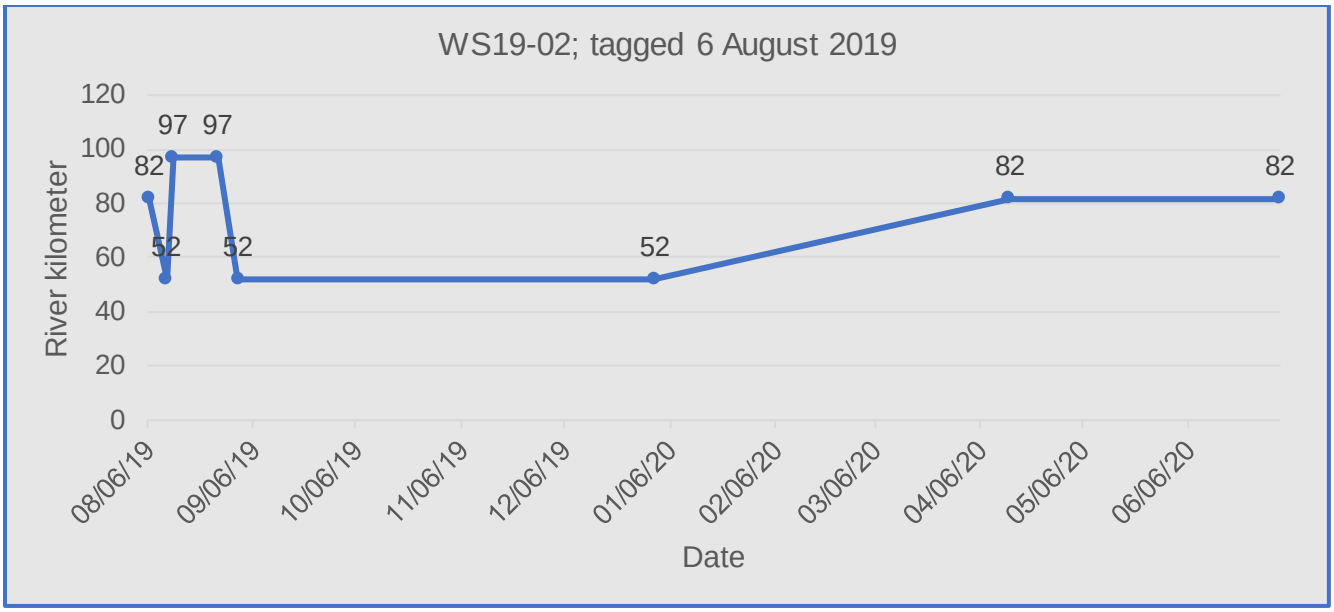

Figure 14. Detection plot for WS19-02; tagged 23 July 2019. Brood year 2017, 53 cm fork length.

Table 18. WS19-03 Detection Summary. Brood year 2017; Tag code A69-1602-12224; tagged 10 September 2019.

Tagging site (rkm 82)	Rio Vista Bridge (rkm 97)	Antioch Bridge (rkm 90)	Benicia Bridge (rkm 52)	Golden Gate (rkm 0.8)
9/10/19; 5/5/20	No detections	No detections	No detections	No detections

Initial tagging site residency: 1 day. Second tagging site residency: 1 day.

White sturgeon movement trends. Table 21 presents a summary of residency periods and travel times between receiver arrays for juvenile white sturgeon tagged in 2019. All three juvenile white sturgeon tagged in 2019 were detected at least once at the tagging site (**Table 21**). Initial residency at the sampling site for all three fish was one day. Two juvenile white sturgeon returned to the vicinity of the sampling site after their departure and detection at either the Rio Vista or Benicia Bridge receiver arrays. The period between departure and return to the tagging site vicinity ranged from 238 to 252 days with a mean of 245 days.

One of three (33 percent) juvenile white sturgeon tagged in 2019 was detected at the Rio Vista Bridge receiver array, a distance of 15 km upstream from the sampling site. The initial detection of WS19-01 at the Rio Vista Bridge was seven days after departure from the tagging site; WS19-01 had a residency period of 13 days at the Rio Vista Bridge.

Two of three (67 percent) juvenile white sturgeon tagged in 2019 were detected at the Benicia Bridge receiver array. Days from sampling site departure to the initial detection at the Benicia Bridge receiver array ranged from two to five days, with a mean of 3.5 days. Initial residency at the Benica Bridge receiver array ranged from one to 598 days, with a mean of 299 days. WS19-02 had a second residency period of 79 days at the Benicia Bridge after a 21 day absence where it was detected at the Rio Vista Bridge. Bridge. No juvenile white sturgeon tagged in 2019 were detected at the Antioch Bridge or Golden Gate receiver arrays.

Table 21. Tagging site, Rio Vista Bridge, Antioch Bridge, and Benicia Bridge initial residency periods and travel times between receiver locations for juvenile white sturgeon tagged in 2019.

Residency (days)							
Tagging site (n=3)		Rio Vista (n=1)		Antioch (n=0)		Benicia (n=2)	
range	mean	range	mean	range	mean	range	mean
1	1	13	13	0	0	1 to 598	299
Travel time from tagging site (days)							
		Rio Vista (n=1)		Antioch (n=0)		Benicia (n=2)	
		range	mean	range	mean	range	mean
		7	7	0	0	2 to 5	3.5

Discussion

2019 was year five of this study, and the 2019 CPUE for juvenile green sturgeon decreased substantially compared to the 2018 CPUE and was similar to the CPUE values from the 2017 sampling season (**Table 22**). The lower 2019 CPUE for juvenile sturgeon is likely a result of the below normal 2018 water year resulting in lower Sacramento River and delta outflows which likely decreased survival of sturgeon eggs and larvae to the juvenile life stage. 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 of green sturgeon to the juvenile life stage is limited to ancillary observations including findings for years 2015 through 2018 of this study, it is likely that green sturgeon exhibit similar patterns.

Table 22. Catch per unit effort (CPUE) for 2015 through 2019; number of Age-1 plus juvenile sturgeon captured per hour of gill net deployment. Age-1 plus juveniles are individuals that have recruited from the previous water year (i.e., 2018 brood year fish recruited from the 2018 water year are Age-1 plus).

Sampling year	Previous water year; classification	Age-1 plus green sturgeon	CPUE	Age-1 plus white sturgeon	CPUE
2015	2014; critically dry	1	0.0033	0	0
2016	2015; critically dry	3	0.0035	10	0.012
2017	2016; dry	4	0.0083	0	0
2018	2017; wet	28	0.115	3	0.0123
2019	2018; below normal	8	0.030	3	0.011

While the sample size for juvenile sturgeon of either species tagged in 2019 is not robust, similar trends in movement patterns and out migration timing (green sturgeon) were observed as in previous years of the study. Unlike juvenile salmonids that enter the delta and typically migrate in a spatial-temporal fashion downstream to the Pacific Ocean, individuals of both species of juvenile sturgeon ranged throughout the SFBDE, making both upstream and downstream migrations or foraging forays. Similar behavior was documented for some individuals of both sturgeon species tagged in 2015 through 2018 (CDFW 2024a-d). Three juvenile green sturgeon detected at the Golden Gate were also detected at nearshore receivers at Point Reyes, Point San Pedro, Ano Nuevo, and the Cement Ship. These fish subsequently returned to the SFBDE and were detected as far upstream as the Antioch Bridge, providing evidence that juvenile green sturgeon do not necessarily remain in the marine environment until sexually mature. Returning to the SFBDE or remaining in the marine environment are alternate life history strategies that could increase overall survival of annual cohorts if rearing conditions in either the SFBDE or Pacific Ocean are suboptimal.

It appears likely that the two sturgeon species may utilize different rearing habitats. White sturgeon are thought to be much more abundant than green sturgeon, although we captured and tagged nearly five-fold more juvenile green sturgeon than juvenile white sturgeon in 2019 across all brood years encountered. To date, no juvenile white sturgeon tagged in over the duration of this study have been detected at the Golden Gate receiver array. Although white sturgeon are anadromous, the vast majority of individuals spend their entire lives in the SFBDE. Juvenile white sturgeon are not known to occur in the Pacific Ocean, although several adult white sturgeon tagged in the SFBDE have been detected as far north as the Columbia River.

The removal of the extensive 69 kHz receiver array in the lower Sacramento River and SFBDE at the end of 2017 resulted in a much reduced capability to track juvenile sturgeon movements and migration patterns. Although CDFW staff deployed receiver

arrays at Rio Vista, Antioch, and Benicia bridges in the summer of 2018, the overall receiver coverage in the lower Sacramento River and SFBDE was greatly reduced in 2019, 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.

References

California Department of Fish and Wildlife. 2024-a. Tagging and Monitoring of Juvenile Sturgeon in the Lower Sacramento River and Sacramento-San Joaquin Delta: 2018 report of findings: available at: CDFW Document Library: https://nrm.cfg.ca.gov/documents/ContextDocs.aspx?cat=R2-Fish

California Department of Fish and Wildlife. 2024-b. Tagging and Monitoring of Juvenile Sturgeon in the Lower Sacramento River and Sacramento-San Joaquin Delta: 2017 report of findings: available at: CDFW Document Library: https://nrm.cfg.ca.gov/documents/ContextDocs.aspx?cat=R2-Fish

California Department of Fish and Wildlife. 2024-c. Tagging and Monitoring of Juvenile Sturgeon in the Lower Sacramento River and Sacramento-San Joaquin Delta: 2016 report of findings: available at: CDFW Document Library: https://nrm.cfg.ca.gov/documents/ContextDocs.aspx?cat=R2-Fish

California Department of Fish and Wildlife. 2024-d. Tagging and Monitoring of Juvenile Sturgeon in the Lower Sacramento River and Sacramento-San Joaquin Delta: 2015 report of findings: available at: CDFW Document Library: https://nrm.cfg.ca.gov/documents/ContextDocs.aspx?cat=R2-Fish

Dubois, J., M. Gingras, E. Gleason. 2010. Review of juvenile sturgeon setline survey. Interagency Ecological Program for the San Francisco Estuary Newsletter 23(3). https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=26542.

Fish, M.A. 2010. A white sturgeon year-class index for the San Francisco Estuary and its relation to delta outflow. Interagency Ecological Program for the San Francisco Estuary Newsletter 23(2). https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentId=26542

Kahn, J., and M. Mohead. 2010. A Protocol for Use of Shortnose, Atlantic, Gulf, and Green Sturgeons. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-OPR-45, 62 p.

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley and Los Angeles.

National Marine Fisheries Service. 2006. Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon.

Poytress, W. R., J. J. Gruber, and J. Van Eenennaam. 2011. 2010 Upper Sacramento River green sturgeon spawning habitat and larval migration surveys. Annual Report of U.S. Fish and Wildlife Service to US Bureau of Reclamation, Red Bluff, CA.

Radtke, L. D. 1966. Distribution of Smelt, Juvenile Sturgeon, and Starry Flounder in the Sacramento-San Joaquin Delta with Observations on Food of Sturgeon. California Department of Fish and Game, pp. 115-119.

Spindler, B. D., S. R. Chipps, et al. (2009). Spatial analysis of pallid sturgeon Scaphirhynchus albus distribution in the Missouri River, South Dakota." Journal of Applied Ichthyology 25(2): 8-13.

Thomas, M.J., A.P. Klmiley 2015. Juvenile green sturgeon movements and identification of critical rearing habitats. In: Klimley, A.P., S.I. Doroshovv, N.A, Fangue, and B.P. May. Sacrameto River green sturgeon migration and popultaion assessment. Sacramento (CA): U.S. Bureau of Reclamation.

U.S. Fish and Wildlife Service. 1995. Age and Growth of Klamath River Green Sturgeon (*Acipenser medirostris*). Klamath River Fishery Resource Office, Yreka, California. 20 p.

Attachment A:

JUVENILE STURGEON TAGGING STANDARD OPERATIONAL PROCEDURES

Revised by Marc Beccio
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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.