EVIDENCE OF SPAWNING BY GREEN STURGEON *Acipenser medirostris* IN THE UPPER SACRAMENTO RIVER, CALIFORNIA

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Kurtis Brown

U.S. Fish and Wildlife Service
Red Bluff Fish and Wildlife Office
10950 Tyler Road,
Red Bluff, California 96080 (email: Kurtis_Brown@fws.gov)

Synopsis— This study reports the only direct evidence of spawning of green sturgeon, *Acipenser medirostris*, in the upper Sacramento River using artificial substrates and larval nets. Two green sturgeon eggs were collected with substrate mats immediately below Red Bluff Diversion Dam. One green sturgeon larva was collected with the larval net at Bend Bridge. We concluded that green sturgeon spawn in the upper Sacramento River, both above and below RBDD. Temperature ranges in the study area (10-15^{0}C) are similar to conditions used in successful artificial rearing of green sturgeon and do not appear to be a limiting factor to successful spawning of green sturgeon. However suitable habitat upstream of RBDD is inaccessible when dam gates are lowered.

Introduction

The green sturgeon, *Acipenser medirostris,* is the most widely distributed member of the sturgeon family. Despite its wide geographic distribution in the northern Pacific Ocean, the green sturgeon is considered a rare or vulnerable species in the United States and Canada (Birstein 1993, Moyle et al. 1994, Cambell 1997) and an endangered species in Russia (Artyukhin, Andronov 1990). Although Russian and Asian forms of the green sturgeon are morphologically similar to the North American form, they are two species. DNA measurements and molecular analyses indicate the two populations are distinct (Birstein et al. 1997). Green sturgeon is identified as a species of special concern by California Department of Fish and Game (CDF&G) and a species of concern by the U.S. Fish and Wildlife Service (USFWS). The only known spawning populations in North America are in the Klamath, Rogue, and Sacramento rivers, all of which have flow regimes that are affected by water projects (Moyle et al. 1994). The operational regime of Red Bluff Diversion Dam (RBDD) which consists of closing the RBDD gates in spring and opening them in the fall started in 1987. Current operation dates are: gates-in May 15, gates-out September 15. This allows an unknown portion of the adult green sturgeon population to migrate past Red Bluff and spawn upstream.

Observations of adult green sturgeon in a 16-kilometer reach below RBDD after the annual spring lowering of the dam gates suggest spawning takes place below the dam (Moyle et al.1995). Rotary screw traps, attached to RBDD just beyond the hydraulic boil caused by the bottom discharge gates, captured five hundred and seventeen sturgeon larvae from 15 July 1994 to 30 June 1995 (Johnson and Martin 1997) and 1,291 sturgeon larvae ranging from 20 to 40mm total length RBDD between 1996 and 2000 (Table 1, Gaines and Martin 2001). Sub-samples of the 1996-2000 year-class larvae raised at the U.C. Davis Aquaculture Facility and identified as

green sturgeon confirmed that spawning occurs upstream of RBDD.

The objective of this study was to identify green sturgeon spawning locations and dates in the upper Sacramento River. This is a report of findings for the year 2001.

Study area

The river below Shasta Dam can be divided into three reaches. The upper river is defined as the reach from Shasta Dam river kilometer (Rkm) 502 to Colusa (Rkm 231) with pool-riffle-and run characteristics. The middle reach is Colusa (Rkm 231) to the mouth of the Feather River (Rkm 128) which includes some spawning areas of white sturgeon. The lower river is defined as the reach from Verona (Rkm 128) to San Francisco Bay. The section of the upper Sacramento River examined for use by spawning green sturgeon adults ranged from Rkm 383 to Rkm 425 (Figure 1). This reach is generally not leveed and can be considered stable. Near Redding, the river is broader and slower, but below Jellys Ferry (Rkm 429) it enters Iron Canyon and forms a series of rapids, becoming a bedrock stream controlled by the underlying geology (Reynolds 1990). At Red Bluff the river enters the valley proper. Despite agricultural and urban development, the upper river remains mostly in a natural state supporting areas of riparian vegetation.

River flows on the upper Sacramento River within the study area are influenced by releases from Shasta and Keswick dams. During winter and early spring, flows can fluctuate significantly due to accretion from tributaries or flood-control releases. Flows in the study area generally range from 169 m^3s^{-1} in winter to 1,415 m^3s^{-1} during flood events. When the dam gates are lowered at RBDD, flows are controlled for meeting irrigation needs from May through September and range from 283 to 425 m^3s^{-1}.

Methods

I used artificial substrate mats of furnace filter material bolted to 86 x 60 cm angle-iron frames (McCabe, Beckman 1990) to sample for green sturgeon eggs. Mats were held in position on the river bottom by a cement filled PVC anchor with three metal flukes. A 9.5 mm-diameter buoy line with a numbered float was attached to the anchor to mark the location of each substrate. Float line length varied with the depth and velocity. I selected sampling areas based on adult sturgeon sitings from river guides and USFWS field crews. I selected sites located upstream of deeper holes in higher velocity water using a depth finder. Coordinates for each site were recorded using a portable GPS unit. I placed artificial substrates at depths of 1.5-3.6 meters. I sampled mats twice weekly, cleaned them of sediment, and replaced them. I sorted samples recovered from the mats in the field and preserved them in 70% ethyl alcohol.

On March 21, three to five substrate mats were placed at nine locations from Rkm 383 to Rkm 425, with a total of 28 mats deployed. Due to time constraints, only 22 mats were "fished" through mid-May. Three mats at RBDD were removed during the period when gates were being lowered. On May 17 two mats were replaced along the right bank and two along the left bank below RBDD.. An average of 23 substrate mats were fished for 15 weeks until 16 July, when spawning was likely to have ended.

Larvae sampling began 26 June and continued twice weekly until 24 July. The net was fished for a total of 21 hours. I sampled sturgeon larvae using a cone shaped net constructed of 1.2 mm polyester square mesh netting similar to that used for collection of sturgeon larvae in the Sacramento River (Kohlhorst 1976). To facilitate navigation, night sampling was limited to three sites located near boat ramps. The boat was secured to a structure in the river when possible or held stationary by the boat operator. Sampling time with the larval net lasted up to thirty

minutes constituting a "set". Because green sturgeon larvae are active in darkness (Van Eenennaam et al. 2000) sampling took place twice weekly during evening and pre-dawn hours for all sites. Evening sampling usually began at 1700h and extended to 2200h. Pre-dawn sampling began at 0400h and ended at 0800h. RBDD (Rkm 390) was fished for eighteen sets; Dog Island (Rkm 396) three sets and Bend Bridge (Rkm 415) nine sets. Two additional sites were chosen for post-dawn sampling; Supan Riffle (Rkm 406) which was fished for ten sets and Salmon Hole (Rkm 424) was fished for three sets. Samples for both techniques were sorted in the field; specimens were preserved with 70% ETOH.

Results

Flow and temperature

During the only significant rainfall event (5 March, 2001) flows as high as 1,500 m^3s^{-1} were recorded at Bend Bridge. Flows during the last week of March through mid- May ranged from 198 to 306 m^3s^{-1}. Average daily flows measured by the California Department of Water Resources at Bend Bridge were 200 m^3s^{-1} when substrate mats were first deployed on 21 March (Figure 2). River temperatures are required to remain below 13.3^0C (at Bend Bridge) to provide for incubation of winter-run chinook salmon eggs, and this is accomplished by temperature controlled releases from Shasta Dam. Daily temperatures upstream of RBDD ranged from 10.7 to 15.8^0C. Daily temperatures below downstream of RBDD ranged from 8.3 to 15.1^0C. Average daily temperatures measured by the California Department of Water Resources at RBDD ranged from 8.3 to 15.1^0C (Figure 3).

Artificial Substrate Sampling

Two sturgeon eggs were found on one of the mats, river left, immediately below RBDD 14 June. The eggs were positively identified as green sturgeon by the UC Davis Genome Lab (Josh Israel, pers. comm. 2001). No other sturgeon eggs were collected from mats at other sites. Adult green sturgeon were observed periodically through June by FWS personnel immediately below RBDD after gates were lowered on 15 May.

Larvae Sampling

One 24-mm total length sturgeon larva was captured during the pre-dawn hours on 13 July at Bend Bridge also identified as a green sturgeon by the UC Davis Genome Lab. Discussions with river guides revealed observations of adult sturgeon at two locations upstream of the study area.

Discussion

Sampling periodicity, limited staffing, short spawning period, and available equipment yielded minimal results. However, the collection of two sturgeon eggs and one sturgeon larvae is the only direct evidence of green sturgeon spawning in the Sacramento River. The study was designed in 1997 using current methodology, e.g.; artificial substrate mats, for the capture of eggs and larvae of white sturgeon. Later findings from artificial spawning and larval rearing of green sturgeon (Van Eenennaam et al. 2001) indicate that green sturgeon eggs may be less adhesive possibly reducing the effectiveness of artificial substrates. This knowledge prompted the decision to use net sampling. Based on the documented behavior of green sturgeon larvae, net sampling was conducted at night.

Information is sparse regarding spawning migrations, spawning or nursery habits of green sturgeon in the upper Sacramento River. In the Klamath River, the spawning period is March-July, with a peak from mid-April to mid-June (Emmett et al. 1991). This time period (April to

June) is comparable with the observations of adult green sturgeon at RBDD (personal observations).

Spawning periods can be estimated based on early development and growth of green sturgeon. Embryonic development of the two eggs collected on 14 June suggests they were spawned on 11 June. The green sturgeon larva, collected on 13 July was estimated 13 days post-hatch. Assuming an incubation period of 6 days, it would have been spawned on 24 June. Both of these dates fall within the spawning period of late April through July as suggested by catch data in rotary screw traps at RBDD from 1995 to 2000 (Figure 4). While lengths in the rotary screw trap data were significant, the small magnitude of the differences in the actual mean values may not be biologically relevant. As sample numbers between years varied, analysis of median values also indicates median length was not the same for all nine years sampled ($P<0.001$) (Figure 4).

Habitat requirements of green sturgeon are poorly known. However, the comparative large egg size, thin chorionic layer on the egg and other characteristics of green sturgeon eggs indicate that colder (8-14^{0}C), cleaner water is required for spawning (S. Doroshov, personal communication). Preferred spawning substrate is likely large cobble, but can range from clean sand to bedrock (Moyle et al. 1995). Substrate immediately below RBDD where eggs were collected is mainly large cobble. Substrate above Bend Bridge, where the larva was collected, is a combination of gravel and bedrock. Substrate and temperature are consistent with expectations at sites where eggs and larva were found.

Cold water releases from Shasta Dam (since 1988), intended for incubation of winter-run chinook eggs may provide optimal temperatures for green sturgeon spawning and egg incubation. Temperature ranges within the study area are similar to conditions used in successful

artificial rearing of green sturgeon and do not appear to be a limiting factor to successful spawning.

The raising of the RBDD gates during upstream migration of adults provides access to additional and possibly better spawning habitat. However suitable habitat upstream of RBDD is inaccessible when dam gates are lowered. The size of upstream migrating adult sturgeon precludes the use of existing fish ladders at RBDD. No sturgeon have been known to pass the ladders since RBDD went into operation in 1966.

Recommendations are to repeat the study with a multi-year approach to establish baseline habitat needs such as substrate type, velocity and temperature. Increase the frequency of larvae sampling during pre-dawn hours as temporal behavior patterns suggest night sampling may be more productive. Change period of sampling to April through July as the study indicates spawning occurs within this time frame.

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References cited

Birstein, V.J. 1993. Sturgeons and paddlefishes: threatened fishes in need of conservation. Conservation Biology 7:773-787.

Deng, X. 2000. Artificial reproduction and early life stages of the green sturgeon (*Acipenser medirostris)*. Unpublished PhD thesis. University of California, Davis.

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

Cambell, R.R. 1997. Rare and endangered fishes and marine mammals of Canada: COSEWIC fish and marine mammal subcommittee status reports: 11. Canadian Field-Naturalist 111:249-257.

Artyukin, E.N., & A.E. Andronov. 1990. A morphological study of the green sturgeon, *Acipenser medirostris* (Chondrostei, Acipenseridae), from the Tumnin (Datta) River and some aspects of the ecology and zoogeography of Acipenseridae. Journal of Icthyology 30:11-21.

Gaines, P.D. & C.D. Martin. 2001. Abundance and seasonal, spatial and diel distribution patterns of juvenile salmonids passing the Red Bluff Diversion Dam, Sacramento River. Red Bluff Research Pumping Plant Report Series, Volume 5, U.S. Fish and Wildlife Service, Red Bluff, CA.

Hillemeir & T. Wilson. 2001. Artificial spawning and larval rearing of Klamath River green sturgeon. Transactions of the American Fisheries Society 130:159-165.

Johnson, R.R & C.D. Martin. 1997. Abundance and seasonal, spatial and diel distribution patterns of juvenile salmonids passing the Red Bluff Diversion Dam, Sacramento River, July 1994 - June 1995. Red Bluff Research Pumping Plant Report Series, Volume 2. U.S. Fish and Wildlife Service, Red Bluff, CA.

McCabe, G.T. & L.G. Beckman. 1990. Use of an artificial substrate sampler to collect white sturgeon eggs. California Fish and Game 76:248-250.

Moyle, P.B., P.J. Foley, & R.M. Yoshiyama. 1994. Status and biology of the green sturgeon, *Acipenser medirostris*. Sturgeon Quarterly 1994 2:7.

Moyle, P.B., R.M. Yoshiyama, J.E. Williams, & E.D. Wikramanayake. 1995. Fish species of special concern in California. California Department of Fish and Game, Inland Fisheries

Division, Rancho Cordova, California.

Reynolds, F.L., R.L. Reavis, & J. Schuler. 1990. Central Valley salmon and steelhead restoration plan. California Department of Fish and Game, Inland Fisheries Division.

Van Eenennaam, J.P., M.A.H. Webb, X. Deng, S.I. Doroshov, R.B. Mayfield, J.J. Cech, Jr., D.C Hillemeir, and T.E. Wilson. 2001. Artificial spawning and larval rearing of Klamath River green sturgeon. Transactions of the American Fisheries Society 130:159-165.

Figure1-

Area view of Northern California showing the location of Red Bluff Diversion Dam (RBDD) and the study area Rkm 383 to Rkm 425

Figure 2-

Daily River Flows Recorded at Bend Bridge from March 1 to July 24, 2001.

Figure 3-

Average daily river temperatures at Red Bluff Diversion Dam march 1 to July 24, 2001.

Figure 4-

Among-year length distributions for juvenile sturgeon (*Acipenser spp*.) Captured by rotary-screw traps at Red Bluff Diversion Dam (RK 391), Sacramento River. CA. Data summarized from January 1995 through June 2000 and April 2002 through December 2004. No sampling was conducted between July 2000 and March 2002. In 1996 and 1997, a total of 124 juvenile sturgeon were grown out and positively identified as green sturgeon (*Acipenser medirostris*). Tukey HSD shows Mean lengths with common letters are not significantly different P>0.05.

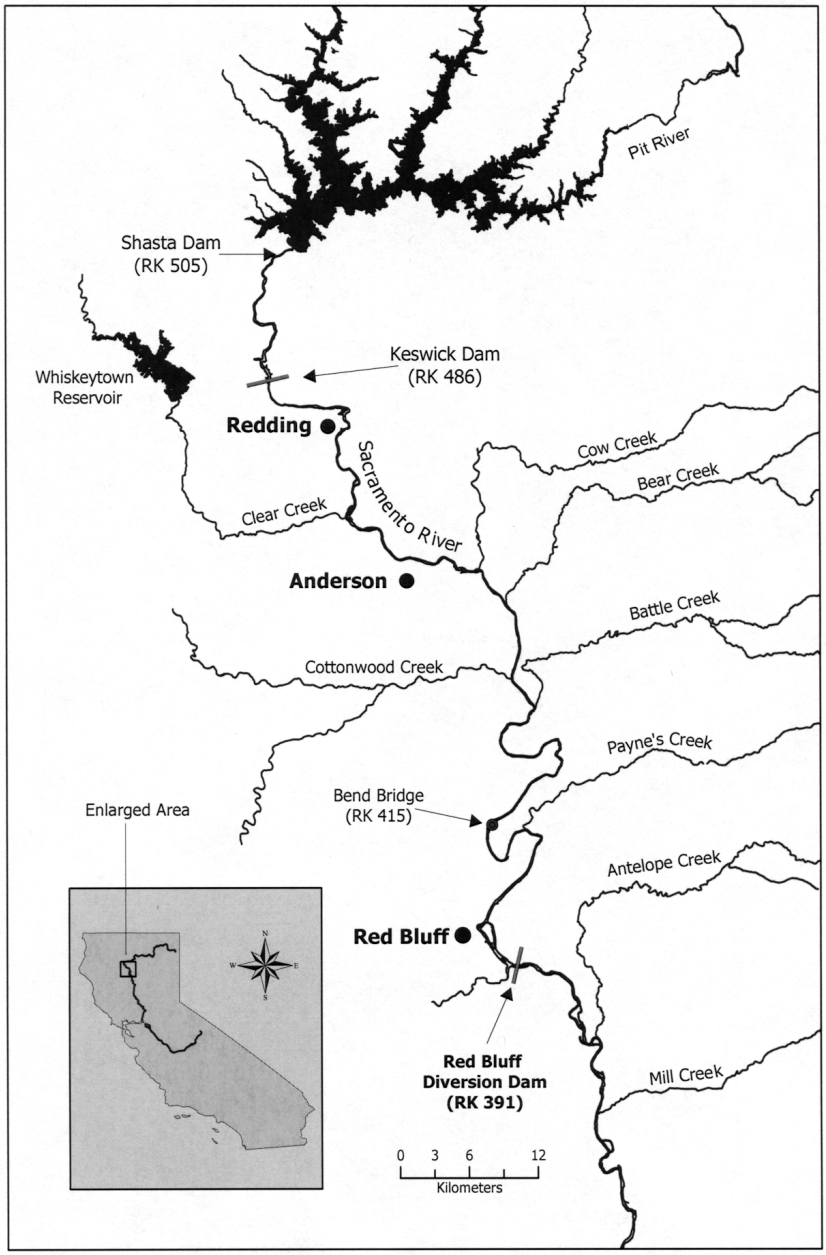

Pit River
Shasta Dam
(RK 505)
Keswick Dam
(RK 486)
Whiskeytown
Reservoir
Redding
Sacramento River
Cow Creek
Bear Creek
Clear Creek
Anderson
Battle Creek
Cottonwood Creek
Payne's Creek
Bend Bridge
(RK 415)
Enlarged Area
Antelope Creek
Red Bluff
Red Bluff
Diversion Dam
(RK 391)
Mill Creek
0 3 6 12
Kilometers

Figure 1

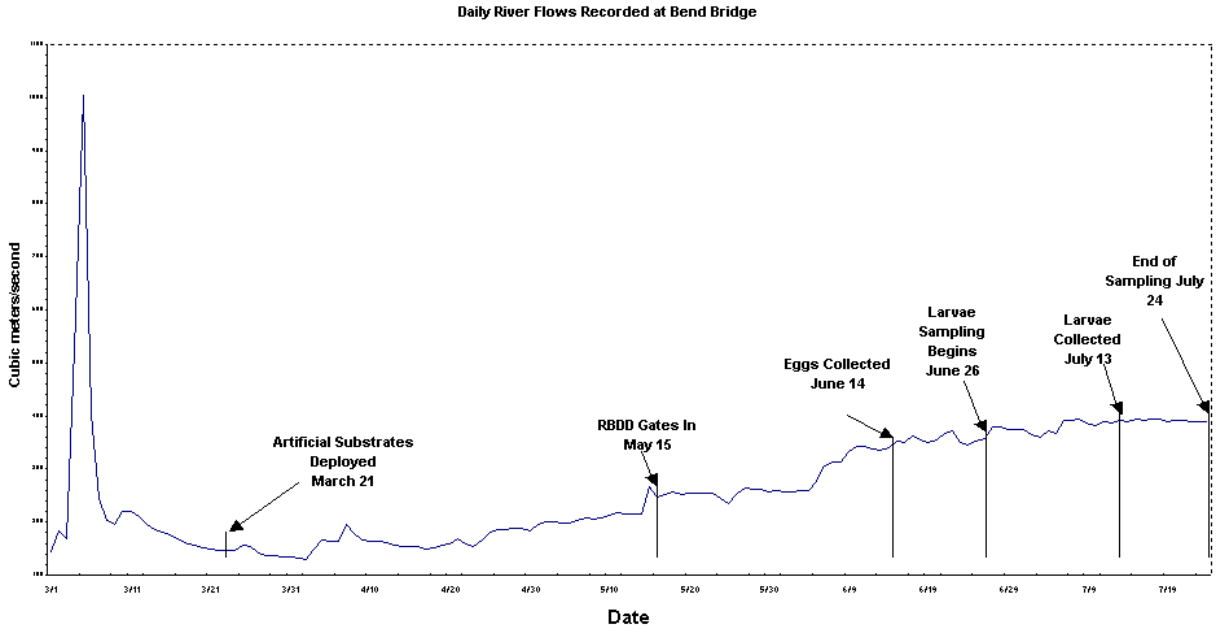

Daily River Flows Recorded at Bend Bridge
Cubic meters/second
Date
Artificial Substrates Deployed March 21
RBDD Gates In May 15
Eggs Collected June 14
Larvae Sampling Begins June 26
Larvae Collected July 13
End of Sampling July 24

Figure 2

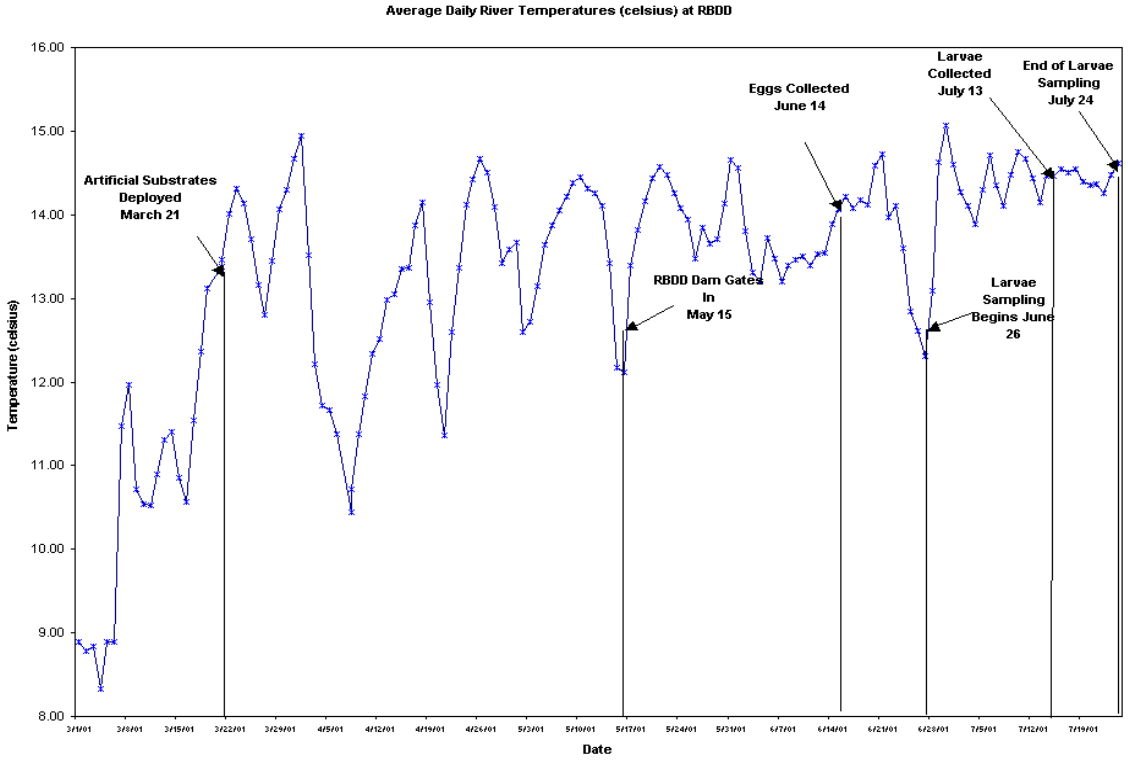
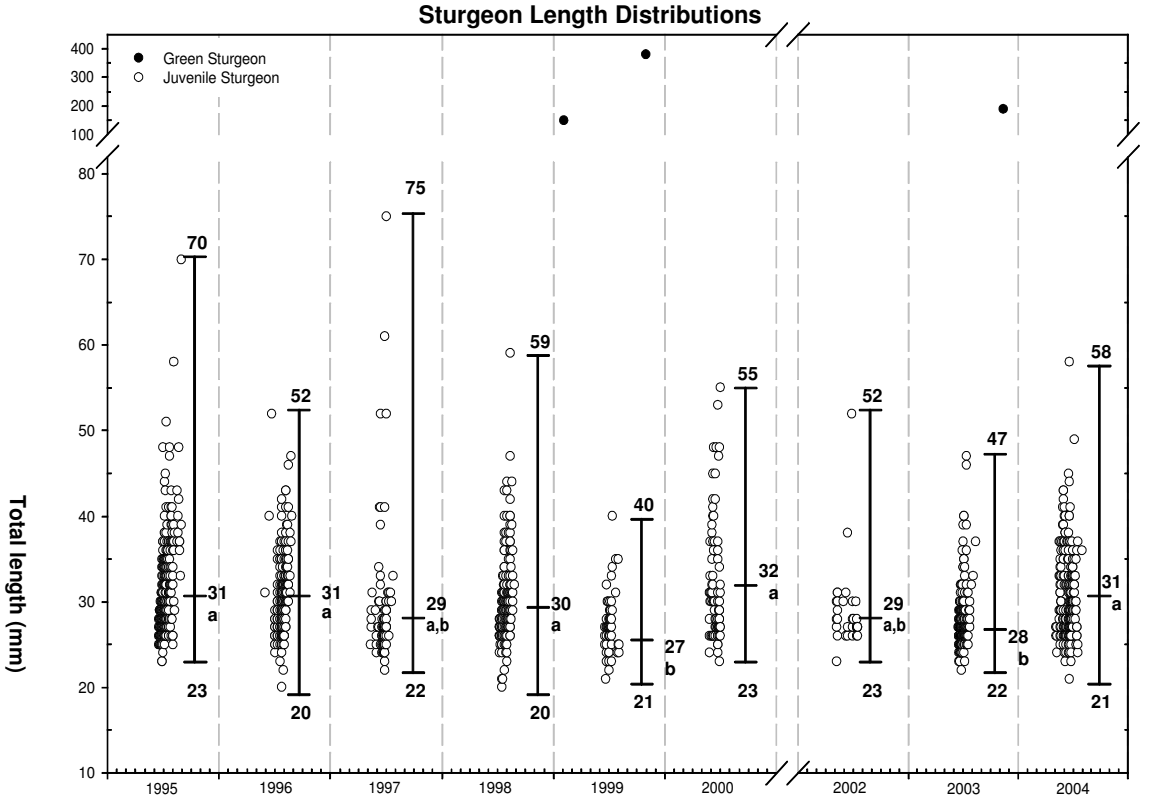

Average Daily River Temperatures (celsius) at RBDD
Temperature (celsius)
Date
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
Artificial Substrates Deployed March 21
RBDD Dam Gates In May 15
Eggs Collected June 14
Larvae Collected July 13
Larvae Sampling Begins June 26
End of Larvae Sampling July 24

Figure 3



Among-year length distributions for juvenile sturgeon (*Acipenser spp.*) captured by rotary-screw traps at Red Bluff Diversion Dam (RK 391), Sacramento River, CA. Data summarized from January 1995 through June 2000 and April 2002 through December 2004. No sampling was conducted between July 2000 and March 2002. In 1996 and 1997, a total of 124 juvenile sturgeon were grown out and positively identified as green sturgeon (*Acipenser medirostris*).

Figure 4

Table 1
Summary of green sturgeon, *Acipenser medirostris,* captured in rotary screw traps at RBDD 1995-2000.

	Year					
	1995	1996	1997	1998	1999	2000
Number captured	414	1363	355	350	78	97
Mean total length (mm)	33	34	30	26	26	31

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