Task 3

Juvenile Green Sturgeon Movements and Identification of Critical Rearing Habitat

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Background

Little is known about the distribution of juvenile green sturgeon in the Sacramento/San Joaquin watershed. Herring fishers within the bay also occasionally capture juveniles of the same size, often in spawning areas because they are believed to feed on the eggs released by the herring. There is a greater need to determine the distribution of juveniles than sub-adults and adults as the movements of six green sturgeon have been described from shipboard tracking in San Francisco Bay (Kelly *et al*. 2007). Based on captures in rotary screw traps operated by the USFWS and DFG, the species is thought to reside in the river during its first year of life, slowly moving downriver during this period. The species is known to become tolerant of saline conditions at approximately 30 cm, a length attained in the wild at about age 1+, which correlates with the collection of larger juvenile fish (20-100 cm TL) at lower-river fish salvage facilities and netted in the delta (Radtke 1966). Juveniles are then thought to reside in the estuary for 1-4 years before initiating their first oceanic out-migration.

Objective

The objective of this study will be to determine the rearing habitat of juvenile green sturgeon within the river, delta, and bay. Ultrasonic telemetry used to record their movements and periods of residence within different regions, some of which are natural and other are altered by the construction of levees and disposal of dredging materials.

Methods

The movements of juvenile green sturgeon and their distribution in the watershed relative to environmental and anthropogenic factors will be determined specifically using two techniques: 1) placing coded tags on them and detecting them with automated, tag detecting monitors distributed in the environment and by implanting coded ultrasonic beacons, and 2) affixing to them depth-sensing transmitters and following them within a boat while periodically recording their position. We will use both techniques to characterize the rearing habitat of juvenile green sturgeon.

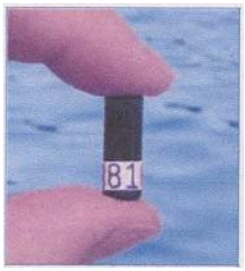

Fig. 1. RECODE beacon.

Automated Monitoring. Firstly, coded beacons (Fig. 1) will be placed in the peritoneum of juveniles and these will be detected with automated, tag-detecting monitors (Fig. 2) deployed throughout the mainstem of the river, delta, and estuary of the Sacramento/San Joaquin watershed. There are nearly 150 tag-detecting monitors distributed within the watershed (Fig. 3).

Fig. 2. VR02 monitor

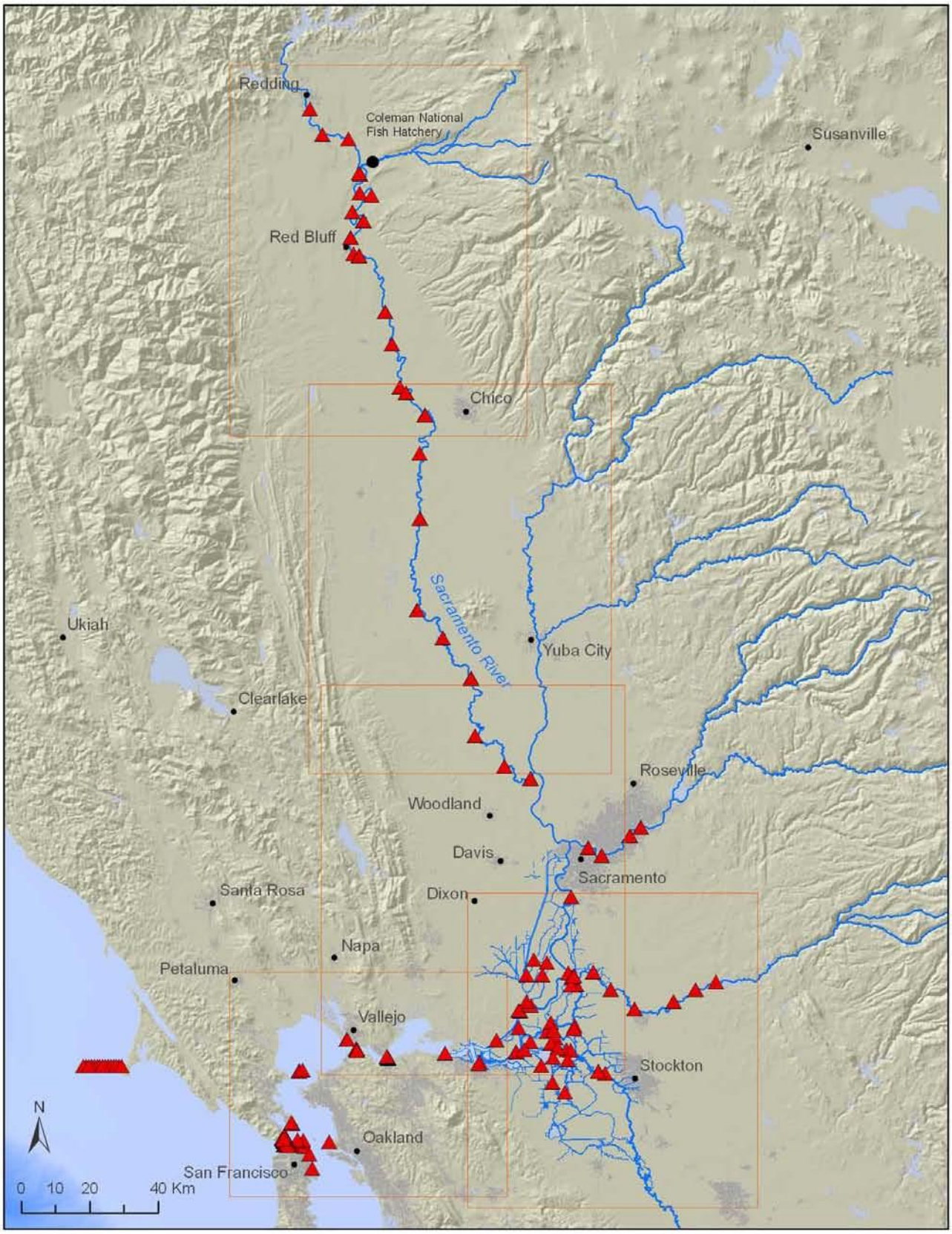

Fig. 3. Locations of automated, tag-detecting monitors capable of detecting juvenile green sturgeon carrying coded ultrasonic beacons.

The challenge for a coded tagging study of juveniles is acquiring individuals for tagging. There are two sources of juveniles. One source is multiple rotary screw traps operated by the U.S. Fish and Wildlife Service immediately downstream of the Red Bluff Diversion Dam (RBDD). Biologists under the supervision of William Poytress have in the past captured post-larval green sturgeon at a rate of 200-300 individuals per year (Fig. 4). Although these post-larvae are less than 2 cm in TL, a size too small for tag implantation, they could be raised to a size appropriate for tag implantation. Richard Corwin and Robert Chase of the Bureau of Reclamation (BOR) can raise post-larvae, captured by the rotary screw traps, in large circular rearing tanks, housed in the laboratory located adjacent to the RBDD operated by the BOR. Post-larval green sturgeon are also captured at the rotary screw trap operated at the Glen Colusa Irrigation District, and these post-larvae will be placed in a large 120 quart cooler equipped with aeration and transported to the RBDD rearing facilities for rearing. Winter and spring of 2006-07 were very dry, and relatively few post-larvae were captured, but we attempted to raise two post-larvae to a larger size. They were successfully raised to sizes > 40 cm TL. Due to the paucity of individuals captured by the traps, these two individuals have been tagged, released into the delta and tracked by boat for a period of four days.

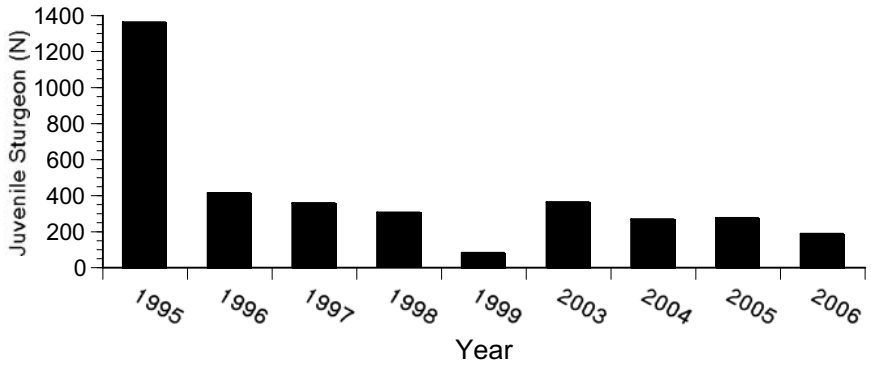

Fig. 4. The number of juvenile green sturgeon captured at the RBDD rotary screw traps from 1995-2006 in mainstream of Sacramento River below RBDD (data from USF&W).

We will capture juvenile green sturgeon in two locations in the Sacramento River watershed. First, small juveniles caught in the rotary screw traps at Red Bluff Diversion Dam (RBDD) and larger juveniles caught at the traps at Glen Colusa Irrigation District (GCID) will be transferred to holding tanks adjacent to the RBDD in a laboratory facility operated by the Bureau of Reclamation. It may be feasible to obtain a sample of 100 fish because from 200 to 400 juveniles have caught by the USF&W over a period of four years from 2003-2006, when the traps were deployed in the mainstream of the Sacramento River immediately downstream of the RBDD. Yet the reduced number of postlarvae captured during the last two years, roughly a dozen during 2007 and only three during 2008 may necessitate our capturing two males and two females, transporting them to the Center for Aquatic Biology and Aquaculture (CABA) at UC Davis, inducing them to spawn artificially, and then returning them to the mainsteam of the river at Antelope Creek. The eggs would be incubated until they hatch, and the larvae grown out using artificial feeds at CABA (see Task 4). The artificial spawning of adults would produce many progeny and enable us to tag as many as 70 juvenile green sturgeon per year. Individuals captured during spring of 2009 would reach as size sufficient to tag during spring of 2010 at the end of Year 1 of the proposed contract. They would be tagged with coded beacons as well as a similar number of individuals during Years 2 and 3 of the study. These individuals would be

released either within the mainstem of the river or the delta to identify their residence times in different habitats within the watershed.

Table I. Juvenile green sturgeon captured at the Delta pumping station during 2006 (data from IEP report, see internet web site, ftp://ftp.delta.dfg.ca.gov).

No.	Date	Time (hrs)	Total Length (cm)	No.	Date	Time (hrs)	Total Length (cm)
1	28 Dec 06	1700	54.0	21	27 July 06	0200	16.5
2	29 Dec 06	0600	32.0	22	27 July 06	0600	19.5
3	03 Oct 06	0200	26.0	23	28 July 06	0600	21.0
4	04 Oct 06	0200	28.0	24	31 July 06	0600	17.7
5	05 Oct 06	0200	36.5	25	31 July 06	0600	15.3
6	05 Oct 06	0400	12.5	26	01 Aug 06	0600	15.5
7	18 Oct 06	2200	30.5	27	02 Aug 06	2359	18.7
8	01 Nov 06	1800	35.0	28	07 Sept 06	1200	26.5
9	04 Nov 06	0200	24.5	29	09 Sept 06	1000	23.0
10	04 Nov 06	0200	36.0	30	16 Sept 06	1000	10.0
11	20 Nov 06	1000	30.1	31	17 July 05	0900	50.6
12	21 Nov 06	2200	27.0	32	11 Dec 01	0900	40.0
13	21 Nov 06	2359	25.5	33	21 Dec 01	0300	48.6
14	22 Nov 06	2359	28.0	34	27 Dec 01	0900	4.2
15	01 Dec 06	2000	32.0	35	15 Oct 01	1400	33.5
16	11 July 06	0900	49.8	36	10 Dec 01	1400	37.5
17	19 Sept 06	0700	28.0	37	02 Mar 01	0300	31.0
18	19 Sept 06	0700	30.0	38	21 Feb 00	0900	28.4
19	19 July 06	0200	15.0	39	21 Feb 00	1500	28.6
20	26 July 06	8888	19.0				

An alternative source of juveniles is the pumping facilities within the Delta. They range in size from 4.2-54.0 cm long. Twenty individuals were captured from October to December 2006 in the pumping facilities (Table I). Biologists at UC Davis have an agreement with both state and federal biologists to place individuals captured in water in a large, 120 quart cooler for either tagging with coded ultrasonic beacons or transportation the Center for Aquatic and Aquaculture (CABA) located at UC Davis, where they will be raised to a sufficient size to implant beacons as part of The Directed Action funded by CDFG.

Two models of coded ultrasonic tags, a model with a life of a year on the smaller juveniles (12-25 cm TL) and a model of a life of three years on larger juveniles (26-50 cm TL), would be placed on juveniles held in captivity. Studies are currently being carried out at UC Davis to determine the minimum size juvenile, into which a transmitter can be inserted into the peritoneum and without reducing its capacity to swim rapidly as well as not to increase the

oxygen consumption during normal swimming. The distribution of the juveniles would be determined by the array of automated tag-detecting monitors deployed throughout the river, delta, and bay.

Shipboard Tracking. Individual green sturgeon, carrying pressure and temperature sensing transmitters, will be released at experimental sites. Four tagged fish will be followed by a two person tracking team each year aboard a small boat equipped with a portable receiver and hydrophone. Tracking will be carried out continuously for 24 hours of the day for a period of five days for each of eight fish. There will be two teams of trackers, and they will each track for 12-hour shifts, and will stay at a hotel near the tracking site when not tracking. The geographical coordinates of the fish will be determined automatically by the receiver and paired with the depths and temperatures from the ultrasonic tags. Water will be pumped into a shipboard tank, where a Hydrolab probe will measure water conductivity, salinity, pH, temperature, and concentration of dissolved oxygen, while software will pair these measurements with depths of the fish and those recorded by a fathometer. At hourly intervals the Hydrolab will be lowered throughout the water column to measure these physical properties at increasing depths.

Results

The tagging and tracking of juveniles, both by an array of tag-detecting monitors and by a team of trackers, will reveal the habitat preferences of juveniles within the river, delta, and bay. The placement of monitors at reaches with levees and water diversions will enable us to determine their effect on the rate of movement and residence times of juveniles. The placement of monitors at dredge disposal and non-dredge disposal sites will provide information about its impact on the behavior of juvenile green sturgeon within the delta and bay.

Task 4

Spawning of Wild Caught Sacramento River Green Sturgeon and Rearing of Juveniles for use in Telemetry Studies[3]

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Objectives

We propose in collaboration with the Biotelemetry Laboratory a maximum of 2 ripe females and 4 ripe males will be captured for spawning induction, each spring. The additional female and 2 males maybe needed if the first attempted spawning is not successful. Considering the amount of time and funds allocated to prepare for one spawning each spring, a 2nd spawning trial during the season, would add little additional cost. These fish would be part of the total requested number of adults to be telemetry tagged by the Klimley Lab, as they would be implanted with tags after spawning. If induced ovulation and egg collection is successful this would be the first documented case of a post-cesarean section green sturgeon tagged and released. The tracking data would provide information on post-spawning survival and spawning periodicity, of both females and males. In addition to providing juveniles for telemetry tagging, the spawning of wild caught southern distinct population green sturgeon would provide valuable data, regarding egg size, fecundity, fertility and quality of eggs and larvae. With the potential further decline in Sacramento River water flow and changes in water quality, a conservation-oriented hatchery, based on information collected in this project, may become, in the future, the only option for mitigation of these and other impacts on the green sturgeon population.

Methods

Broodstock captured from the Sacramento River will be transported to the UC Davis, Putah Creek Aquaculture Facility in a sturgeon transport trailer and then held in 1 or 2 twelve foot diameter circular tanks that will be semi-recirculating with an in-line chiller to maintain appropriate water temperatures for spawning induction.

Spawning induction procedures, egg incubation and larval rearing techniques for green sturgeon have already been established (Van Eenennaam, *et al*., 2001; 2004; 2005; 2006; 2008). Briefly, to determine female maturity, eggs will be sampled with a 5mm ID Teflon tubing through a small abdominal incision. Eggs will be bisected to measure egg polarization index (PI, relative distance of the germinal vesicle from the animal pole (Van Eenennaam, *et al*. 2006) which is a measure of a female's readiness to spawn. Males will be selected based on the presence of large white testis when sampled. The spawning induction of female green sturgeon will be a priming injection of 1 µg/kg GnRHa, followed by a second injection of 19 µg/kg (12 h later), and for males, a single injection of 10 µg/kg. Ovulation is expected 12-16 hours after the

[3] Either a Section 10 permit will be required from NMFS or a collecting permit from CDFG to collect the adults and spawn them. We are currently communicated with Jeff McLain and David Woodbury about the necessity of spawning wild adults and setting up a program of artificial propagation for the green sturgeon.

resolving injection. Ovulated eggs would be collected (see Cesarean Surgery procedures below) not later than 1.5 h after ovulation, briefly rinsed in freshwater, and fertilized with milt diluted 1:200 for at least 4 min, or until the eggs start to adhere to the sides of the fertilization container. Fertilized eggs would be silted for 1 h and incubated in upwelling incubators. Optimally, all these procedures should be performed within the temperature range of 12 to 16^{o}C.

Cesarean Surgery: When ovulated eggs have been released by the female (the tank is checked for eggs every hour beginning at 10 hours post-2nd injection) the female is removed from the holding tank by tube-net and placed into an anesthetic bath (MS-222@50 ppm) until equilibrium is lost and gill ventilation is every 2-3 seconds. The female is removed from the anesthetic bath by carefully placing her into a hooded stretcher placed in the tank. The stretcher is lifted, water drained and moved to sawhorse supports. The gills of the female are then irrigated with fresh oxygenated water containing 25 ppm MS-222, which is exchanged with fresh water every 10 minutes, to ensure the fish does not stop ventilating its gills. Using a 100 qt cooler, small submersible water pump, and 1" diameter tygon tubing, we use this small recirculation system to keep the female under a moderate state of anesthesia, during which the female is still ventilating her gills, but is calm.

Due to the fact that sturgeon have internal mullerian ducts and cannot be easily hand-stripped like salmonids, the most efficient way to remove eggs is by caesarian section. After anesthetizing the female, the incision area is gently swapped with 10% iodine and an 8-10 cm long incision is made in the abdomen using a # 10 scalpel blade and a Brown Adson tissue forceps. The location of the incision is slightly lateral to the mid-line to contain about 1.2 cm thick of muscle and 4-6 ventral scutes anterior from the pelvic fin. All surgical tools, and egg collection equipment are sterilized and aseptic conditions maintained. Eggs are removed using plastic spoons with no sharp edges. After egg collection (takes about 15 minutes) and insertion of the telemetry tag, the incision is closed by two sets of sutures (takes about 15 minutes) for added strength, to ensure the peritoneum will be closed, and to help with apposition and rapid healing. The first is an internal suture used to bring the peritoneum and bottom half of the muscle together and the second is an external suture for the top part of the muscle and skin. The internal suture is made using single interrupted stitches with the PDS II absorbable violet monofilament suture #0, with a swaged-on CT-2 taper needle. The external stitches will use the same suture material except a larger swaged-on CP-1 cutting needle is needed to cut through the tough sturgeon skin. The external sutures used are a special tension suture pattern called the "far-near-near-far" pattern. The advantage of this suture is that it apposes the skin edges and provides a degree of tension, which is important for the large sturgeon females when they become more active as they are healing. The female is placed into a recovery tank and observed continually until she is swimming normally. The female will be released at the point of capture after 3-4 days observation. The amount of days the individual fish are held in captivity, before and after spawning, needs to be kept at a minimum. Wild-caught green sturgeon refuse to feed in captivity, and the cesarean incision healing would certainly be impaired in non-feeding fish, leading to suffering and mortality.

The UCD system for embryo incubation is already constructed but requires two small submersible chillers to maintain water temperatures during egg incubation Larval rearing would require a minimum of 6-4' diameter tanks, for the critical weaning period, after yolk adsorption.

And as the larvae grow, larger tanks will be used for grow-out until individuals are large enough for telemetry tagging.

The larvae at UCD will be cared for by Doroshov and Klimley's labs. Systems for larval rearing of sturgeon are already available at UCD. The sites at UCD are supplied with well water and growth would be much faster than fish grown out at the Bureau site using river water.