2012 UPPER SACRAMENTO RIVER GREEN STURGEON SPAWNING HABITAT AND YOUNG-OF-THE-YEAR MIGRATION SURVEYS

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Cover Photo: RBDD with gates raised courtesy of USFWS using an Olympus Stylus 8000 digital camera.

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2012 Upper Sacramento River Green Sturgeon Spawning Habitat and Young-of-the-Year Migration Surveys

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***Abstract*.—** Through the sampling and positive identification of green sturgeon eggs using artificial substrate mats, three spawning sites in the Sacramento River were confirmed in 2012. Between April 29 and May 30, 2012, fifty-eight green sturgeon eggs and one post hatch larva were collected from RK 426 (N = 16), RK 424.5 (N = 40), and RK 332.5 (N = 3). Eggs were sampled for the third consecutive year from the Sacramento River at RK 426, for the fourth of five years at RK 424.5 and for the second consecutive year at RK 332.5. No egg samples were collected at RK 451 near the mouth of Cow Creek and no adults were detected at this site in 2012. Sample depths for green sturgeon eggs collected from all three sites combined ranged from 3.7 to 11.2 m ($\bar{x}$ = 8.2 m).

Sacramento River flows at RK 426/RK 424.5 ranged from 220 to 323 m^3s^{-1} ($\bar{x}$ = 270 m^3s^{-1}) and 274 to 297 m^3s^{-1} ($\bar{x}$ = 287 m^3s^{-1}) upstream of the GCID diversion (RK 332.5) during the estimated spawning period. Corresponding water temperatures ranged from 12.7 to 14.8°C ($\bar{x}$ = 13.6°C) at RK 426/RK 424.5 and 14.3 to 16.4°C ($\bar{x}$ = 15.3°C) at RK 332.5. From 2008 through 2012, green sturgeon spawning habitat has been identified at seven locations covering a 94 river kilometer reach of the Sacramento River, but in 2012 the RBDD site was not sampled because the gates were not lowered and adult aggregations were not observed.

Zero green sturgeon larvae were captured in the month of July using a benthic D-net. A total of 4,809 minutes of sampling occurred upstream of confirmed spawning areas in an effort to document coarse scale spawning activity in the furthest upstream reaches of the unrestricted portion of the Sacramento River below Keswick Dam. Sacramento River flows ranged from 394 to 407 m^3s^{-1} ($\bar{x}$ = 402 m^3s^{-1}). Mean daily water temperatures for the month of July ranged from 11.6 to 12.5°C ($\bar{x}$ = 12.0°C) at Ball's Ferry Bridge (midway between RK 470 and RK 430 sample sites).

Juvenile sampling efforts using a benthic D-net during the months of October through mid-December targeting a hypothesized juvenile green sturgeon migration to overwintering areas resulted in the capture of zero sturgeon. Improper gear type, habitat selection, or insufficient effort may have contributed to the lack of captures. Future sampling effort should focus on gear and habitat types that have proven to be successful for other juvenile sturgeon species in other large river systems.

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Introduction

The Sacramento River in Northern California currently hosts the only known annual spawning population of Southern Distinct Population Segment (SDPS) green sturgeon, *Acipenser medirostris*, which was listed as threatened under the Federal Endangered Species Act on April 7, 2006 (BRT 2005; NMFS 2006). Heightened concern by the U.S. Bureau of Reclamation (USBR) regarding the potential impacts of the Red Bluff Diversion Dam (RBDD) to green sturgeon prompted the initiation of a series of studies focused on determining how multiple life history stages of this population may be affected by dam operations. From 2008 through 2012, the USBR and the University of California, Davis (UCD) conducted research and monitoring on the adult life history phase of SDPS green sturgeon. The U.S. Fish and Wildlife Service (USFWS) concentrated on the earliest life history stages of SDPS green sturgeon through egg deposition, larval and juvenile migration surveys. Heath and Walker (1987) noted the sampling of eggs and larvae as an important method to identify spawning and nursery areas. Knowledge of these areas has been deemed critical to understand the overall abundance of fish populations (Hjort 1914; May 1974; Hempel 1979). Until recently, detailed information on these critical areas for SDPS green sturgeon has been extremely limited.

Seven spatially discrete SDPS green sturgeon spawning areas were confirmed on the Sacramento River, CA through egg sampling by the USFWS between 2008 and 2011 (Poytress et al. 2009-2012). Larval drift characteristics were also documented. All data collected as part of the multi-entity collaborative efforts from 2008 through 2011 was used to guide the timing, specific locations, and methods used to conduct the 2012 green sturgeon egg and young-of-the-year migration surveys.

Objectives

The objectives of this fifth-year study were to: (1) determine if spawning is occurring at the uppermost observed adult green sturgeon holding area, (2) determine if there is a shift in the temporal and/or spatial distribution of spawning patterns in green sturgeon (via egg deposition) above and below RBDD during the first year RBDD was not in operation, (3) monitor a limited number of the 2008-2011 confirmed spawning sites for repeated spawning site use, (4) monitor the environmental conditions of the sites where eggs were collected and characterize spawning habitat in terms of water temperature, depth, and river discharge, (5) investigate if larval sturgeon are present upstream of previously confirmed spawning areas, and (6) test the effectiveness of a benthic D-net in sampling juvenile green sturgeon within the upper Sacramento river during a hypothesized fall migration period.

This annual report addresses, in detail, egg and young-of-the-year sampling of green sturgeon for the period April 5 through December 14, 2012. This report describes green sturgeon spawning areas and young-of-the-year sampling efforts from multiple upper

Sacramento River sites centered on the RBDD. Juvenile migration sampling was conducted as a pilot effort between October and mid-December of 2012 to test the feasibility of using larval sampling gear to capture juvenile green sturgeon. This report is being submitted to the USBR to comply with contractual reporting requirements for funding administered through the Fish and Wildlife Coordination Act.

Study Area

The Sacramento River originates in Northern California near Mt. Shasta from the springs of Mt. Eddy (Hallock et al. 1961). It flows south through 600 kilometers of the state draining numerous slopes of the coast, Klamath, Cascade, and Sierra Nevada ranges and eventually reaches the Pacific Ocean via San Francisco Bay (Figure 1). Shasta Dam and its associated downstream flow regulating structure, Keswick Dam, have formed a complete barrier to upstream anadromous fish passage since 1943 (Moffett 1949). The 94 river kilometer (RK) reach between Keswick Dam (RK 485) and RBDD (RK 391) supports areas of intact riparian vegetation and largely remains unobstructed. Below RBDD the river encounters greater anthropogenic influence as it flows south to the Sacramento-San Joaquin Estuary.

Sampling was concentrated within a 149.4 river kilometer reach of the Sacramento River from the Bonnyview Bridge (RK 470) to Gianella Bridge (RK 320.6) with RBDD roughly halfway in-between (Figure 1). The 2012 study area contained seven previously confirmed spawning microhabitats (Poytress et al. 2009-2012). The study area was expanded upstream from prior years to include one potential spawning microhabitat associated with the presence of adult green sturgeon based on acoustic telemetry data (Heublein et al. 2009) and DIDSON sonar data (Ethan Mora, UCD, unpublished data), with two larval sampling locations upstream of confirmed spawning areas (Poytress et al. 2012). The study area in 2012 included three egg sampling and two larval sampling locations upstream of RBDD and one egg sampling and two juvenile sampling locations downstream of RBDD (Figure 1).

Methods

***Egg sampling surveys*.—** Sampling for green sturgeon eggs was performed by deploying artificial substrate samplers (i.e., egg mats) in close proximity to presumed spawning areas based on visual observations, side-scan sonar, and acoustic telemetry data (R. Corwin, USBR and M. Thomas and E. Mora, UCD, unpublished data). Egg mats were constructed using two 89 x 61-cm rectangular sections of furnace filter material secured back to back within a welded steel framework (McCabe and Beckman 1990; Schaffter 1997). The orientation of the furnace filter material allows either side of the egg mat to collect eggs. Egg mats were held in position by a three-fluke cement-filled poly-vinyl chloride (PVC) anchor attached to the upstream end of the egg mat using 9.5-mm diameter braided polypropylene rope. A labeled float was attached to the downstream end of each egg mat using 9.5-mm diameter braided polypropylene rope. Float line length and number of floats varied between egg mats depending on water depth and velocity.

Multiple egg mats were placed in four locations on the Sacramento River commonly known as the mouth of Cow Creek (RK 451), the mouth of Ink's Creek (RK 426), Massacre Flats (RK 424.5), and Glenn-Colusa Irrigation District (GCID) Hole (RK 332.5) upstream of the oxbow inlet channel (Figure 1). Mats were predominantly deployed in the "within pool" microhabitats (areas flanking deepest portions of pools) based on the results of the 2008 - 2011 studies (Poytress et al. 2009-2012). The exact number of egg mats deployed at each site depended upon the physical area of each site and the need to maintain a useable river channel for public river transit or fishing.

Egg mat sampling consisted of visual inspection, generally twice a week, throughout the sample period. Paired egg mats were retrieved from the river, placed on a boat in a custom made egg mat carrier, and initially inspected on both sides by at least two field crew members. Egg mats were then rinsed with river water to remove debris and sediment and then re-inspected. Rinse water and debris were filtered using a removable 3.2-mm mesh net placed within the egg mat carrier below each egg mat to capture any dislodged eggs. After a second inspection and inspection of the mesh nets, egg mats were redeployed.

Eggs collected from each mat were counted and identified to species in the field. Eggs were measured, both maximum length and width, in the field using digital calipers (±0.01 mm). All suspected green sturgeon and unidentified eggs were placed into vials of 95% ethyl alcohol (EtOH) for species confirmation and further analysis. Eggs were pooled, by species, into the same vial only when found on the same side of one egg mat. Suspected green sturgeon eggs were sent to UCD for positive species confirmation, photography, measurement of egg diameter, and determination of developmental stage (Dettlaff et al. 1993). Laboratory analysis of EtOH fixed egg size, both maximum length and width, was measured (± 0.001 mm) using an Olympus dissecting microscope with a camera lucida, and a Nikon Microplan II digital image analyzing tablet.

Spawn date and time was estimated based on egg collection date and developmental stage, then back-calculated using average daily water temperature (Wang et al. 1985, 1987; Deng et al. 2002) from the nearest Sacramento River gauging station or temperature logger. Non-green sturgeon fish eggs were field identified using an egg key provided by Rene Reyes of the U.S. Bureau of Reclamation's Tracy Fish Salvage Facility (Reyes 2011). Non-fish eggs (e.g., amphibian), were noted and returned to the water or saved for laboratory examination.

Environmental and sample effort data was collected during both the setting and retrieval of the egg mats. Environmental data consisted of: GPS coordinates recorded at the water surface directly above each egg mat, river flow, water temperature, turbidity, egg mat depth, weather condition, and moon phase. Hourly water temperature was monitored at or near each site using a Stowaway® Tidbit temperature logger maintained by UCD personnel. Sacramento River hourly flow data for the sites above RBDD were obtained from the California Data Exchange Center's Bend Bridge gauging station (http://cdec.water.ca.gov/cgi-progs/queryF?BND). River flow for the lowermost site was obtained from the California Data Exchange Center's Vina-Woodson Bridge gauging station (http://cdec.water.ca.gov/cgi-progs/queryF?VIN). Sample effort data was calculated using the date and time individual egg mats were set and retrieved.

***Larval migration surveys*.—** Larval drift sampling was scheduled to occur upstream of confirmed spawning areas (Poytress et al. 2012) and during previously documented peak larval migration timing (i.e., July; Gaines and Martin 2002, Poytress et al. 2012) in an attempt to coarsely document spawning activity in the furthest upstream reaches of the unrestricted portion of the Sacramento River below Keswick Dam. Based on previous studies of the Sacramento River (Brown 2007; Poytress et al. 2009-2012) and laboratory studies (Van Eenennaam et al. 2001; Kynard et al. 2005) indicating nighttime migration activity, larval sampling was planned to occur primarily between the hours of 20:00 and 01:00.

A benthic D-net was used throughout the season, similar to nets previously used for larval sturgeon sampling in the Sacramento River (Kohlhorst 1976; Brown 2007). The net was constructed of 3.2-mm DuPont 66 nylon fiber mesh fashioned into a 3.0-m long tapered cone and attached to a steel frame with a circumference of 2.8-m including a flat base of 80 cm. A 6,620-ml PVC aquatic sample bucket (15.2 x 43.2 cm) was attached to the cod end allowing for easy access to collected samples. An additional layer of 1.6-mm Delta knotless netting was sewn inside the latter 45.7 cm of the 3.2-mm netting to prevent larval sturgeon from being injured or escaping prior to entering the collection bucket.

Steel bar stock was added to the base of the net frame to properly orient the net in the current and sink it to the river bottom during sampling. In general, a total weight of 27 kg was determined to be sufficient for proper net orientation during sampling. The net was attached via a 4.8-mm diameter steel aircraft cable bridle to 4.8-mm Amsteel Blue® rope and positioned using a hydraulic winch. The net was allowed to drift downstream behind the boat until it contacted the river bottom.

Larval drift sampling was scheduled for five nights per week alternating between two sample sites: Bonnyview Bridge (RK 470) and Jelly's Ferry Bridge (RK 430; Figure 1). Sites were selected based on proximity to potential spawning locations, safe transit at night, and the presence of adequate tie-off structures (i.e., bridge supports) in the thalweg.

Sampling effort was designed to consist of 300 minutes of wetted net time per night between the hours of 20:00 to 01:00 and continued for one hour past the last collection of green sturgeon larvae. Two bridge supports at Bonnyview Bridge and Jelly's Ferry Bridge allowed for multiple sampling locations, however, only the bridge support located in the thalweg (Poytress et al. 2010) was used for sampling. During standard sampling, the net was generally set to sample for 10, 20, or 30-minute sets depending on debris accumulation, fish occurrence and mortality.

Effort and environmental data collected for each sample site included: set and retrieve times and dates, tie-off distance, net-set distance, turbidity, and river velocity. D-net sample depth was measured by mounting an Onset Corporation® Depth Logger to the frame of the D-net. Data derived from the logger allowed us to determine which net-sets sampled properly as indicated by the variability of the depth measurements during each deployment.

The river velocity was measured during each tow in the center of the mouth of the D-net using a General Oceanic® Model 2030 flowmeter. Set time was defined as the time the net became properly oriented in the river during deployment and retrieve time was recorded when the net broke the surface during retrieval.

Collected samples were field sorted with the amount and type of debris recorded. All fish sampled were identified to species, measured, and enumerated. Green sturgeon eggs were identified to species, enumerated and retained in 95% EtOH for laboratory examination and species identification/confirmation. Non-sturgeon eggs were identified using the egg identification key provided by Rene Reyes of the U.S. Bureau of Reclamation's Tracy Fish Salvage Facility (Reyes 2011). Green sturgeon larvae incidental mortalities (morts) and eggs were retained in 95% EtOH for genetic identification (Israel et al. 2004) and developmental stage assessment (Dettlaff et al. 1993). Live green sturgeon larvae in good condition were returned to the river. Non-sturgeon larval fish collected were visually identified to the genus level primarily in the field (in some cases in the lab) and/or noted to the species level and race using length-at-date criteria developed by Greene[1] (1992) in the case of salmonids. Non-target species were returned to the river when identified in the field.

Pilot effort juvenile migration surveys.—Juvenile migration sampling was scheduled to occur during the fall period to encompass a timeframe of 180 days post hatch (dph) for green sturgeon and during the period when river temperatures decreased to 10° C or below (Kynard et al. 2005). Based on previous studies on the Sacramento River (USFWS, unpublished data) and laboratory studies (Kynard et al. 2005) indicating migration activity peaking during nocturnal hours for 110-180 dph juveniles, sampling was scheduled to occur for 360 minutes per night primarily between the hours of 18:00 and 24:00. A benthic D-net, as described within the larval migration survey methods, was used throughout the juvenile sampling period.

Juvenile sampling was scheduled for five nights per week alternating between two sample sites: Tehama Bridge (RK 369) and Gianella Bridge (RK 320.6; Figure 1). Sites were selected based on the premise that juveniles would be migrating downstream from summer hatching and rearing habitat to overwintering habitat (Kynard et. al. 2005). Safe transit at night and the presence of adequate tie-off structures (i.e., bridge supports) in the thalweg (Poytress et al. 2010) were also prerequisites. During standard sampling, the net was generally set to sample for 10, 20, or 30-minute sets depending on debris accumulation, fish occurrence and mortality.

Effort and environmental data collected for each sample site included: set and retrieve times and dates, tie-off distance, net-set distance, turbidity, and river velocity. D-net sample depth was measured by mounting an Onset Corporation® Depth Logger to the frame of the D-net. Data derived from the logger allowed us to determine which net-sets sampled properly as indicated by the variability of the depth measurements during each deployment. The river velocity was measured in the center of the mouth of the D-net during the first two

[1] Generated by Sheila Greene, California Department of Water Resources, Environmental Services Office, Sacramento (May 8, 1992) from a table developed by Frank Fisher, California Department of Fish and Game, Inland Fisheries Branch, Red Bluff (revised February 2, 1992). Fork lengths with overlapping run assignments were placed with the latter spawning run.

samples each night using a General Oceanic® Model 2030 flowmeter. Set time was defined as the time the net became properly oriented in the river during deployment and retrieve time was recorded when the net broke the surface during retrieval.

Collected samples were field sorted with the amount and type of debris recorded. All fish sampled were identified to species, measured (fork and total length), weighed, and enumerated. Incidental mortalities (morts) of juvenile green sturgeon were retained in 95% EtOH for genetic identification (Israel et al. 2004). Live green sturgeon juveniles in good condition were returned to the river after processing. Non-sturgeon fish samples collected were visually identified to the genus level primarily in the field and/or noted to the species level and race using length-at-date criteria developed by Greene (1992) in the case of salmonids. Non-target species were returned to the river when identified in the field.

Results

Egg sampling surveys.— Egg mat sampling occurred between April 5 and July 14, 2012. Egg mats sampled a total of 1,393.7 wetted mat days (wmd; one mat set 24 hours). Sampling effort between the four sites ranged from 181.0 to 550.7 wmd ($\bar{x}$ = 348.3 wmd; Table 1). On April 11, 2012 all egg mats were retrieved due to an increase in river discharge from a spring storm event. Egg mats were redeployed within three to four days after the event. On five separate occasions, high water velocity and aquatic vegetation buildup on the float lines displaced mats from the Cow Creek sampling site. One mat was lost and never retrieved at Cow Creek likely due to the buildup of aquatic vegetation sinking the float and line.

Between April 29 and May 30, 2012, fifty-eight green sturgeon eggs and one post hatch larva were collected from RK 426 (N = 16), RK 424.5 (N = 40), and RK 332.5 (N = 3; Table 2). Egg samples were collected on nine different sample days (Figure 2) and were sampled from one (N = 4), two, (N = 2), three (N = 1) or four (N = 2) egg mats at each sample site. Daily positive egg sample totals, per site, ranged from 1 to 18 ($\bar{x}$ = 7.3). Six of the eighteen egg mats that collected eggs had an egg located on both the top and bottom of the egg mat. Catch per unit effort (sturgeon eggs/wmd) ranged from 0.000 at Cow Creek to 0.111 at the Massacre Flats site ($\bar{x}$ = 0.051). Catch per unit effort for all sites combined was 0.042 green sturgeon eggs/wmd (Table 1).

Green sturgeon eggs (48 of 59) were assessed for developmental stage and described using Detlaff et al. (1993). The remaining eleven eggs (19%) were either crushed, marbled or fungus laden preventing accurate assessment. Embryonic developmental assessment indicated eggs were between stage 2 (recently oviposited) and stage 44 (post hatch larva). Based on date and location of capture, water temperature, stage of development, and the assumption that a female requires 12 to 20 hours to release all of her eggs, samples were likely collected from seven or eight different females who spawned between April 28 and May 25, 2012 (Table 2).

Egg diameter (width and length) was measured in the field (prior to fixation) and in the lab (post fixation) on 53 and 44 of the eggs, respectively. Of the directly comparable measurements ($N = 43$), field width and length measurements ranged from 3.09 to 4.96 mm ($\bar{x} = 3.88$ mm) and 3.35 to 5.39 mm ($\bar{x} = 4.21$ mm), respectively. Laboratory width and length measurements ranged from 3.45 to 4.33 mm ($\bar{x} = 3.89$ mm) and 3.69 to 4.50 mm ($\bar{x} = 4.04$ mm), respectively. The one post-hatch larva sampled by egg mats on May 23, 2012 was approximately 22.5 mm in total length.

Egg mats sampled in water depths ranging from 2.4 to 13.1 m ($\bar{x} = 7.0$ m; Table 3). Sample depths for green sturgeon eggs collected from all three sites ranged from 3.7 to 11.2 m ($\bar{x} = 8.2$ m; Figure 3).

Sacramento River flows at RK 426 and RK 424.5 ranged from 159 to 433 m^3s^{-1} ($\bar{x} = 307$ m^3s^{-1}) during the sample period and 220 to 323 m^3s^{-1} ($\bar{x} = 270$ m^3s^{-1}) during the estimated spawning period (Figure 4). Sacramento River flows upstream of the GCID diversion ranged from 202 to 543 m^3s^{-1} ($\bar{x} = 314$ m^3s^{-1}) during the sample period and 274 to 297 m^3s^{-1} ($\bar{x} = 287$ m^3s^{-1}) during the estimated spawning period (Figure 5).

Mean daily water temperatures ranged from 10.6 to 15.7°C ($\bar{x} = 12.7$°C) at RK 426 and RK 424.5 (Figure 4). Mean daily water temperatures ranged from 11.5 to 17.9°C ($\bar{x} = 15.5$°C) at RK 332.5 (Figure 5). During the estimated spawning period, water temperatures ranged from 12.7 to 14.8°C ($\bar{x} = 13.6$°C) at RK 426 and RK 424.5 and 14.3 to 16.4°C ($\bar{x} = 15.3$°C) at RK 332.5.

Turbidity values derived from surface grab samples at RK 426 and RK 424.5 ranged from 1.2 to 9.2 nephelometric turbidity units (NTU) throughout the sample period ($\bar{x} = 2.7$ NTU). During the estimated spawning period at RK 426 and RK 424.5, turbidity ranged from 1.84 to 3.5 NTU ($\bar{x} = 2.7$ NTU). Turbidity values derived from surface grab samples at RK 332.5 ranged from 1.3 to 15.9 NTU ($\bar{x} = 4.4$ NTU) throughout the sample period and 2.8 to 4.6 NTU ($\bar{x} = 3.7$ NTU) during the estimated spawning period.

Larval migration surveys.— Larval drift sampling at Bonnyview Bridge (RK 470) and Jelly's Ferry Bridge (RK 430) occurred on alternating nights between July 1 and July 26, 2012. Wetted net time totaled 4,809 minutes (80.2 hours) during weekly standard sampling efforts (Table 4). Net-set times ranged from 15 to 52 minutes ($\bar{x} = 30.8$ minutes; Table 4).

Sacramento River conditions beyond mid-June were relatively stable and primarily regulated water releases from Shasta/Keswick Dam (Figure 1). Sacramento River flows ranged from 394 to 407 m^3s^{-1} ($\bar{x} = 402$ m^3s^{-1}; Figure 4). Mean daily water temperatures for the month of July ranged from 11.6 to 12.5°C ($\bar{x} = 12.0$°C) at Ball's Ferry Bridge (RK 445) located roughly midway between upper and lower larval D-net sample sites.

Turbidity values derived from surface grab samples at Bonnyview Bridge ranged from 1.1 to 1.9 NTU ($\bar{x} = 1.5$ NTU), and 1.5 to 2.1 NTU ($\bar{x} = 1.8$ NTU) for the Jelly's Ferry Bridge site. Debris loads from collected samples were generally very light at Bonnyview Bridge to moderate at Jelly's Ferry Bridge; typically consisting of detritus and aquatic vegetation.

Net sample depths varied between sites and ranged from 2.6 to 4.5 m ($\bar{x}$ = 4.1 m) at Bonnyview Bridge and 3.2 to 3.7 m ($\bar{x}$ = 3.5 m) at Jelly's Ferry Bridge (Table 4). Water velocities measured at the mouth of the D-net ranged from 0.3 to 0.8 ms^{-1} ($\bar{x}$ = 0.6 ms^{-1}) at Bonnyview Bridge and 0.5 to 1.2 ms^{-1} ($\bar{x}$ = 0.9 ms^{-1}) at Jelly's Ferry Bridge (Table 4).

Zero green sturgeon larvae were captured during the one month sampling period in 2012. No samples were lost due to gear failure. Only incidental capture species were sampled including young-of-the-year salmonids (Table A1).

***Pilot effort juvenile migration surveys*.—** Juvenile sturgeon sampling using a benthic D-net took place from October 2 to December 14, 2012. Of 55 evenings scheduled to be sampled, 44 evenings were sampled. During the period, 5 days could not be sampled due to boat and equipment failures. The remaining 6 evenings were not sampled due to early winter storms with subsequent high flow and debris levels resulting in unsafe sampling conditions (Figure 6).

Wetted net time totaled 7,975 minutes (132.9 hours); alternating between Tehama Bridge (RK 369) and Gianella Bridge (RK 320.6) typically between 18:30 and 21:00 (Table 5). Standard sampling at Gianella Bridge occurred from a bridge piling for a total of 1,136 minutes. Exploratory sampling downstream of Gianella Bridge (RK 320.5), anchored to the substrate near a river constriction point, occurred for 2,303 minutes (Table 5). Net-set times for all sites combined ranged from 20 to 68 minutes ($\bar{x}$ = 32.3 minutes; Table 5).

Net sample depths varied among sites and ranged from 0.6 to 1.7 m ($\bar{x}$ = 1.5 m) at Tehama Bridge (RK 369), 1.1 to 1.3 m ($\bar{x}$ = 1.2 m) at Gianella Bridge (RK 320.6), and 0.7 to 4.7 m ($\bar{x}$ = 2.2 m) downstream of Gianella Bridge (RK 320.5). Water velocities measured at the mouth of the D-net ranged from 0.5 to 1.0 ms^{-1} ($\bar{x}$ = 0.9 ms^{-1}) at Tehama Bridge (RK 369), 0.5 to 1.0 ms^{-1} ($\bar{x}$ = 0.7 ms^{-1}) at Gianella Bridge (RK 320.6) and 0.5 to 1.5 ms^{-1} ($\bar{x}$ = 1.0 ms^{-1}) downstream of Gianella Bridge (RK 320.5; Table 5).

Sacramento River flows at Vina-Woodson Bridge ranged from 176 to 208 m^3s^{-1} ($\bar{x}$ = 188 m^3s^{-1}) in October, 180 to 1,139 m^3s^{-1} ($\bar{x}$ = 231 m^3s^{-1}) in November, and 225 to 2,490 m^3s^{-1} ($\bar{x}$ = 576 m^3s^{-1}) in December through the sampling period (Figure 6). Water temperatures collected near Woodson Bridge midway between the two sample sites were assumed to be representative of both sites. Sacramento River water temperatures ranged from 11.2 to 15.8°C ($\bar{x}$ = 13.7°C) in October, 10.0 to 14.4°C ($\bar{x}$ = 12.1°C) in November, and 8.9 to 13.2°C ($\bar{x}$ = 11.1°C) in December through the sampling period (Figure 6).

Turbidity samples collected at each site ranged from 1.1 to 15.0 NTU ($\bar{x}$ = 3.3 NTU) at Tehama Bridge (RK 369), 1.6 to 17.3 NTU ($\bar{x}$ = 6.7 NTU) at Gianella Bridge (RK 320.6), and 1.5 to 25.8 NTU ($\bar{x}$ = 11.5 NTU) below Gianella Bridge (RK 320.5). Debris loads from collected samples were generally very light to moderate at all sites; typically consisting of leaves and aquatic vegetation.

Zero green sturgeon juveniles were captured during the 2012 fall sampling period. Five samples were compromised due to equipment failure. Only incidental capture fish species were sampled including young-of-the-year salmonids (Table A2).

Discussion

Egg sampling surveys.— Green sturgeon eggs were collected using artificial substrate mats from three of the four sample sites on the Sacramento River in 2012. Egg collections reconfirmed spawning for the second and third consecutive sampling season at RK 332.5 and RK 426, respectively. In 2011, acoustic monitoring and sonar data indicated a limited presence of green sturgeon adults at RK 424.5 and for the first time in four years no eggs were collected at this site (Poytress et al. 2012). In 2012, however, 40 eggs were collected between April 29 ($N = 4$), May 2 ($N = 20$), May 5 ($N = 13$), and May 20 ($N = 5$), representing four separate spawning events at RK 424.5. Field observations, (i.e., breaching, acoustic detections, and side-scan images) indicated that numerous adult sturgeon were present at the time of these spawning events. Currently, it remains unclear whether the eggs from each spawning event came from a single spawning female or if multiple females were contributing to each of the four sampled spawning events. Genetic analyses of the egg samples are being conducted by National Marine Fisheries Service Southwest Science Research Center and may help to determine the number of spawners contributing to each spawning event (Israel and May 2010).

The 2012 egg sampling area was extended 25 river kilometers upstream from the previously confirmed green sturgeon spawning grounds as sturgeon were observed below the mouth of Cow Creek (RK 451) during 2010 and 2011 DIDSON based acoustic surveys. These surveys indicated sturgeon were holding for extended periods and based on timing, possibly spawning (E. Mora, UCD, pers. comm.). Egg sampling within this area proved to be difficult as high water velocities and the buildup of aquatic vegetation on the buoy float lines pulled egg mats out of the sample area or submerged their floats altogether. Ultimately, no eggs were collected at RK 451 and no adult fish were observed at this site during the 2012 DIDSON surveys (E. Mora, UCD, pers. comm.).

Adult green sturgeon presence near the mouth of Cow Creek may be driven by site fidelity or possibly river conditions as these variables were considerably different between 2011 and 2012. Sacramento River flows during the adult spawning migration (Thomas et al. 2013) exceeded 560 m^3s^{-1} for 26 consecutive days in March and April of 2011[2]. In contrast, the 2012 river flows exceeded 560 m^3s^{-1} for only 16 hours on March 28. Three spring freshets provided 12 days of potential attraction flow in excess of 300 m^3s^{-1} to the upper reach of the Sacramento River in March and April of 2012[3].

Heublein et al. (2009) documented a single acoustically tagged adult male sturgeon near the mouth of Cow Creek at the end of May in 2005 for an indeterminate period of time. Flood control releases from Shasta/Keswick Dam elevated river discharge in excess of 560 m^3s^{-1} beginning on May 5 through May 23, 2005. Elevated flood control releases (> 300

[2] USGS Water Data Report 2011; http://wdr.water.usgs.gov/wy2011/pdfs/11377100.2011.pdf
[3] USGS Water Data Report 2012; http://wdr.water.usgs.gov/wy2012/pdfs/11377100.2012.pdf

m^3s^{-1}) continued through the middle of June in 2005 until flood control criteria were met. Similar flood control releases occurred in the spring of 2011, the most recent year adult sturgeons were observed in this area. Egg sampling at the mouth of Cow Creek (RK 451) during years when adult sturgeons are present will help determine if this area is utilized for spawning and if occupation of the area corresponds with periods of high spring flows or when specific adults return back to the system (i.e., spawning site fidelity).

***Post-RBDD egg collection timing*.—** Egg samples collected between April 29 and May 30, 2012 estimated the spawning period to be 29 days in duration (Figure 2). Markedly, 2012 was the first year since 1967 the RBDD gates were not lowered during the spring period impounding the Sacramento River at Red Bluff as a new screened pumping plant was employed (NMFS 2009). In 2012, the estimated spawning period was 29 days shorter compared to the mean period ($\bar{x}$ =58 days) determined from sampling years' 2008-2011(range 39 - 85 days; Poytress et al. 2009-2012) when the RBDD was seasonally operated (Figure 7). Although the distribution pattern appeared truncated, no significant statistical difference was detected for the median spawning date between 2012 and the previous four years (One Way ANOVA; $F_{(4,41)}= 1.668$, $P = 0.176$). Our ability to detect any statistical significance was possibly hindered due to small sample size and therefore a lack of statistical power (i.e., not collecting eggs from the same sites for several years consecutively over many days). Conversely, the 2012 estimated spawning period was very similar in duration to that determined in 2010 (Figure 7).

The temporal distribution pattern of larval green sturgeon collected between May 17 and June 26 in the RBDD rotary screw traps strongly support the overall timing of the 2012 egg collections (Figure 4). Prior years' data have consistently indicated green sturgeon larval distribution showing a bimodal pattern with abundance peaking in June and again in July (Poytress et al. 2011-2012). In 2012 this was not observed, likely due to the lack of a spawning site immediately below partially closed RBDD gates during the spring time. Overall, the 2012 egg and larval sampling data support the theory of an overall shorter duration spawning period in 2012, but also suggest natural variability in spawn timing (Figure 7) unrelated to RBDD gate operations.

***Bounds of Sacramento River green sturgeon spawning*.—** The original focus of the spawning habitat research was to identify specific spawning microhabitat characteristics and the overall spatial distribution of green sturgeon spawners within the Sacramento River upstream and downstream of the RBDD. Limited financial resources did not allow us to repeatedly sample each confirmed spawning location in all five years of study. The resources allocated permitted us to identify what is believed to be the lower extent of green sturgeon spawning in the Sacramento River at RK 332.5. Acoustic tag migration data collected by USBR and UCD researchers indicate that adults are not holding or spending significant amounts of time below this section of the Sacramento river during pre- or post-spawn time periods (Thomas et al. 2013; USBR, unpublished data).

Zero eggs were sampled at RK 451 in 2012, but it remains highly likely that in some years' green sturgeon utilize this area for spawning based on the timing of habitat use. Additional years of egg sampling could determine definitively if this is the uppermost reach of spawning in the Sacramento River, as opposed to the current known limit at RK 426 (Poytress et al. 2012). As a result, we can only hypothesize that RK 451 is the uppermost spawning site in the Sacramento River as acoustic data has indicated only transient migration patterns of one to two individuals above this site (Heublein et al. 2009; M. Thomas, UCD, pers. comm.). Moreover, Sacramento River water temperature compliance points set for endangered winter-run Chinook salmon (NMFS 2009) result in mean daily water temperatures during April through June (i.e., average spawning period) which are less than or equal to 11°C above RK 470. These sub-optimal water temperatures near and upstream of RK 470 could have deleterious effects to green sturgeon progeny survival via decreased hatch rates and shorter hatchlings (Van Eenennaam et al. 2005). One consequence to green sturgeon of river temperature management exclusively for winter Chinook is an approximately 120 river kilometer segment between RK 451 and RK 330 on the Sacramento River where spawning habitat is thermally acceptable during the spring spawning period in most years.

***Larval migration surveys*.—** Benthic D-net larval surveys conducted upstream of confirmed spawning locations in an attempt to indirectly determine additional upstream green sturgeon spawning habitat during July of 2012 yielded no green sturgeon captures (Table 4). Basic habitat conditions (i.e., flow and temperature) at Jelly's Ferry Bridge (RK 430), and to a lesser extent at Bonnyview Bridge (RK 470), appeared to be similar to where spawning has been documented in previous years (Poytress et al. 2009-2012). Water temperatures midway between the two larval sample sites were slightly lower than optimal ($\bar{x}$ = 12.0°C) for larval survival (Van Eenennaam et al. 2005), but assumedly some progeny would survive the upper river temperatures had spawning occurred within this upper reach. In contrast to 2010 and 2011, zero adult sturgeon were documented at RK 451 during the spawning season of 2012 (E. Mora, UCD, pers. comm.).

The temporal distribution of green sturgeon captured by the RBDD rotary traps suggest another possible explanation for why no larvae were observed in the upper reaches of the Sacramento River in July of 2012. The 2012 sturgeon larvae capture period was distinctly different than the prior 16 years of sampling (USFWS, unpublished data). Zero green sturgeon larvae were captured during the month of July which has typically been a peak month of sturgeon captures. This indicates that larval D-net sampling may have occurred too late in the season to detect 2012 progeny within this reach (Figure 4).

The absence of an RBDD gate closure in 2012 resulted in the loss of a semi-productive green sturgeon spawning location (Poytress et al. 2009 and 2012) at RBDD immediately upstream of rotary traps. The spring closure of RBDD in years prior to 2012 likely resulted in a prolonged spawning period and correspondingly longer larval detection period by rotary traps in this reach of the Sacramento River. Overall, based on the 2012 D-net larval sample data it remains unclear whether spawning occurs above RK 426 of the Sacramento River as efforts did not target the timing of the 2012 migration (Figure 4) which has been demonstrated to coincide with the timing of captures using rotary traps (Poytress et al. 2012).

***Pilot effort juvenile migration surveys*.—** Juvenile sampling efforts using a benthic D-net during the months of October through mid-December when it is hypothesized that juvenile green sturgeon migrate to overwintering areas (Kynard et al. 2005) resulted in the capture of zero sturgeon. Sampling efforts focused on the time period and water temperatures targets (110-180 days post hatch and 10 °C) that Kynard et al. (2005) indicated were drivers for a secondary movement pattern of green sturgeon young-of-the-year in the laboratory (Figure 6). Equipment malfunctions and relatively strong fall storms resulted in less than ideal effort during potentially critical time periods in November. The hours sampled were generally between 18:00 and 22:00 and, on average, were the hours of peak daily temperatures ($\bar{x}$ = 12.8 °C). Peak daily temperatures during the fall period would seem to be conducive to active migration from a metabolic perspective. Juvenile green sturgeon behavioral data collected by Kynard et al (2005) indicated the greatest downstream movement patterns of juveniles to be around 20:00 for migrating juveniles. The 2012 juvenile sampling data did not indicate passage during this period at our sample sites.

Total nightly sampling effort may have been too low to detect migration or sturgeon may have simply passed, en masse, during one of the fall storm events that precluded sampling. Anecdotal evidence of a juvenile green sturgeon captured during fall trammel net sampling near Ryde, CA by the California Department of Water Resources (B. Schreier, pers. comm.) indicated presence of a juvenile green sturgeon (320 mm TL) following a storm event in November. The event resulted in a 250% increase in upper Sacramento River discharge at Bend Bridge to a value of over 400 m^3s^{-1}. The fish was captured 5 days after the discharge increase in the upper river, albeit on the downslope of the same flow event some 335 river kilometers downstream along the river margin. The importance of the first fall storm event has been noted for winter Chinook smolts as a migration cue (Poytress 2007) and at least one juvenile sturgeon has been captured during a first fall storm event using rotary traps (USFWS, unpublished data).

It remains unclear if a benthic D-net is an effective gear type for sampling larger, juvenile sturgeon. Although very effective for capturing larvae with limited swimming ability in moderately fast river velocities (Poytress et al. 2011 and 2012), larger juvenile sturgeon may be much more likely to detect and avoid capture or entrainment in this gear type. Conversely, the thalweg habitat that proved effective for larval capture (Poytress et al. 2010-2012) may not be appropriate for sampling juveniles as they likely change their spatial distribution patterns as they grow (Hayes et al. 1996).

Research on juvenile white sturgeon (*Acipenser transmontanus*) has proven successful using active gears such as beam trawls in the Columbia River (Parsley et al. 1989; Parsley and Beckman 1993) and within the Lower Fraser River (Glova et al. 2008-2010) and for pallid and shovelnose sturgeon (*Scaphirhnchus spp.*) using push trawls (Ridenour et al. 2011). Seines and e-fishing were found to be successful for sampling juvenile lake sturgeon (*Acipenser fulvescens*; Kempinger 1996). Passive gears such as gill nets were found to be effective for juvenile Gulf sturgeon (*Acipenser oxyrinchus desotoi;* Sulak and Clugston 1998), lake sturgeon (Barth et al. 2009; Haxton 2011), and white sturgeon (Neufield and Spence 2002; Golder Associates Ltd. 2003).

Future juvenile sampling efforts should focus on sampling a variety of gear types and habitats through the fall period in an attempt to capture juvenile green sturgeon in the Sacramento River. Overall, a better understanding of the habitat use, migration timing and spatial distribution patterns of juvenile Sacramento River green sturgeon is needed. Further testing of the Kynard et al. (2005) based hypothesis of a migration to overwintering habitat to determine migration cues out of the freshwater environment of the Sacramento River to the brackish waters of the Sacramento San Joaquin Delta Estuary is imperative to better manage the operations of the Central Valley Project as well as to aid in the recovery of this threatened fish species.

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Tables

Table 1. Summary of green sturgeon egg sampling effort in wetted mat days (wmd; one sampler set for 24 hours), total number of green sturgeon eggs sampled by site (GST Eggs) and catch per unit effort (CPUE) at four sites on the upper Sacramento River, CA.

Location	Habitat	Start Date	End Date	Egg Mats (*N*)	Sample Effort (wmd)	GST Eggs	CPUE (eggs/wmd)
Cow Creek (RK 451)	Pool	4/5/12	7/10/12	4	302.6	-	0.000
Ink's Creek (RK 426)	Pool	4/5/12	7/10/12	2	181.0	16	0.088
Massacre Flats (RK 424.5)	Pool	4/5/12	7/10/12	4	359.3	40*	0.111
GCID Hole (RK 332.5)	Run/Glide	4/6/12	7/14/12	6	550.7	3	0.005
			Total	**16**	**1,393.7**	**59**	**0.042**

*Includes one post hatch larvae collected on 5/23/12.

Table 2. Summary of estimated spawn dates and times for green sturgeon egg samples collected on the upper Sacramento River, CA. Estimated spawn date and time were back-calculated based on stage of embryogenesis (Dettlaff et al. 1993), developmental rates of green sturgeon (Deng et al. 2002), and mean daily Sacramento River water temperatures. Comments describe additional information related to developmental stage of the embryo.

Date	Location	Egg Count	Estimated Spawn Date	Estimated Spawn Time	Stage	Comments
4/29/2012	RK 424.5	1	-	-	-	cannot tell if fertilized or not (crushed/misshapen)
4/29/2012	RK 424.5	1	-	-	-	marbled egg, cannot tell if fertilized and died or not fertilized
4/29/2012	RK 424.5	1	04/28/12	6:00 AM	13	gastrulation
5/2/2012	RK 424.5	1	05/02/12	2:00 AM	6	8 cell stage
5/2/2012	RK 424.5	1	05/02/12	12:00 AM	9	64 cell stage
5/2/2012	RK 424.5	1	05/02/12	3:00 AM	5	4 cell stage
5/2/2012	RK 424.5	1	05/02/12	2:00 AM	6	8 cell stage
5/2/2012	RK 424.5	1	05/01/12	6:00 PM	10	late cleavage
5/2/2012	RK 424.5	1	05/02/12	8:00 AM	2	appears to be a recently oviposited egg (no cleavage yet, but appears viable)
5/2/2012	RK 424.5	1	-	-	-	misshapen, cannot see stage but appears to have been fertilized, no accurate size data
5/2/2012	RK 424.5	1	05/02/12	3:00 AM	5	4 cell stage
5/2/2012	RK 424.5	1	05/01/12	12:00 PM	11	early blastula
5/2/2012	RK 424.5	1	05/02/12	4:00 AM	4	2 cell stage
5/2/2012	RK 424.5	1	05/01/12	6:00 PM	10	late cleavage
5/2/2012	RK 424.5	1	05/02/12	7:00 AM	3	grey crescent
5/2/2012	RK 424.5	1	05/02/12	2:00 AM	6	8 cell stage
5/2/2012	RK 424.5	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/2/2012	RK 424.5	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/2/2012	RK 424.5	1	05/02/12	1:00 AM	7	16 cell
5/2/2012	RK 424.5	1	05/02/12	8:00 AM	2	appears to be a recently oviposited egg (no cleavage yet, but appears viable)
5/2/2012	RK 424.5	1	05/02/12	2:00 AM	6	8 cell stage

Table 2. Continued.

Date	Location	Egg Count	Estimated Spawn Date	Estimated Spawn Time	Stage	Comments
5/5/2012	RK 424.5	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/5/2012	RK 424.5	1	05/03/12	12:00 PM	16	
5/5/2012	RK 424.5	1	05/02/12	10:00 PM	18	very early neurulation
5/5/2012	RK 424.5	1	05/03/12	6:00 AM	17	
5/5/2012	RK 424.5	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/5/2012	RK 424.5	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/5/2012	RK 424.5	1	05/02/12	5:00 PM	19	early neurulation
5/5/2012	RK 424.5	1	05/02/12	10:00 PM	18	very early neurulation
5/5/2012	RK 424.5	1	-	-	17	
5/5/2012	RK 424.5	1	05/02/12	5:00 PM	19	early neurulation
5/5/2012	RK 424.5	1	05/02/12	10:00 PM	18	very early neurulation
5/5/2012	RK 424.5	1	-	-	17	
5/5/2012	RK 424.5	1	05/02/12	5:00 PM	19	early neurulation
5/11/2012	RK 426	1	05/10/12	6:00 AM	13	gastrulation
5/11/2012	RK 426	1	05/11/12	4:00 AM	6	8 cell stage
5/14/2012	RK 426	1	05/14/12	3:00 AM	4	1st cleavage
5/14/2012	RK 426	1	05/13/12	12:00 PM	11	early blastula
5/14/2012	RK 426	1	05/13/12	12:00 PM	11	early blastula
5/14/2012	RK 426	1	05/13/12	12:00 PM	11	early blastula
5/14/2012	RK 426	1	05/14/12	8:00 AM	2	bulging shape, no size measurements, appears just oviposited
5/14/2012	RK 426	1	05/14/12	3:00 AM	5	4 cell stage, no accurate size due to bulging shape
5/14/2012	RK 426	1	-	-	-	crushed, cannot tell anything, no accurate dia data

Table 2. Continued.

Date	Location	Egg Count	Estimated Spawn Date	Estimated Spawn Time	Stage	Comments
5/14/2012	RK 426	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/14/2012	RK 426	1	05/14/12	4:00 AM	4	1st cleavage
5/14/2012	RK 426	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/14/2012	RK 426	1	05/14/12	12:00 AM	9	64 cell stage
5/14/2012	RK 426	1	05/14/12	12:00 AM	9	64 cell stage
5/14/2012	RK 426	1	05/13/12	6:00 AM	10	late cleavage
5/14/2012	RK 426	1	05/14/12	2:00 AM	6	8 cell stage
5/14/2012	RK 426	1	05/14/12	4:00 AM	4	1st cleavage, no accurate size due to bulging shape
5/20/2012	RK 424.5	1	05/19/12	6:00 AM	13	early gastrulation, fixed very oblong…no accurate size data
5/20/2012	RK 424.5	1	-	-	-	marbled…cannot tell if fertilized and then died or was not fertilized
5/20/2012	RK 424.5	1	05/19/12	12:00 PM	11	early blastula
5/20/2012	RK 424.5	1	05/19/12	6:00 AM	13	early gastrulation
5/20/2012	RK 424.5	1	05/19/12	10:00 AM	12	
5/23/2012	RK 424.5	1	05/01/12	+/- 3 days	44	approx stage 44, 22.5mm long larvae
5/27/2012	RK 332.5	1	05/25/12	3:00 AM	19	early neurulation
5/30/2012	RK 332.5	1	-	-	-	crushed, cannot tell anything, no accurate dia data
5/30/2012	RK 332.5	1	-	-	-	not viable (fungus covered) cannot tell if fert and died or was non-fertilized, no accurate size data
	Total	**59**				

Table 3. Summary of egg mat sample depths and green sturgeon egg sample depths recorded during the 2012 green sturgeon egg mat sampling season.

		Sample Depths (m)			GST Egg Sample Depths (m)		
Sample Location	**Microhabitat**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**
Cow Creek (RK 451)	Pool	2.4	5.5	8.7	-	-	-
Ink's Creek (RK 426)	Pool	3.7	8.1	12.8	5.5	10.5	11.2
Massacre Flats (RK 424.5)	Pool	3.7	7.3	13.1	3.7	7.3	8.6
GCID Hole (RK 332.5)	Pool/Glide	4.4	7.2	10.5	7.2	7.3	7.6

Table 4. Larval benthic D-net total sample effort, average net-set times, GST catch, net depth and water velocity for samples collected during 2012 larval green sturgeon sampling on the Sacramento River, CA.

					Depth (m)			Velocity (m/sec)		
Sample Type	**Sample Site**	**Effort (min)**	**Ave Set (min)**	**GST Catch**	**Min**	**Ave**	**Max**	**Min**	**Ave**	**Max**
Continuous	Bonnyview Bridge (RK 470)	2,236	31	0	2.6	4.1	4.5	0.3	0.6	0.8
Continuous	Jelly's Ferry Bridge (RK 430)	2,573	30	0	3.2	3.5	3.7	0.5	0.9	1.2
	Total	**4,809**								

Table 5. Juvenile benthic D-net total sample effort, average net-set times, GST catch, net depth and water velocity for samples collected during 2012 juvenile green sturgeon sampling on the Sacramento River, CA.

					Depth (m)			Velocity (m/sec)		
Sample Type	**Sample Site**	**Effort (min)**	**Ave Set (min)**	**GST Catch**	**Min**	**Ave**	**Max**	**Min**	**Ave**	**Max**
Continuous	Tehama Bridge (RK 369)	4,536	32	0	0.6	1.5	1.7	0.5	0.9	1.0
Continuous	Gianella Bridge (RK 320.6)	1,136	33	0	1.1	1.2	1.3	0.5	0.7	1.0
Exploratory	Below Gianella Bridge (RK 320.5)	2,303	32	0	0.7	2.2	4.7	0.5	1.0	1.5
	Total	**7,975**								

Figures

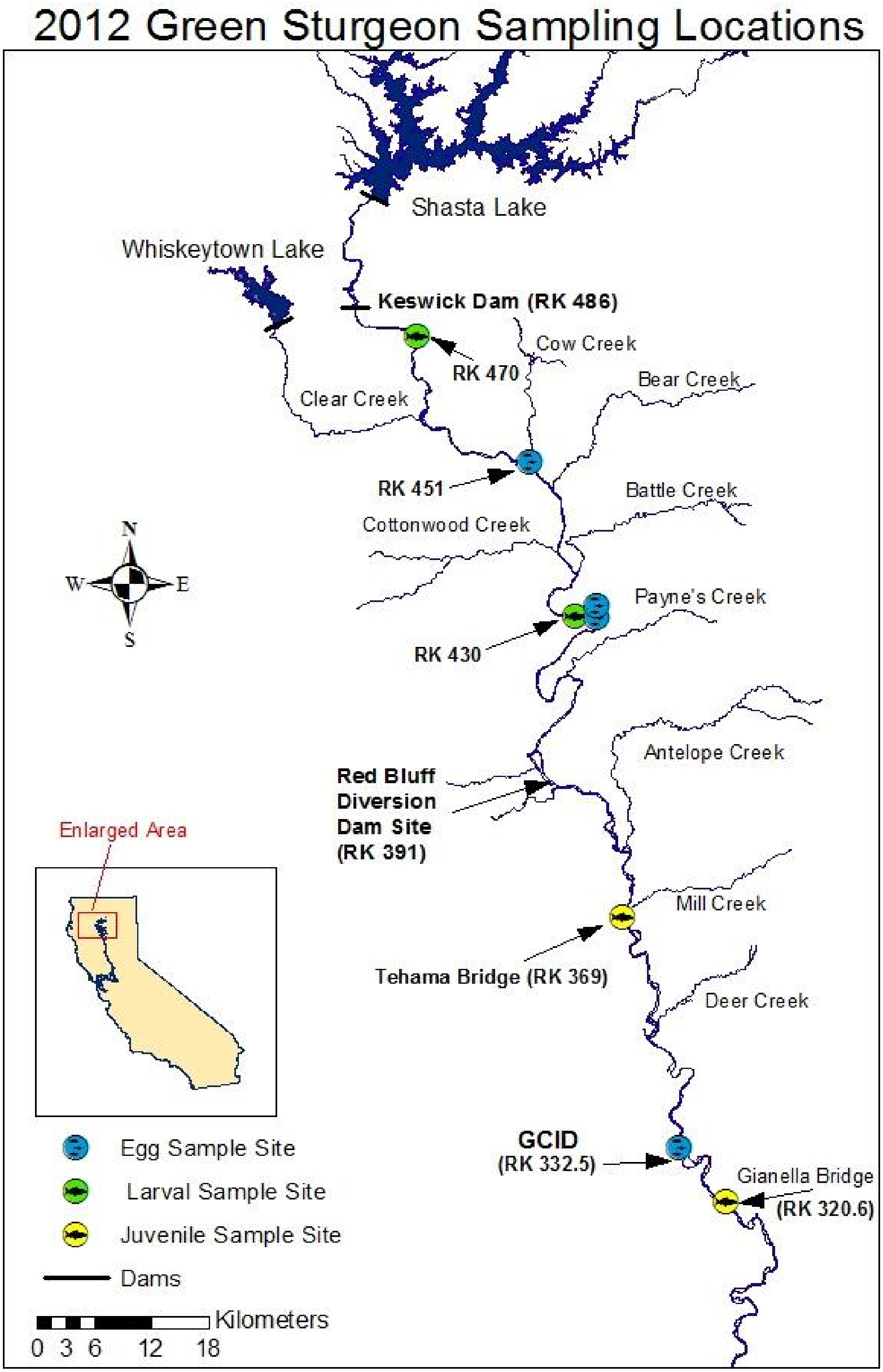


Figure 1. Green sturgeon egg, larval and juvenile sample sites on the upper Sacramento River, CA.

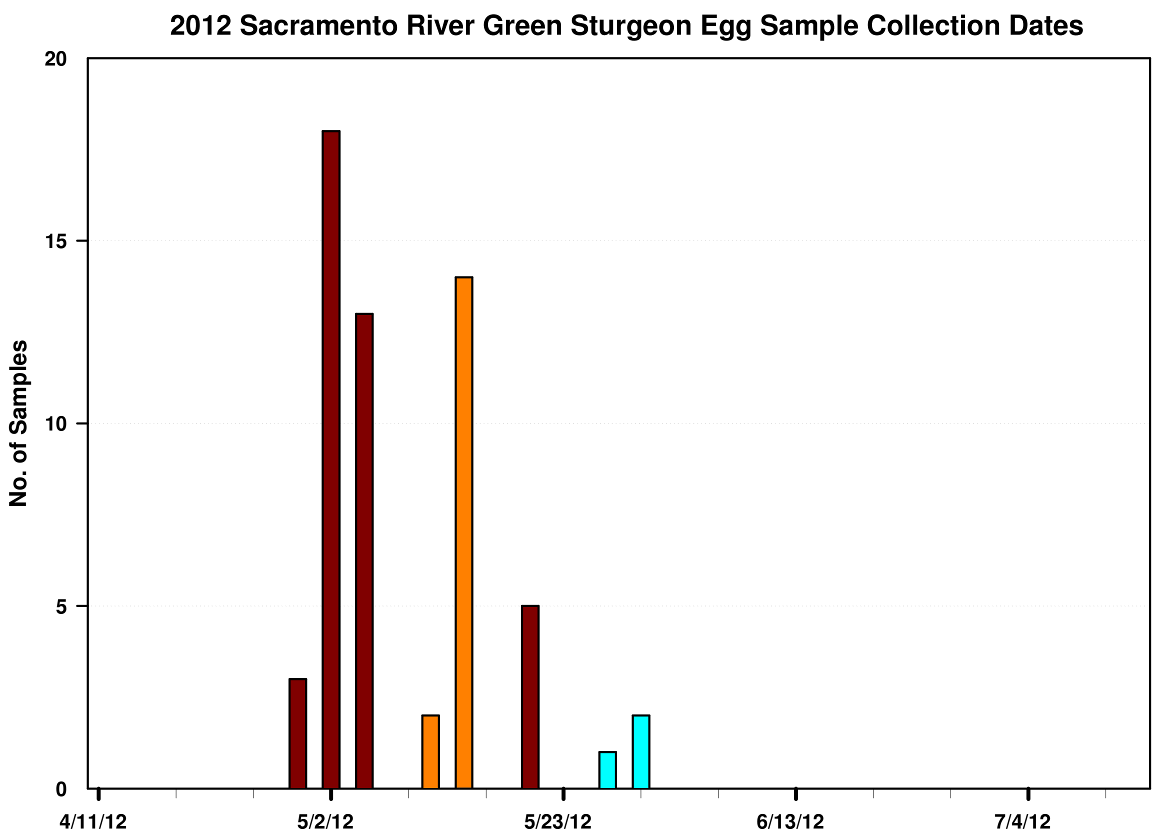


Figure 2. Temporal distribution of green sturgeon egg samples collected at Ink's Creek (RK 426; orange bars), Massacre Flats RK 424.5; red bars), and GCID Hole (RK 332.5; blue bars) on the Sacramento River, CA.

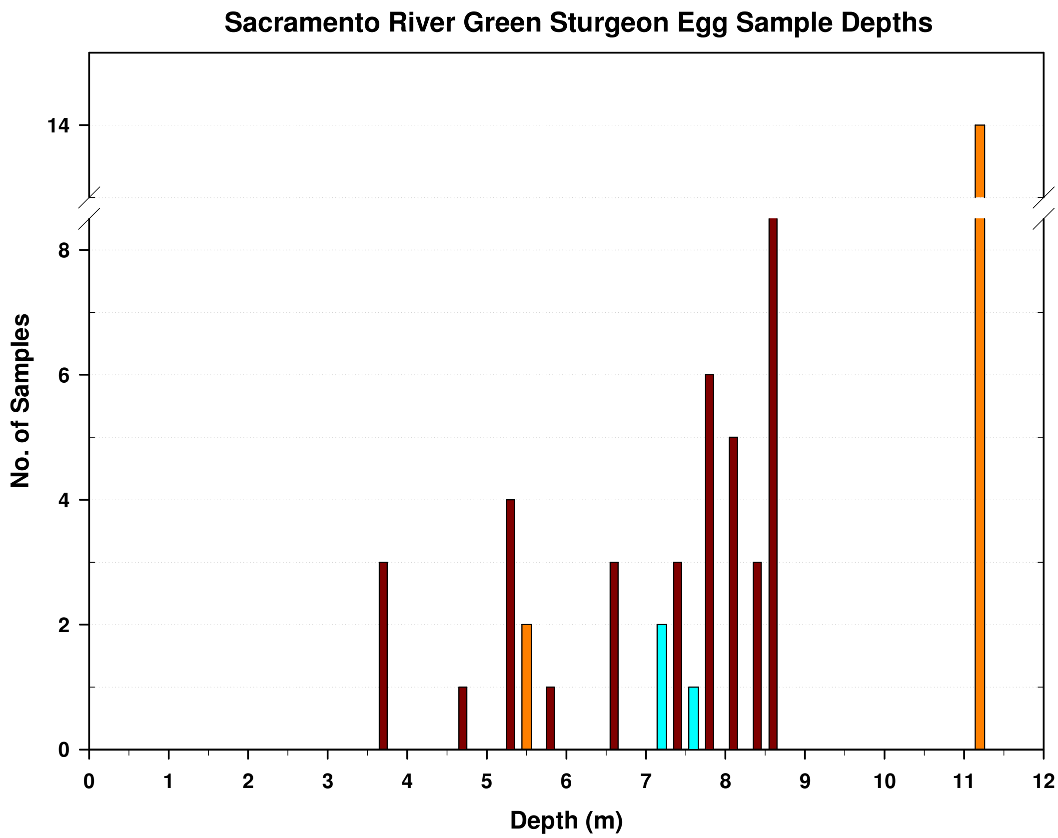


Figure 3. River depths of green sturgeon egg samples collected at Ink's Creek (RK 426; orange bars), Massacre Flats (RK 424.5; red bars), and GCID Hole (RK 332.5; blue bars) on the Sacramento River, CA for the period April 29 – May 30, 2012.

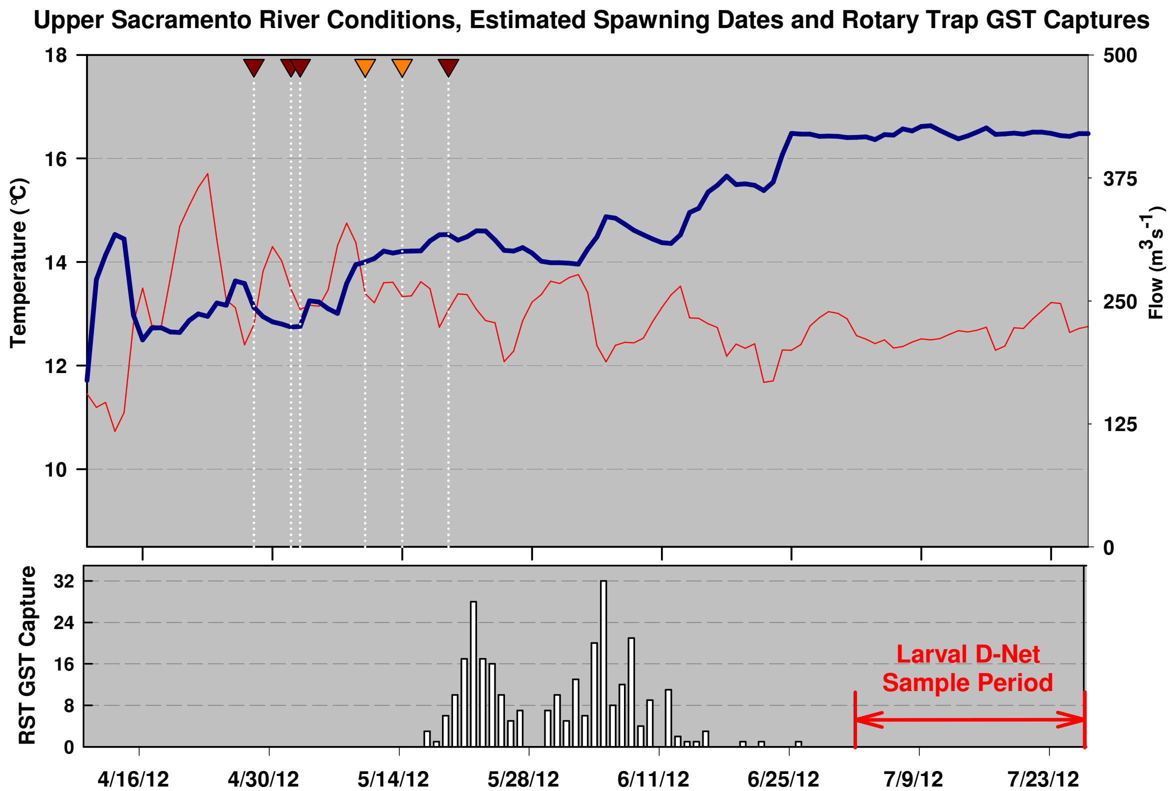


Figure 4. Sacramento River mean daily flow (dark blue) and temperature (red) at Bend Bridge gauging station. Inverted triangles indicate estimated spawning dates at Ink's Creek (RK 426; orange) and Massacre Flats (RK 424.5; dark red). Histogram (below) indicates the timing of green sturgeon larvae collected by rotary screw traps at Red Bluff Diversion Dam (RK 391) and larval D-net sampling period above RK 426.

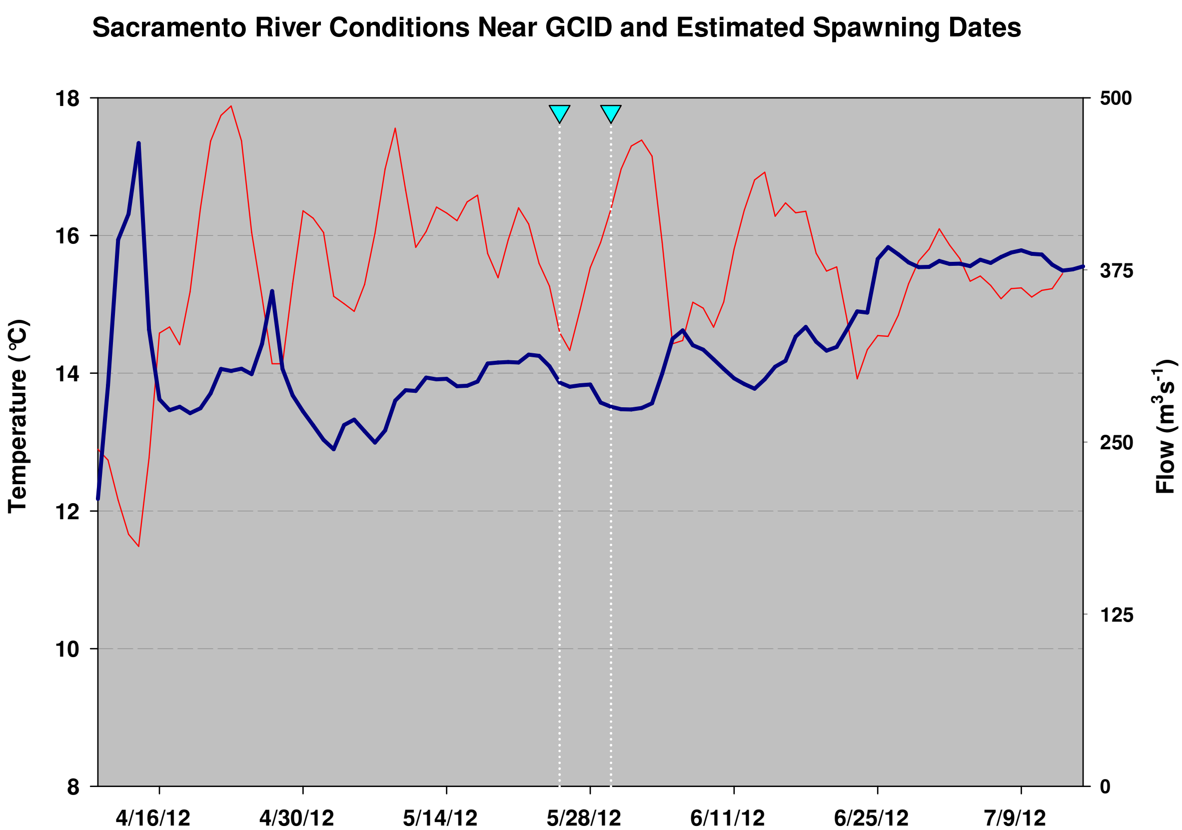
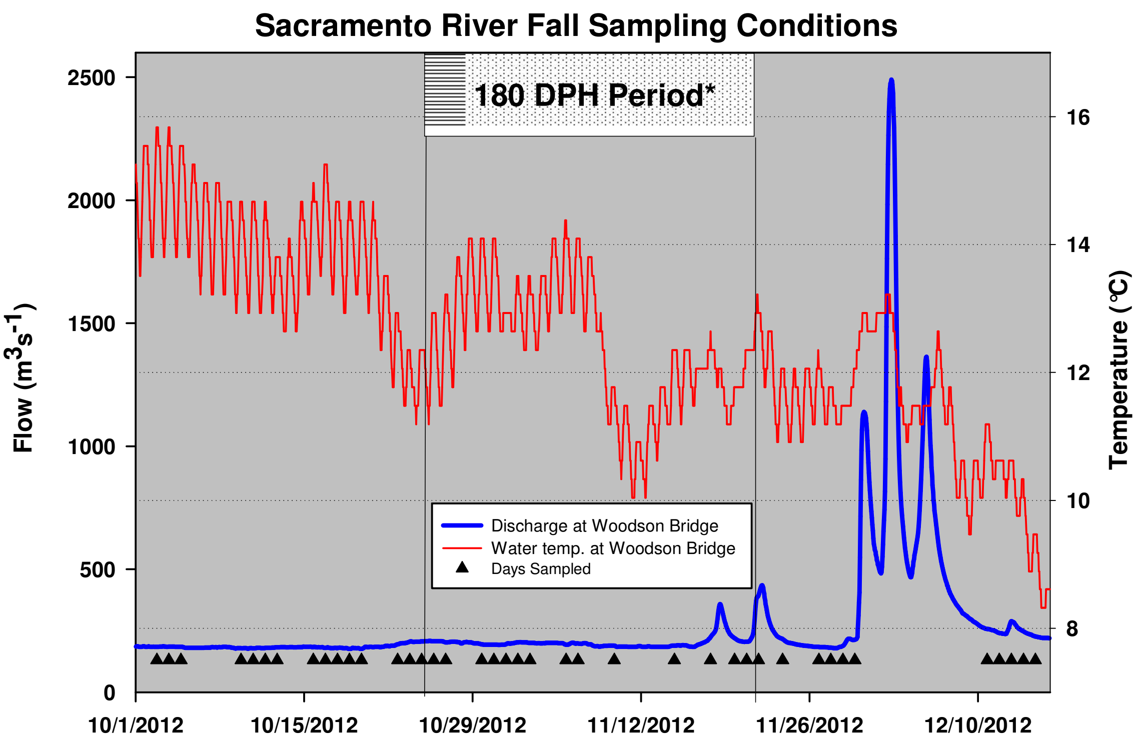


Figure 5. Sacramento River mean daily flow (dark blue) at Vina-Woodson Bridge Gauging Station and mean daily temperature (red) below GCID diversion. Inverted triangles indicate estimated spawning dates at GCID Hole (RK 332.5; light blue).



* Based on estimated spawning dates from eggs sampled during spring of 2012.

Figure 6. Sacramento River conditions during fall juvenile green sturgeon sampling efforts. D-net sampling occurred from October 2 through December 14 at Tehama Bridge (RK 369) and Gianella Bridge (RK 320.6) on alternating evenings.

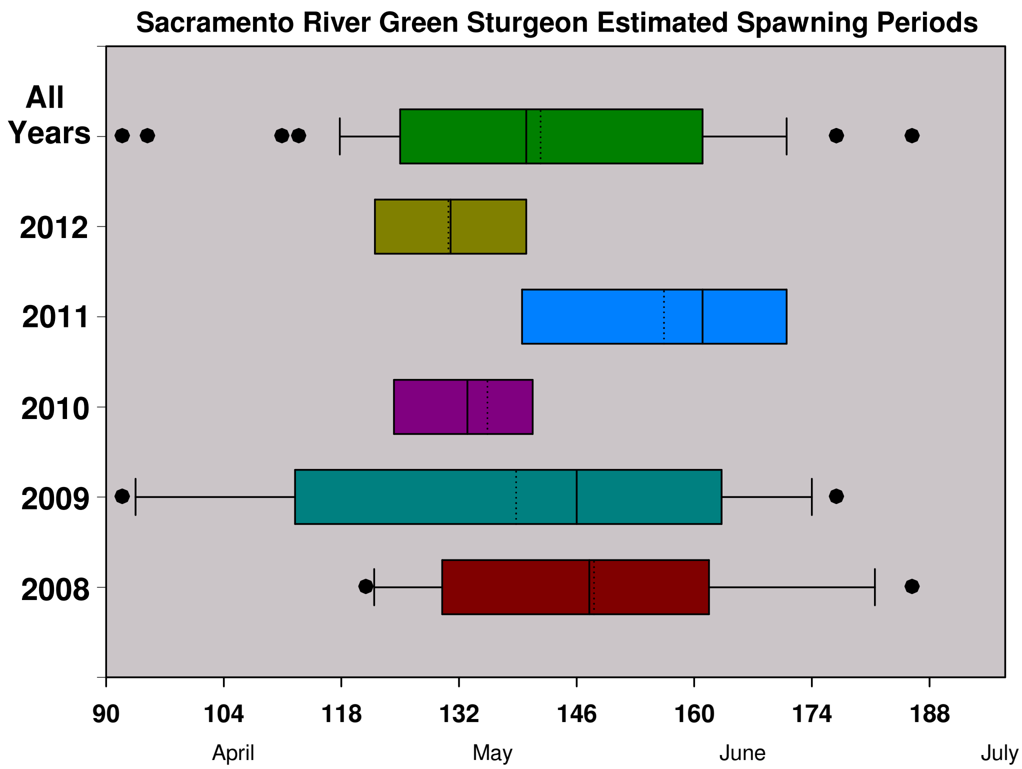


Figure 7. Boxplots displaying Julian days of median (line) and mean (dotted), 10^{th}, 25^{th}, 75^{th} and 90^{th} percentiles, and outliers of estimated spawning events derived from annual egg mat sample collections for the period 2008 through 2012.

Appendix

APPENDIX I (List of Tables)

Table **Page**

Appendix A1. Larval sampling benthic D-net incidental fish captures and disposition.

Fish Species	Alive*	Mortality*
Chinook Salmon	1	-
Cottid Spp. (fry)	5	-
Cyprinid Spp. (fry)	4	1
Lampretra Spp. (ammocoetes)	10	-
Rainbow Trout	27	2
Riffle Sculpin	1	-
Sacramento Sucker	6	-

* Released back to river at sample site

Appendix A2. Juvenile sampling benthic D-net incidental fish captures and disposition.

Sample Type	Sample Site	Species	Alive*	Mortality*
Continuous	Tehama Bridge (RK 369)	Chinook Salmon	14	-
Continuous	Tehama Bridge (RK 369)	Cyprinid Spp. (fry)	2	2
Continuous	Tehama Bridge (RK 369)	Lampetra Spp. (ammocoetes)	9	1
Continuous	Tehama Bridge (RK 369)	Sacramento Sucker	4	1
Continuous	Tehama Bridge (RK 369)	Three Spine Stickleback	1	1
Continuous	Gianella Bridge (RK 320.6)	Chinook Salmon	1	-
Continuous	Gianella Bridge (RK 320.6)	Cyprinid Spp. (fry)	11	2
Continuous	Gianella Bridge (RK 320.6)	Lampetra Spp. (ammocoetes)	10	-
Continuous	Gianella Bridge (RK 320.6)	Riffle Sculpin	1	-
Continuous	Gianella Bridge (RK 320.6)	Sacramento Sucker	9	4
Continuous	Gianella Bridge (RK 320.6)	Three Spine Stickleback	1	-
Anchored	Gianella Bridge (RK 320.5)	Chinook Salmon	3	-
Anchored	Gianella Bridge (RK 320.5)	Cyprinid Spp. (fry)	2	2
Anchored	Gianella Bridge (RK 320.5)	Lampetra Spp. (ammocoetes)	47	-
Anchored	Gianella Bridge (RK 320.5)	Riffle Sculpin	1	-
Anchored	Gianella Bridge (RK 320.5)	Sacramento Sucker	15	6
Anchored	Gianella Bridge (RK 320.5)	Three Spine Stickleback	1	-
Anchored	Gianella Bridge (RK 320.5)	Unidentified larva	1	-

* Released back to river at sample site