2011 San Joaquin River Sturgeon Spawning Survey

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Zachary J. Jackson
U.S. Fish and Wildlife Service

Joel P Van Eenennaam
University of California, Davis

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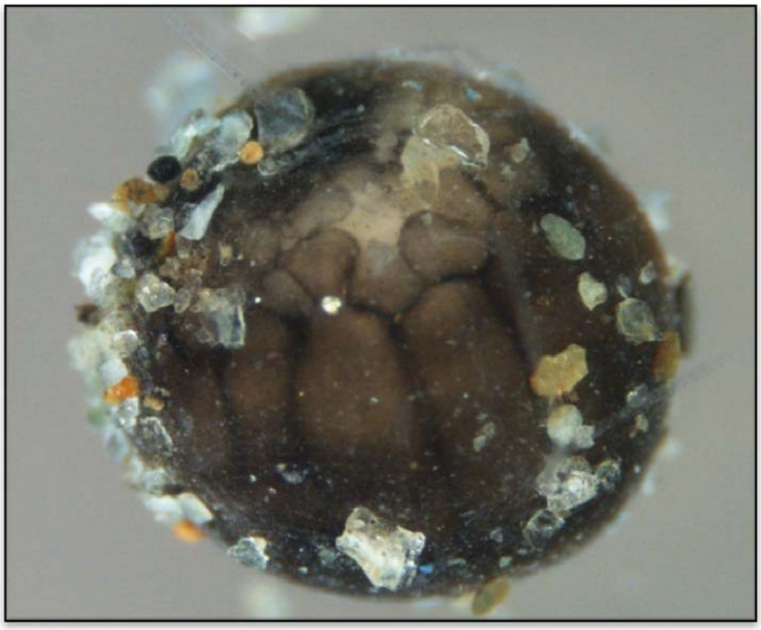
Final Annual Report



Prepared by:

Josh J. Gruber[1], Zachary J. Jackson[2]*, and Joel P. Van Eenennaam[3]

[1]U.S. Fish and Wildlife Service
Red Bluff Fish and Wildlife Office
10950 Tyler Road
Red Bluff, California 96080

[2]U.S. Fish and Wildlife Service
Stockton Fish and Wildlife Office
850 Guild Ave., Suite 105
Lodi, CA 95240

[3]University of California, Davis
Department of Animal Science
One Shields Avenue
Davis, California 95616-8521

*Corresponding author: Zachary_Jackson@fws.gov

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Cover Photo: White sturgeon egg sampled from the San Joaquin River on 25 April 2011 using artificial substrate samplers. Photo courtesy of University California, Davis using an Olympus dissecting microscope with a camera lucida.

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Preface

The following is the final report for the U.S. Fish and Wildlife Service's investigations on anadromous sturgeon spawning in the San Joaquin River between RK 119 and RK 148, funded by the Central Valley Project Improvement Act (CVPIA) Anadromous Fish Restoration Program in Fiscal Year 2011. Title 34, Section 3406(b)(1) of the CVPIA, Public Law 102-575, requires the Secretary of the Interior to develop within three years of enactment and implement a program which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991. Section 3406(b)(1) also states that "this goal shall not apply to the San Joaquin River between Friant Dam and the Mendota Pool."

The purpose of these investigations is to provide scientific information to the Central Valley Project Improvement Act Anadromous Fish Restoration Program to assist in developing restoration recommendations that will help meet program objectives and achieve its anadromous fish doubling goal.

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Josh J. Gruber

U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, 10950 Tyler Road, Red Bluff, California 96080, USA

Zachary J. Jackson

U.S. Fish and Wildlife Service, Lodi Fish and Wildlife Office, 850 Guild Ave., Suite 105, Lodi, CA 95240, USA

Joel P. Van Eenennaam

Department of Animal Science, University of California, One Shields Avenue, Davis, California 95616, USA

Abstract.— White sturgeon (*Acipenser transmontanus*) in the Sacramento-San Joaquin river system were previously known to spawn only in the Sacramento River within a 86 km reach between Knight's Landing (RK 145) and Colusa (RK 231). Several researchers have suggested that spawning may occur occasionally in the Feather and San Joaquin rivers. Our work provides the first documentation of spawning in the San Joaquin River, California. Artificial substrate samplers (i.e., egg mats) were deployed within a 29 km reach of the San Joaquin River from Sturgeon Bend (RK 119) to upstream of Laird Park (RK 148) from 18 April 2011 to 16 May 2011. During the sample period, 23 white sturgeon eggs were collected downstream of Laird Park at RK 142, 19 of which were viable and between developmental stages 9 and 27. Based upon capture location, date of capture, water temperature, stage of development, and the assumption that a female takes 12–20 hours to release all of her eggs, the eggs likely represent a single spawning event that began on 24 April 2011 at approximately 1300 hours. The results of this survey confirm that white sturgeon do spawn in the San Joaquin River and may be an important source of production for the white sturgeon population in the Sacramento-San Joaquin river system.

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Introduction

Sturgeon (*Acipenser* spp.) migration and spawning in California's Sacramento River system has been well documented by direct observation, angler catch, and detection of eggs, larvae, and young-of-the-year sturgeon (Kohlhorst 1976; Schaffter 1997; Beamesderfer et al. 2004; Poytress et al. 2009, 2010, 2011). Several researchers have speculated that sturgeon also spawn within the San Joaquin River system (Kohlhorst 1976; Schaffter 1997; Beamesderfer et al. 2004), but it has not been confirmed through any direct sampling activities. Numerous juvenile and larval sturgeon have been collected on the lower San Joaquin River (Beamesderfer et al. 2004), but these fish are believed to have entered the system from the Sacramento River through the lower Mokelumne River, Georgiana Slough, or the Three Mile Slough (Stevens and Miller 1970). California Department of Fish and Game (CDFG) concluded "based on movement of other fishes in the Delta, young green sturgeon found in the lower San Joaquin could easily, and most likely, come from the known spawning population in the Sacramento River" (CDFG 2002).

Information regarding sturgeon distribution in the San Joaquin River is limited to anecdotal reports and CDFG sturgeon report card data (Gleason et al. 2008; DuBois et al. 2009, 2010, 2011). Information regarding sturgeon habitat use and movements throughout the San Joaquin River is lacking, but critical to improve management and protection of these species. Angler fishing report cards (Gleason et al. 2008; DuBois et al. 2009, 2010, 2011) document a small sturgeon fishery in the reach of the San Joaquin River upstream from Stockton, California (RK 64.4; Figure 1). Since implementation of the Sturgeon Report Card in 2007, anglers have reported catching 158 white (*A. transmontanus*) and 6 green sturgeon (*A. medirostris*) on the San Joaquin River upstream from Stockton (Gleason et al. 2008; DuBois et al. 2009, 2010, 2011). Of the reported fish, 106 (67%) white and 5 (83%) green sturgeon were caught between Stockton and the Hwy 140 bridge (RK 202). The remaining 52 (33%) white and 1 (17%) green sturgeon were caught upstream from the Hwy 140 bridge. Reports indicated anglers concentrate in two areas locally known as Sturgeon Bend (RK 119) and Laird Park (RK 148; H. Rutherford, CDFG warden, personal communication). Additionally, anglers and game wardens indicate fish caught during March and April commonly expel milt or eggs during handling, indicating that spawning could be occurring nearby.

Sampling eggs and larvae of fishes is an important method to identify spawning and nursery areas (Heath and Walker 1987). Knowledge of these areas has been deemed critical to understanding the overall abundance of fish populations (Hjort 1914; May 1974; Hempel 1979). The primary focus of this study was to determine if sturgeon are spawning in the San Joaquin River by collecting fertilized sturgeon eggs on artificial substrate samplers.

Study Area

The San Joaquin River originates from the central Sierra Nevada and drains parts of the Sierra Nevada and Diablo ranges. It flows through 531 km of the state, first west towards the floor of the Central Valley of California, then north towards the Sacramento-San Joaquin Estuary, eventually reaching the Pacific Ocean. Friant Dam (RK 430.5) constructed in 1942, forms a complete barrier to upstream anadromous fish passage. Downstream of Friant Dam, the river encounters increasingly greater anthropogenic influence through water diversions and habitat alteration. Sampling occurred in a 29-km reach of the San Joaquin River from Sturgeon Bend (RK 119) to upstream of Laird Park (RK 148) and was concentrated in a 7-km reach near Laird Park in Stanislaus County, CA (Figure 1).

Methods

Sturgeon eggs were sampled by deploying artificial substrate samplers (i.e., egg mats) in close proximity to presumed spawning areas based on hydraulic conditions, side-scan sonar images, and angler and warden observations. Egg mats were constructed using two 89 x 65 cm rectangular sections of furnace filter material secured back to back within a welded steel framework (McCabe and Beckman 1990; Schaffter 1997; Poytress et al. 2009). The orientation of the furnace filter material allowed either side of the egg mat to collect eggs. Egg mats were held in position by a 2.0-kg anchor attached to the upstream end of the egg mat using two 76-cm lengths of 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.

Paired egg mats were placed in eight locations between Sturgeon Bend and upstream of Laird Park (Figure 1). Mats were predominantly deployed within pool microhabitats (i.e., areas flanking deepest portions of pools).

Environmental and sample effort data were 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, water temperature, river discharge, turbidity, egg mat depth, and weather condition. Hourly water temperature and discharge data for the lower sites (RK 119, 124, 131) were obtained from the U.S. Bureau of Reclamation (USBR) gauging station located near Vernalis, California through the California Data Exchange Center. Water temperature and discharge data from the upper sites (RK 141, 142, 144, 146, and 148) were obtained from the CDFG thermograph located downstream of Laird Park and California Data Exchange Center gauging station near Patterson, California, respectively. Sample effort data consisted of the date and time individual egg mats were set and retrieved.

Egg mat sampling consisted of visual inspection, generally twice a week, throughout the sample period. Paired egg mats were retrieved from the river after initial deployment, placed on the deck of a boat in a custom made egg mat carrier, and initially inspected on both sides by at least two field crew members. After initial inspection, egg mats were rinsed with water to remove debris and sediment and then re-inspected. Rinse water and debris were filtered by 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 egg mat inspection and inspection of the mesh nets, egg mats were redeployed.

Egg samples were counted and identified to species for each egg mat in the field using an egg key (Reyes et al. 2007; Wang 2010; Reyes 2011). Maximum egg lengths and widths were measured in the field using digital calipers (± 0.01 mm). All suspected sturgeon and unidentified eggs were placed into vials of 95% ethyl alcohol (EtOH) for laboratory identification and further analysis. Suspected sturgeon eggs were sent to the University of California, Davis (UCD) for 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. Representative photographs were taken with a Nikon DS-U1 digital camera connected to the microscope.

Spawn date was back-calculated using the egg collection date, developmental stage, and mean daily water temperature (Wang et al. 1985, 1987; Deng et al. 2002) recorded on a CDFG thermograph located downstream of Laird Park.

Results

Egg mats were deployed from 18 April to 16 May 2011 (Table 1) sampling a total of 183.2 wetted mat days (wmd; one mat set for 24 hours) between eight sample sites. Sampling was discontinued at the RK 119, 124, 131, 144, and 146 after two samples due to sampling difficulty in high river discharge. Sixty-nine percent (125.6 of 183.2 wmd) of the total sampling effort was expended on three sample sites in the area around Laird Park (RK 141, RK 142, and RK 148). Maximum sampling effort (26.6%; n = 48.7 wmd) was expended at the RK 142 sample site.

Twenty-three white sturgeon eggs were collected at RK 142 over a four-day period (25 April to 28 April 2011). One egg was destroyed during processing and 22 eggs were transferred to UCD for analysis. Eighty-three percent (n = 19) of the eggs were viable and staged (Table 2). Two eggs were likely fertilized and later died during embryogenesis. One egg appeared deformed (or died) at the neural tube formation (stage 19) and would not have been viable to hatch.

San Joaquin River discharge ranged from 154.5 to 417.5 $m^3 s^{-1}$ (μ = 283.9 $m^3 s^{-1}$) at the upper sites and 359.6 to 758.9 $m^3 s^{-1}$ (μ = 536.1 $m^3 s^{-1}$) at the lower sites throughout the sample period. Water temperatures ranged from 14.5 to 21.7 °C (μ = 18.0 °C) at the upper sites and 13.9 to 18.2 °C (μ = 15.9 °C) at the lower sites during the sample period. On days that eggs were collected river discharge and water temperature averaged 355.5 $m^3 s^{-1}$ and 18.5 °C at RK 142 (Figure 2). Turbidity grab samples ranged from 16.6 to 28.6 nephalometric turbidity units (NTU; μ = 21.7 NTU) among sites during the sample period. One turbidity sample (17.1 NTU) was taken on 28 April at RK 142 when eggs were collected.

Egg mats were deployed at river depths ranging from 4.3 to 12.3 m (μ = 7.6 m; Table 3). Egg samples were collected from mats deployed at depths ranging from 8.2 to 10.5 m with a weighted average depth of 9.6 meters.

Minimum and maximum egg diameter were measured in the field and lab on 83% (n = 19) and 87% (n = 20) of egg samples, respectively. Lab measurements were not taken on non-viable eggs (n = 2) because they began to degenerate, swell, and become covered in fungus, making accurate measurements of size impossible. In comparison, field egg measurements were slightly larger than laboratory measurements (post fixation; Table 4). Field length and width measurements averaged 3.48 and 3.18 mm, respectively. Laboratory length and width measurements averaged 3.30 and 3.08 mm, respectively. Discrepancies between measurements are likely a factor of the accuracy of the instrument used and shrinkage resulting from fixation in 95% ethyl alcohol.

Discussion

In April 2011, the collection of white sturgeon eggs documented white sturgeon spawning in the San Joaquin River. The developmental stage of collected eggs suggests the eggs were part of a single spawning event which began on 24 April 2011 at approximately 1300 hours. Based upon capture location, date of capture, water temperature, stage of development, and the assumption that it takes a female 12–20 hours to release all of her eggs, the eggs likely came from a single female. Eggs from this single spawning event were collected on both sides of the egg sampler over multiple days, consistent with the detection of green sturgeon eggs in the Sacramento River (Poytress et al. 2009, 2010, 2011). Assuming a single spawning event, it remains unknown whether incubating eggs are dislodged by subsequent placements of egg mats themselves or if incubating eggs drift downstream as the sediment they adhered to is transported naturally by the river current.

Mean daily water temperatures near the spawning site during the estimated spawn timing was 17.7 °C. This temperature is within preferred white sturgeon spawning temperatures reported on the Sacramento and lower Columbia rivers (Kohlhorst 1976; Parsley et al. 1993; McCabe and Tracy 1994). Mean daily water temperatures obtained from hourly readings at USBR Vernalis gauging station for water years 1999 through 2011 indicate mean daily water temperatures on the San Joaquin River are favorable for white sturgeon spawning between February and May before climbing above 18.0 °C (Figure 3). Kohlhorst (1976) detected 93% of white sturgeon spawning between March and April on the Sacramento River. Our delay in sampling, due to high flows, likely resulted in prior spawning events being undetected. Future egg sampling should be conducted between mid-February and mid-May to coincide with favorable spawning temperatures within the San Joaquin River and white sturgeon spawn timing on the Sacramento River.

Mean daily river discharge recorded on the Stanislaus River at Ripon, California and the Tuolumne River at Modesto, California between 18 April to 16 May 2011 account for at least one third of the total San Joaquin river mean daily discharge recorded at the Vernalis Gauging station during our sample period. Water temperatures during our sample period ranged from 14.5 to 21.7 °C (μ = 18.0 °C) and 13.9 to 18.2 °C (μ =15.9 °C) at the upper and lower sites, respectively. Cold water inputs from the Stanislaus and Tuolumne rivers at RK 121 and 134, respectively, represented nearly 40% of the San Joaquin River discharge at Vernalis during our sample period resulting in a decrease of 2.1 °C in mean daily water temperature from the upper (RK 143) to lower (RK 119) sample sites (Table 5; Figure 4).

The contributions of these two rivers provide cold water important in maintaining optimal spawning temperatures within the lower San Joaquin River and white sturgeon may be utilizing these areas as spawning habitat.

Egg sampling was initially intended to target areas surrounding Sturgeon Bend (RK 119) and Laird Park (RK 143) based upon prior years angler reports. High flows and associated debris limited our ability to sample near the Sturgeon Bend (RK 119). Numerous deep pools containing high water velocities are located within the 24 river kilometers between these two sample sites. Researchers commonly rely on spatial and temporal habitat information obtained from radio and acoustic tagged sturgeon to direct placement of egg mats (Poytress et al. 2009, 2010, 2011). That information on the San Joaquin River is lacking, making placement of egg samplers more difficult. Significant effort should be designated to implant acoustic transmitters in sturgeon within the San Joaquin River upstream of Sherman Lake to reveal areas used by sturgeon for holding and spawning activities.

CDFG Sturgeon Report Card data indicates six green sturgeon were caught within the San Joaquin River upstream of Stockton, five of which were caught in March and April (Gleason et al. 2008; DuBois et al. 2009, 2010, 2011). Although the data indicates the presence of a limited number of green sturgeon, it is possible that some fish go unreported (e.g., poaching; Beamesderfer et al. 2004) or a proportion of the 143 reported white sturgeon may be misidentified. It remains unknown how and to what extent green sturgeon use the San Joaquin River. However, their reported presence coincides with the spawning migration of the Southern Distinct Population Segment of green sturgeon within the Sacramento River (Poytress et al. 2009, 2010, 2011). Although there is a slight temporal overlap in spawn timing between white and green sturgeon (Kohlhorst 1976; Poytress et al. 2009), no documentation exists where these two sturgeon species spawn in close proximity to each other. A factor that may be driving this is turbidity. Generally, green sturgeon spawn in areas where turbidity is less than 10 NTU (Poytress et al. 2009, 2010, 2011). Conversely, white sturgeon spawn in areas that are generally turbid in nature (μ = 42 NTU; Perrin et al. 2003). Average turbidity values in the study reach were 22 NTU. Because of elevated turbidity levels in the San Joaquin River we hypothesize that any green sturgeon on a spawning run within the San Joaquin River system may be seeking out less turbid water upstream or within one of the tributaries to the San Joaquin River. Therefore, focusing future egg sampling efforts between RK 119 and RK 148 may limit the ability to detect spawning green sturgeon in the San Joaquin River.

In addition to egg sampling, larval sampling with a benthic D-net has been accepted as an effective method to document the spawn timing of sturgeon species (Kohlhorst 1976). Although larval samples will not provide information on specific spawning locations, methods used in Dettlaff et al. (1993) can be used to estimate spawn timing. The bridge abutments at the Airport Way (RK 115.5) and Grayson Road (RK 143) crossings provide an ideal tie-off location for larval D-net sampling of white sturgeon aggregates at Sturgeon Bend (RK 119) and Laird Park (RK 143), in addition to a known spawning location at RK 142. Larval sampling at these two locations would provide the opportunity for detection of larval green sturgeon dispersing from speculated spawning locations within the Stanislaus, Tuolumne, Merced, or upper San Joaquin rivers. Furthermore, without documentation of larval white sturgeon in the San Joaquin River above Mossdale, it is unknown if spawning events within the San Joaquin River are a source of larval production for the Sacramento-San Joaquin white sturgeon population.

Average daily discharge in the San Joaquin River in early 2011 was two to three times higher than the mean daily discharge for water years 1991 to 2010 (Figure 5). As speculated by researchers, river discharge levels of this magnitude triggered white sturgeon to enter and spawn within the San Joaquin River System. Additional egg and larval sampling, in conjunction with acoustic tracking, should to be continued throughout a variety of water year types to better understand the spatial and temporal distribution and habitat preferences of white sturgeon in the San Joaquin River.

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Literature Cited

Beamesderfer, R., M. Simpson, G. Kopp, J. Inman, A. Fuller, and D. Demko. 2004. Historical and current information on green sturgeon occurrence in the Sacramento and San Joaquin rivers and tributaries. S.P. Cramer & Associates, Inc for State Water Contractors, Sacramento, California.

California Department of Fish and Game. 2002. California Department of Fish and Game comments to NMFS regarding green sturgeon listing. California Department of Fish and Game, Sacramento, California.

Deng, X., J. P. Van Eenennaam, and S. I. Doroshov. 2002. Comparison of early life stages and growth of green and white sturgeon. Pages 237—248 *in* W. Van Winkle, P. J. Anders, D. H. Secor, and D. A. Dixon, editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

Dettlaff, T. A., A. S. Ginsburg, and O. I. Schmalhausen. 1993. Sturgeon fishes: developmental biology and aquaculture. Springer-Verlag, New York.

DuBois, J., M. Gingras, and R. Mayfield. 2009. 2008 sturgeon fishing report card: preliminary data report. California Department of Fish and Game, Stockton, California.

DuBois, J., B. Beckett, and T. Matt. 2010. 2009 sturgeon fishing report card: preliminary data report. California Department of Fish and Game, Stockton, California.

DuBois, J., T. Matt, and T. MacColl. 2011. 2010 sturgeon fishing report card: preliminary data report. California Department of Fish and Game, Stockton, California.

Gleason, E., M. Gingras, and J. DuBois. 2008. 2007 sturgeon fishing report card: preliminary data report. California Department of Fish and Game, Stockton, California.

Heath, M. R., and J. Walker. 1987. A preliminary study of the drift of larval herring (*Clupea harengus L.*) using gene-frequency data. Journal du Conseil International pour l'exploration de la Mer 43:139–145.

Hempel, G., 1979. Early life history of marine fish: the egg stage. University of Washington Press, Seattle.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapports et Proces-verbaux des Réunions. Conseil International pour I'Éxploration de la Mer 20: 1–228.

Kohlhorst, D. W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Department of Fish and Game 62:32–40.

May, R. C. 1974. Larval mortality in marine fishes and the critical period concept. Pages 3—19 *in* J. H. S. Blaxter, editor. The early life history of fish. Springer-Verlag, New York.

McCabe, G. T., and L. G. Beckman. 1990. Use of an artificial substrate to collect white sturgeon eggs. California Department of Fish and Game 76(4):248–250.

McCabe, G. T., Jr., and C. A. Tracy. 1994. Spawning and early life history of white sturgeon, *Acipenser transmontanus*, in the lower Columbia River. Fisheries Bulletin 92:760–772.

Moyle, P. B. 2002. Inland fishes of California, 2nd edition. University of California Press, Berkeley, California.

Parsley, M. J., L. C. Beckman, and C. T. McCabe, Jr. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream from McNary Dam. Transactions of the American Fisheries Society 122:217–227.

Perrin, C. J., L. L. Rempel, M. L. Rosenau. 2003. White sturgeon spawning habitat in an unregulated river: Fraser River, Canada. Transactions of the American Fisheries Society 132:154–165.

Poytress, W. R., J. J. Gruber, D. A. Trachtenbarg, and J. P. Van Eenennaam. 2009. 2008 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, California.

Poytress, W. R., J. J. Gruber, and J. P. Van Eenennaam. 2010. 2009 upper Sacramento River green sturgeon spawning habitat and larval migration surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, California.

Poytress, W. R., J. J. Gruber, and J. P. 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 U.S. Bureau of Reclamation, Red Bluff, California.

Reyes, R. C., B. W. Bird, and P. F. Raquel. 2007. Guide to the fishes of the Tracy Fish Collection Facility. U.S. Department of Interior, Bureau of Reclamation, Tracy Series Volume 36.

Reyes, R. C. 2011. Dichotomous key to fish eggs of the Sacramento-San Joaquin river delta. U.S. Department of Interior, Bureau of Reclamation, Tracy Technical Bulletin 2011-1.

Schaffter, R. G. 1997. White sturgeon spawning migrations and location of spawning habitat in the Sacramento River, California. California Fish and Game 83:1–20.

Stevens, D. E., and L. W. Miller. 1970. Distribution of sturgeon larvae in the Sacramento-San Joaquin river system. California Fish and Game 56(2):80–86.

Wang, Y. L., R. K. Buddington, and S. I. Doroshov. 1987. Influence of temperature on yolk utilization by the white sturgeon, *Acipenser transmontanus*. Journal of Fish Biology 30:263–271.

Wang, J. C. S. 2010. Fishes of the Sacramento-San Joaquin river delta and adjacent waters, California: a guide to early life histories. U.S. Department of Interior, Bureau of Reclamation, Tracy Series Volume 44 Special Publication.

Tables

Table 1. Location of sites sampled on the San Joaquin River, California, by river kilometer (RK), sampling date, effort in wetted mat days, and the proportion of effort at each site in relation to total effort expended during 2011 egg mat sampling. A wetted mat day is equivalent to one mat set for 24 hours.

Sample Site	Sample Dates	Wetted Mat Days	% Effort
RK 119	18 April - 25 April	10.5	5.8%
RK 124	18 April - 25 April	13.6	7.4%
RK 131	18 April - 25 April	13.7	7.5%
RK 141	18 April - 16 May	37.2	20.3%
RK 142	21 April - 16 May	48.7	26.6%
RK 144	21 April - 16 May	14.2	7.7%
RK 146	25 April - 28 April	5.5	3.0%
RK 148	25 April - 16 May	39.7	21.7%
Total Effort	18 April - 16 May	183.2	100.0%

Table 2. Size, estimated spawn timing, and developmental stage of white sturgeon eggs collected on the San Joaquin River, California during 2011.

Sample		Egg Diameter		Spawning		Developmental	
Date	Vial #	Min	Max	Date	Hour	Stage	Comments
25 April	11-001	2.794	3.063	25 April	0100	10	late cleavage
25 April	11-002	3.099	3.388	25 April	0300	09	64-cell
25 April	11-003	2.945	3.103	25 April	0100	10	late cleavage
25 April	11-004	3.130	3.516	25 April	0300	09	64-cell
25 April	11-005	3.448	3.499	25 April	0100	10	late cleavage
25 April	11-006	2.958	3.116	25 April	0100	10	late cleavage
25 April	11-007	2.977	3.201	25 April	0100	10	late cleavage
25 April	11-008	2.983	3.208	25 April	0100	10	late cleavage
25 April	11-009	2.898	3.110	24 April	2300	11	early blastula
25 April	11-010	3.006	3.251	24 April	2300	11	early blastula
25 April	11-011	2.905	3.220	25 April	0100	10	late cleavage
25 April	11-012	2.899	3.103	25 April	0100	10	late cleavage
25 April	11-013	3.014	3.601	25 April	0100	10	late cleavage
25 April	11-014	3.090	3.104	24 April	2300	11	early blastula
25 April	11-015	3.099	3.368	24 April	2300	11	early blastula
27 April	11-016	3.268	3.532	24 April	1500	19	early neurulation
27 April	11-017	3.166	3.179	24 April	1500	19	early neurulation
27 April	11-018	3.194	3.316	24 April	1500	19	early neurulation
28 April	11-019	3.343	3.553	24 April	1300	27	short cardiac tube, tail bud
28 April	11-020	-	-	25 April	-	-	fungus dead egg = dia. not accurate, cannot tell stage
28 April	11-021	3.331	3.587	25 April	-	-	deformed or arrested embryonic develop., not viable
28 April	11-022	-	-	25 April	-	-	fungus dead egg = dia. not accurate, cannot tell stage

***Spawning date and time was estimated by back-calculation based on the developmental stage of embryogenesis (Dettlaff et al. 1993), developmental rates of white sturgeon (Deng et al. 2002), and daily water temperatures near Laird Park on the San Joaquin River.

Table 3. Description of sites sampled with egg mats during 2011 in the San Joaquin River, California. Sample sites expressed as river kilometers (RK), depths (m) sampled at each site throughout the season, and depth (m) of mats that collected white sturgeon eggs.

Sample Site	Sample Depths (m)			White Sturgeon Egg Sample Depths (m)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
RK 119	9.2	12.3	10.3	-	-	-
RK 124	6.3	10.1	8.1	-	-	-
RK 131	5.5	10.1	7.1	-	-	-
RK 141	4.6	9.2	7.3	-	-	-
RK 142	4.8	11.1	8.2	8.2	10.5	9.6
RK 144	5.4	7.8	6.0	-	-	-
RK 146	6.6	7.4	7.0	-	-	-
RK 148	4.3	12.2	7.1	-	-	-

Table 4. Measurements (mm) from live white sturgeon eggs processed in the field and processed in the laboratory after fixation in ethyl alcohol.

	Mean ± SD (mm)		**Min-Max (mm)**	
	Length	**Width**	**Length**	**Width**
Field	3.48 ± 0.29	3.18 ± 0.28	3.00 – 4.02	2.75 – 3.68
Lab	3.30 ± 0.198	3.08 ± 0.17	3.06 – 3.60	2.79 – 3.45

Table 5. Mean daily river discharge ($m^3 s^{-1}$) on the San Joaquin River near Patterson (SJRP), Stanislaus River at Ripon (SRR), Tuolumne River at Modesto (TRM), San Joaquin River near Vernalis (SJRV), and proportion of San Joaquin River discharge at Vernalis contributed by tributary inputs [((SRR+TRM)/SJRV)*100); tributary contribution] between 18 April and 16 May 2011. River discharge data queried by station on California Data Exchange Center website.

	River Discharge* by Location ($m^3 s^{-1}$)				
Date	**SJRP**	**SRR**	**TRM**	**SJRV**	**Tributary Contribution**
18-Apr-11	417	81	223	754	40%
19-Apr-11	400	81	218	739	40%
20-Apr-11	390	81	209	723	40%
21-Apr-11	382	75	199	705	39%
22-Apr-11	376	70	191	683	38%
23-Apr-11	371	70	185	666	38%
24-Apr-11	365	70	176	653	38%
25-Apr-11	355	71	168	641	37%
26-Apr-11	349	71	160	630	37%
27-Apr-11	335	71	157	614	37%
28-Apr-11	326	70	157	600	38%
29-Apr-11	319	70	153	586	38%
30-Apr-11	309	64	138	571	35%
1-May-11	301	58	123	546	33%
2-May-11	286	57	111	519	32%
3-May-11	272	57	108	494	33%
4-May-11	260	57	107	471	35%
5-May-11	253	56	105	454	36%
6-May-11	248	56	111	442	38%
7-May-11	242	56	115	441	39%
8-May-11	235	56	116	439	39%
9-May-11	232	56	116	434	40%
10-May-11	203	57	115	425	40%
11-May-11	187	57	112	414	41%
12-May-11	176	57	107	401	41%
13-May-11	168	57	99	388	40%
14-May-11	163	56	95	377	40%
15-May-11	156	57	97	371	42%
16-May-11	155	57	96	366	42%

*River discharge data queried by station from California Data Exchange Center (http://cdec.water.ca.gov/)

Figures

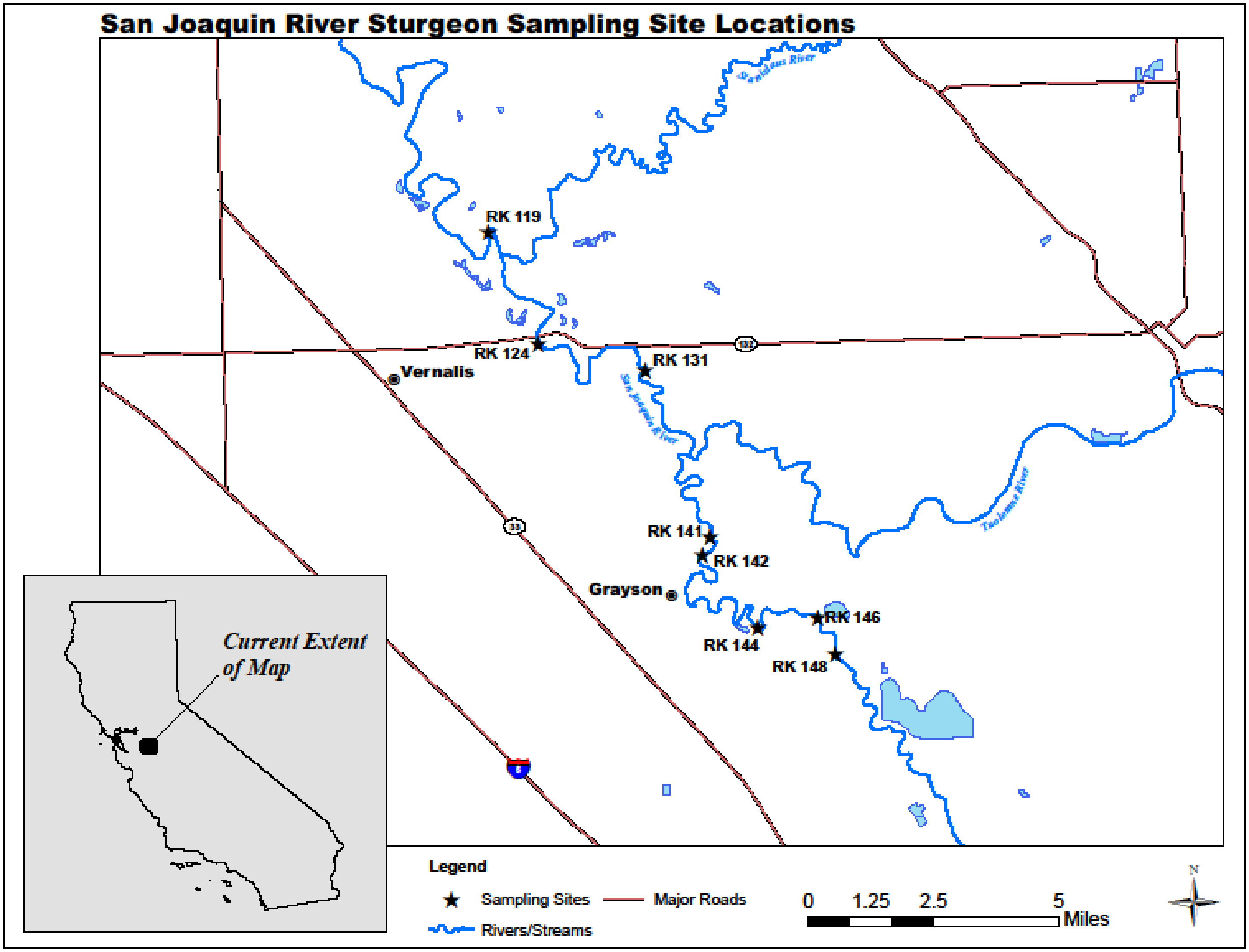

Figure 1. Location of egg mat sample sites on the San Joaquin River, California between Sturgeon Bend (RK 119) and upstream of Laird Park (RK 148).

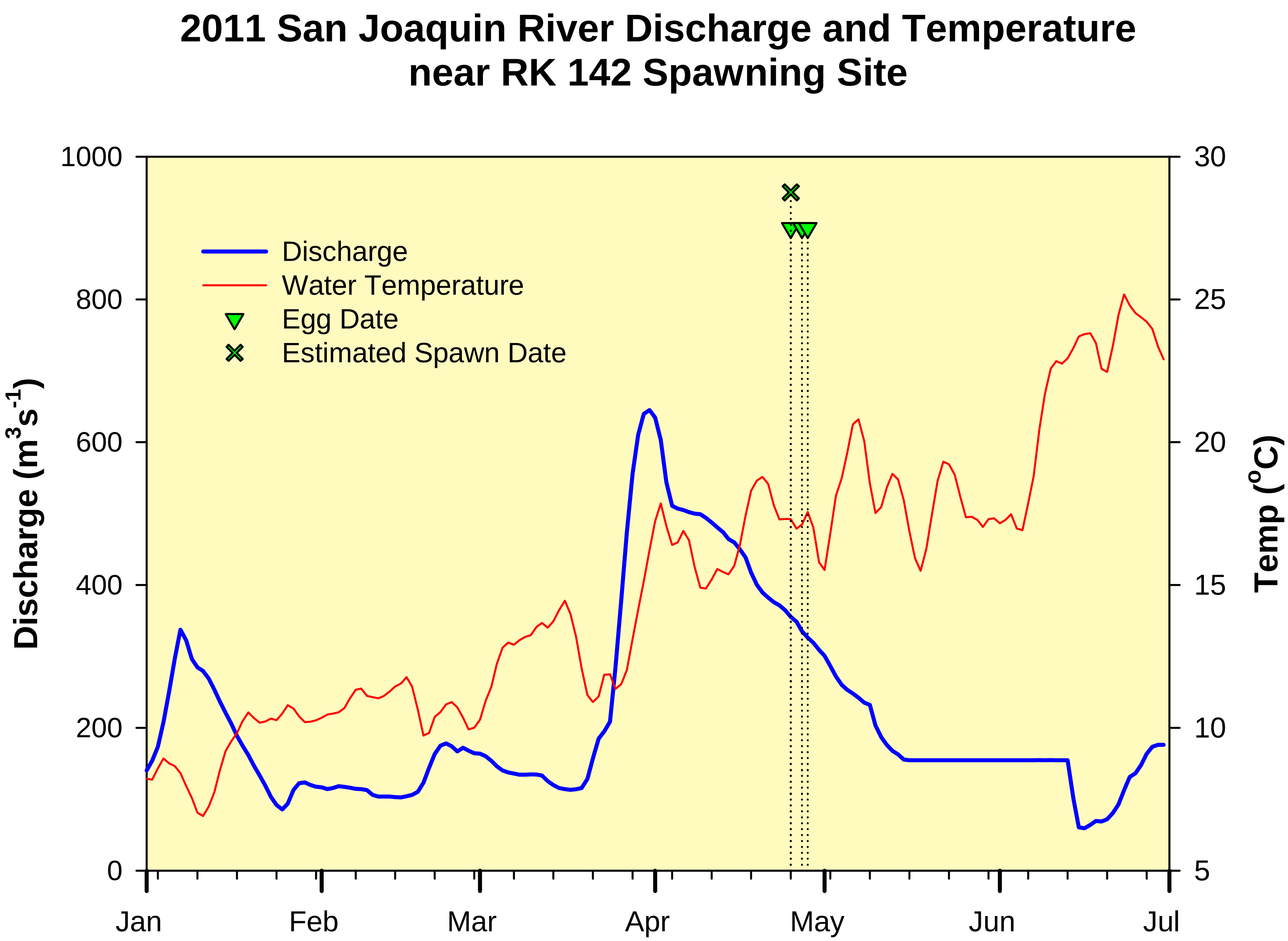

Figure 2. Mean daily discharge ($m^3\ s^{-1}$) and water temperature (°C) observed in 2011 on the San Joaquin River near RK 142. Green triangles represent dates when white sturgeon eggs were collected. The green *X* indicates the estimated spawn date for the 23 eggs collected at RK 142. Discharge and temperature measurements were obtained from the California Data Exchange Center gauging station near Patterson, California and California Department of Fish and Game thermograph near Laird Park, respectively.

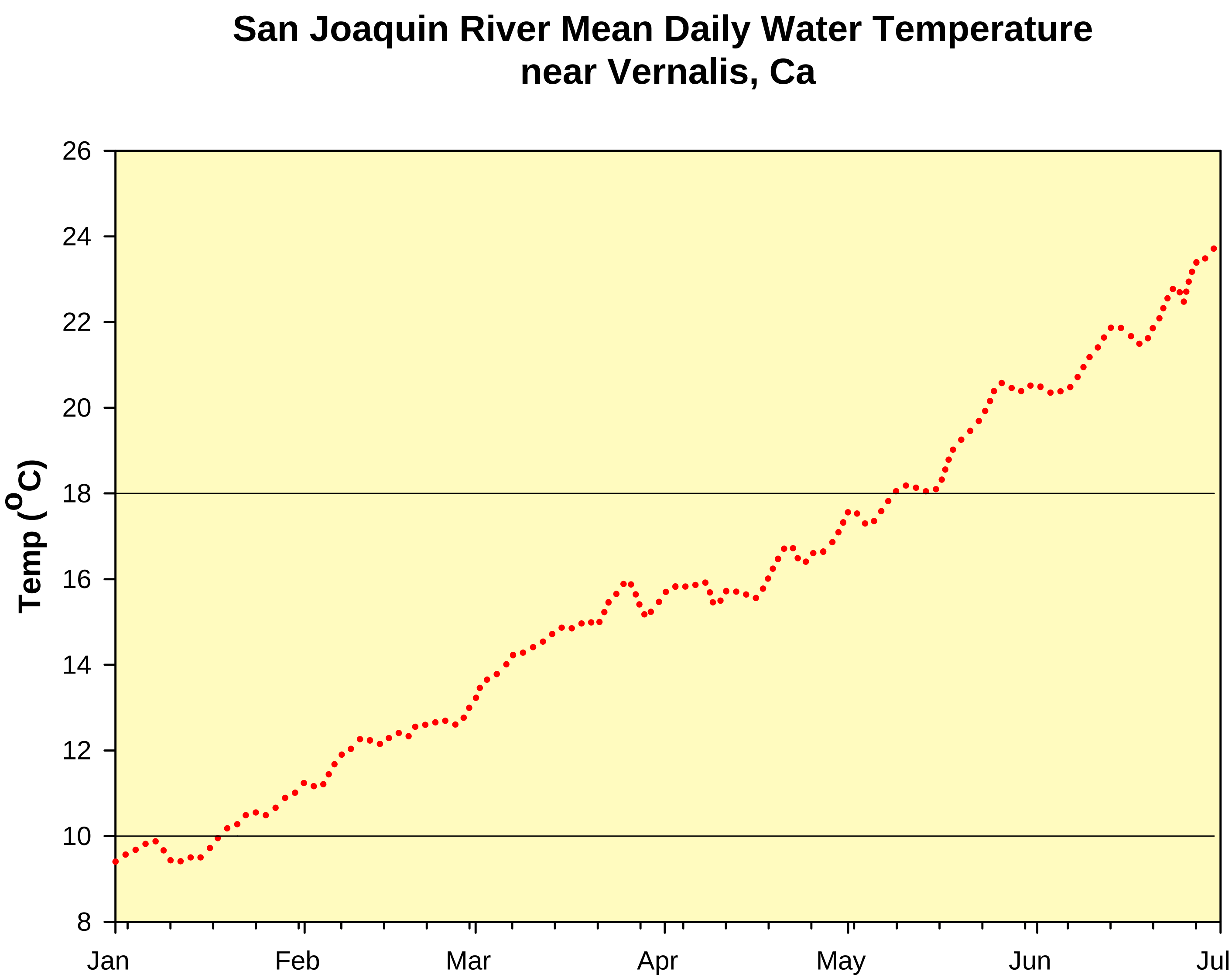

Figure 3. San Joaquin River mean daily water temperature (°C) recorded at the U.S. Bureau of Reclamation gauging station near Vernalis, California from 26 February 1999 to 1 July 2011. Horizontal bars indicate upper and lower optimal spawning temperatures for white sturgeon (Parsley et al., 1993; McCabe and Tracy 1994).

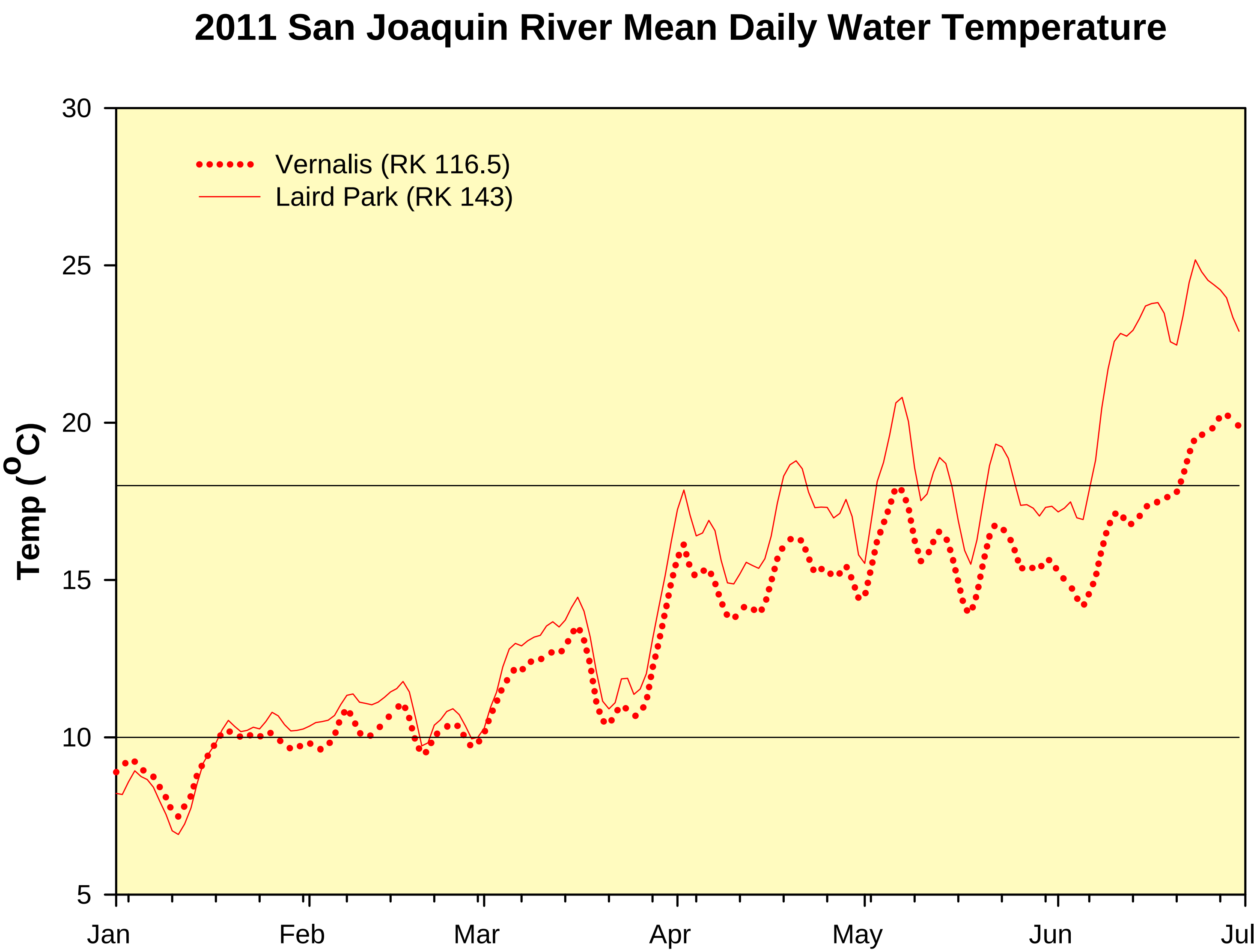

Figure 4. San Joaquin River mean daily water temperature (°C) during 2011 recorded at RK 116.5 and RK 143 by U.S. Bureau of Reclamation gauging station and California Department of Fish and Game thermograph, respectively. Horizontal bars indicate upper and lower optimal spawning temperatures for white sturgeon (Parsley et al., 1993; McCabe and Tracy 1994).

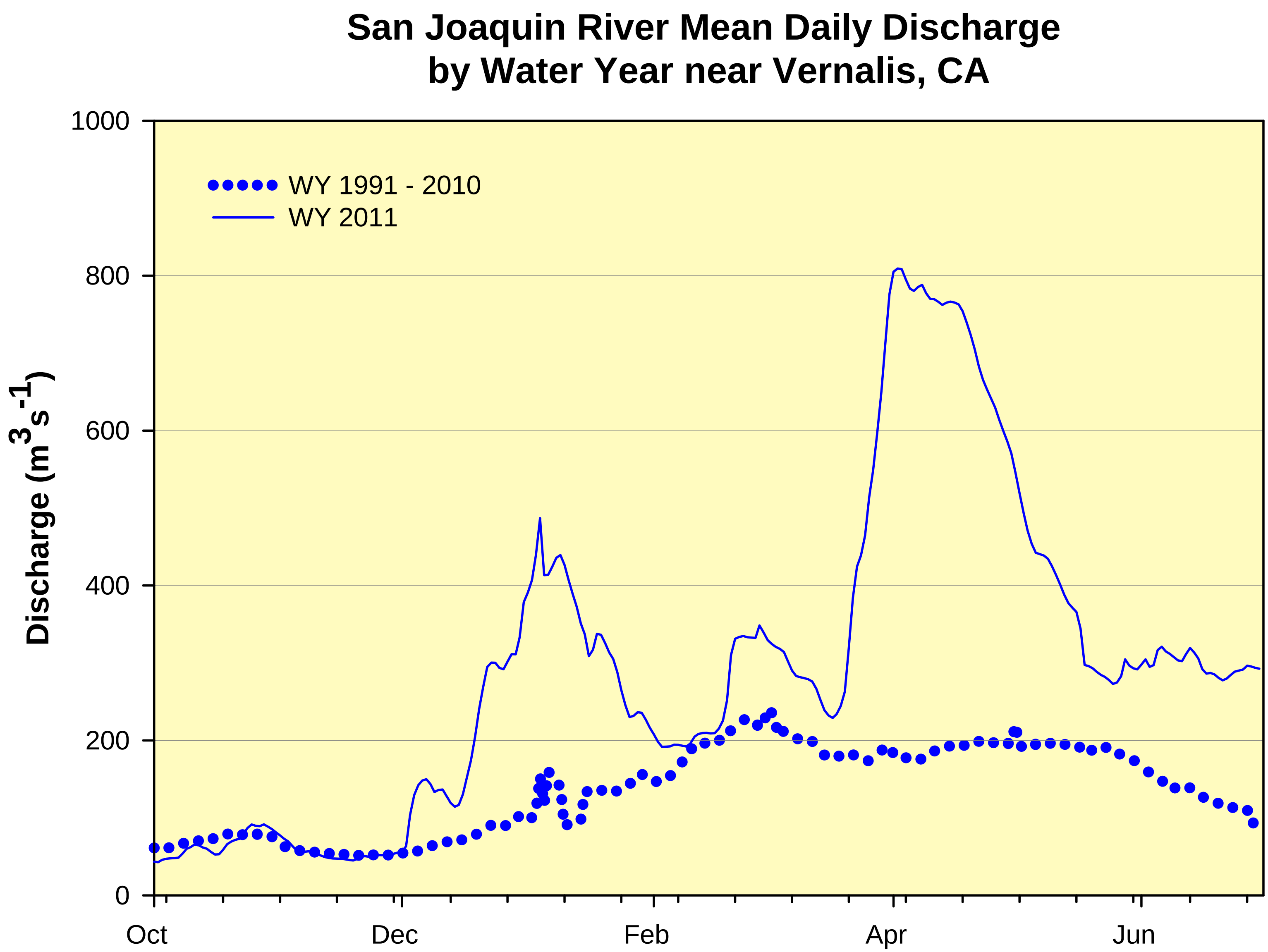

Figure 5. San Joaquin River mean daily discharge ($m^3 s^{-1}$) by water year at the California Data Exchange Center gauging station near Vernalis, California.