Klamath River Green Sturgeon Acoustic Tagging and Biotelemetry Monitoring 2010

Final Technical Report
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Yurok Tribal Fisheries Program staff display a freshly tagged green sturgeon on the Klamath River in 2010.

INTRODUCTION

The green sturgeon (*Acipenser medirotris*) is an anadromous Pacific Ocean sturgeon found in the coastal waters and rivers of western North America (Moyle 2002). Their distribution ranges from Ensenada, Mexico to the Bering Sea, Alaska (Scott and Crossman 1973; Moyle 2002). The only confirmed spawning streams are the Rogue River in Oregon, and the Sacramento and Klamath Rivers in California. Recent genetic studies have identified two distinct population segments (dps); one from the north and one from the south. Individuals belonging to the northern distinct population segment spawn in the Rogue and Klamath rivers, while green sturgeon that spawn in the Sacramento River belong to the southern distinct population segment (Israel et al. 2004).

Green sturgeon life history, abundance, and distribution data are limited. Green sturgeon use freshwater primarily for spawning and are mostly observed in saltwater and brackish estuaries of large coastal rivers where they spend the majority of their lives (Scott and Crossman 1973; Parks 1978; Houston 1988). However, stream residency has been documented during summer and fall for up to six months in the Klamath and Rogue rivers (Benson et al. 2005; Erickson et al. 2002). Timing of emigration from the Klamath River was related to increased discharge, particularly the first freshets of the autumn and winter (Benson et al. 2005).

Green sturgeon populations in North America are considered vulnerable to endangered (Musick et al. 2000). The southern dps has been listed as threatened on the federal endangered species list and the northern dps is considered a species of special concern by the Nation Marine Fisheries Service. Presumed spawning populations in the Eel, South Fork Trinity, and San Joaquin rivers have been extirpated within the last 25 to 30 years (Moyle et al. 1995). Mature spawners in other populations are reduced, with mature females potentially numbering in the low hundreds (Musick et al. 2000; Moyle 2002). Furthermore, anthropogenic activities can detrimentally affect green sturgeon populations, particularly dams and hydroelectric projects (Houston 1988; Moyle et al. 1995; Erickson et al. 2002). Flows on the Sacramento, Rogue, and Klamath rivers are artificially manipulated and reduced, and while the full effects of flow manipulations on sturgeon are not known, they are sensitive to flow conditions for migrational cues (Benson et al. 2005; Erickson et al. 2002). Existing data are limited for this species, particularly regarding its abundance, distribution within its range, population dynamics, and ecological requirements. Until these parameters are identified and sufficiently understood, green sturgeon should be considered rare and a species of special concern, especially due to the extreme vulnerability of sturgeons globally (Houston 1988; Birstein 1993; Birstein et al. 1997; Musick et al. 2000; Moyle 2002).

To Yurok Tribal members, green sturgeon are considered sacred beings, and these large fish are an extremely valuable source of food in the early spring months. The Yurok people have lived along the banks of the Klamath River for millennia, subsisting in large part on the Klamath's once abundant runs of anadromous fish. Water quality and water quantity issues in particular have led to large scale declines in Klamath River anadromous fishes (NRC 2004), and the status of green sturgeon populations are not currently known. The Yurok Tribe is concerned that declines in green sturgeon numbers may be imminent or undetected, and has therefore initiated a long term study intended to gather as much useful information on these revered fish as possible.

From 2002 to 2005, the Yurok Tribal Fisheries Program (YTFP) captured and tagged 56 adult green sturgeon in the Klamath and Trinity rivers. In 2002 and 2003, we used radio biotelemetry and focused our study on in-river movements and migrations of adult green sturgeon (see Benson et al. 2005). Studies conducted in 2004 and 2005 also examined in-river movements, however, in these years we used acoustic biotelemetry which allowed us to also determine where green sturgeon go in the marine environment after emigrating from the Klamath River. Green sturgeon from all four study years were internally tagged with either radio or acoustic transmitters or both. The acoustic transmitters used in 2004 and 2005 had a life expectancy of up to five years, so it is possible that some are still operational as of 2010. Since 2002, the YTFP has deployed acoustic monitoring receivers throughout the lower reaches of the Klamath, Trinity, and Salmon rivers in order to track the movements of any returning green sturgeon tagged in the Klamath River basin. This information will help researchers evaluate survival trends as well as spawning periodicity. Numerous green sturgeon have also been tagged at various locations in California, Oregon, and Washington, and our receivers will detect any of these fish if they enter the Klamath River. These data can assist researchers in evaluating long distance migration movement patterns. From 2006 to 2009, we also deployed a small receiver array (1 to 3 receivers) approximately one to two km offshore from the mouth of the Klamath River in the Pacific Ocean. These receivers can detect if any tagged green sturgeon are migrating through, or aggregating in, the ocean near the Klamath River mouth. Previously, this receiver array off of the mouth of the Klamath River has detected numerous sturgeon tagged at a wide variety of locations using this area as a presumed winter holding habitat.

Due to the five year lifespan of the acoustic tags previously used, most will be non-operational after 2010. In order to preserve this valuable source of data, the YTFP resumed acoustically tagging green sturgeon in the Klamath River. In the spring of 2009 we captured and tagged four adult green sturgeon with acoustic tags that have a ten year lifespan. We also deployed our acoustic in-river and oceanic receiver array to track the tagged individuals, as well as any others that entered the Klamath River. In 2010 we repeated this approach, and captured and tagged 20 adult green sturgeon. This technical memorandum summarizes our findings from the 2010 tagging and monitoring season.

METHODS

Receiver Array

Beginning in April of 2010, we deployed an array of 8 acoustic receivers (Vemco Ltd., VR2 and VR2Ws) at sites downstream of river kilometer (rkm) 108 in the mainstem Klamath River (Figure 1). The receivers were deployed at locations where river currents were relatively slow and depths were greater than ten feet. The receivers were attached to a plastic coated stainless steel cable that was anchored to the river bottom and connected to the shore. Receivers were downloaded via laptop computer on a bi-monthly basis or opportunistically throughout the study period. We removed the receiver array from the river in December of 2010, with the exception of the Blue Creek (rkm 26) receiver that was deployed year round. The oceanic array is described herein as rough seas prevented downloading and maintenance during attempted research voyages in 2010.

Tagging

Fish were captured using a single stranded monofilament $7^{1/4}$ in (stretched) mesh gill nets. The nets were 37 meshes deep (approximately 22 ft deep), 75 ft long, and were set in a large eddy near Coon Creek Falls (rkm 57) (Figure 1). A number of green sturgeon were captured by tribal members at Weitchpec Bar (70) (Figure 1) and donated to the YTFP for tagging. Captured sturgeon were either tagged immediately, or held in black PVC culvert live wells overnight in the river. Each captured fish was weighed, had its fork length and total length measured, and had a mid-lateral scute count (both sides) recorded. We also collected a small DNA sample from the dorsal fin of each sturgeon. These samples are stored in micro-centrifuge tubes containing a solution of 95% ethanol.

An acoustic tag was surgically implanted into the abdominal cavity of each captured green sturgeon. The sturgeon was prepared for surgery by placing it ventral side up in a sling with a water filled hood at one end, which was slanted downhill so the fish's gills stayed in contact with fresh water at all times. An assistant monitored the breathing of each sturgeon during the surgery and regularly filled the hood with fresh water.

The incision and insertion process involved making a five centimeter (cm) incision immediately to the right of the mid-line on the ventral side of the fish. The incision point was started approximately 10 cm anterior from base of the pelvic fins. The exterior skin surface was pulled upward while making the insertion to protect the internal organs from accidental damage. When a clean incision was achieved, we checked for evidence of sex, and inserted the acoustic tag toward the posterior of the fish. The incision was closed with three to four interrupted cross stitches using size 1 Polydioxanone (PDS II) violet monofilament suture, 70 cm in length attached to a CP-1 36 mm, double-edged cutting needle. In general, the surgery lasted an average of five to six minutes (min) but never exceeded 10 min, and each fish was held after surgery for up to one half hour before being released to verify visible recovery.

The acoustic tags we used were made by Vemco Ltd. from Ontario, Canada. Fifteen of the tags are model V-16-6X coded pinger transmitters, which has a diameter of 16 mm, length of 92 mm, and weighs 16 grams. The other five tags are model V-16TP-6X, these tags have temperature and pressure sensors and were donated by the U.S. Geological Survey. Both tags are designed to last a minimum of 3,650 days.

Mainstem Klamath River temperatures were monitored during this project by the YTFP at rkm 72 using an Onset Hobo Pro V2 water temperature monitor. Klamath River discharge was measured by the United States Geologic Survey (USGS) gauging station at rkm 13 near Klamath, California (station number 11530500).

RESULTS

Twenty adult green sturgeon were captured and tagged in the Klamath River between May 10th and June 24th, 2010. Two fish were captured and tagged at rkm 57, and 18 were captured and

tagged at rkm 69. Tagged green sturgeon had an average length of 185 cm and an average weight of 45 kilograms (kg). Eight of the captured fish were females and twelve were males (Table 1). Females were generally larger than males, averaging 204 cm in length and 58 kg in weight, while males averaged 173 cm in length and 37 kg in weight (Figure 2).

Our in-river acoustic receiver array was deployed from April 1st through December 1st, 2010. All tagged green sturgeon were detected by at least one of our acoustic receivers, and functional receivers detected between seven and sixteen tagged fish each. There were no detections on our receiver placed in the Trinity River at rkm 72 (Table 2). The receiver at Blue Creek (rkm 26) malfunctioned and at this point we have been unable to retrieve the data from its memory. Our receiver at Aikens Hole (rkm 79) was damaged on August 19th and stopped collecting data; we were able to download all data up to that point. No fish from studies outside of the Klamath River were detected by our receiver array; also, we detected no fish from any previous Klamath River studies. Three sturgeon tagged previously were captured in the Hoopa and Yurok tribal subsistence fishery in 2010. These fish were tagged prior to 2009 and had inoperable transmitters so they were not detected by our receiver array. One of these fish was tagged in the Klamath River in 2002, one was tagged in the Trinity River in 2003, and one was tagged in Grey's Harbor, Washington in 2005 by the Washington Department of Fish and Wildlife.

The maximum daily discharge of the mainstem Klamath River (rkm 13) during the 2010 study period was 57,900 cubic feet per second (cfs) on June 5th and the minimum was 3,090 cfs recorded on September 16th. The maximum daily average river temperature recorded in the mainstem Klamath River (rkm 70) during the study period was 23.6°C on July 27th with a minimum of 9.2°C on May 22nd (Figure 3).

Thirteen tagged green sturgeon were detected moving upstream after being released and six were recorded making downstream movements. One tagged individual was detected by our receiver at the release location but not thereafter (fish 10) (Figure 4). Ten of the twenty tagged green sturgeon exited the river during the spring or summer of 2010 as river discharges were on the descending limb of the hydrograph (Figures 3 and 5). Seven tagged green sturgeon emigrated from the Klamath River in the fall with the first significant increase in river discharge (Figures 3 and 6). Three tagged green sturgeon were not detected by receivers in the Klamath River estuary, so their river emigration timing is unknown. Green sturgeon that left the Klamath River in the spring spent an average of 24 days in the Klamath River after tagging. All but two of these spring out-migrating fish (6 and 8) migrated no further upstream than rkm 70 (Figure 5). Fish emigrating in the fall had an average river residency of 163 days after tagging (Table 1). All but one of the green sturgeon that left the river in the fall were detected at rkm 87 or above (Figure 4). Both male and female green sturgeon that exited the river in the fall were generally larger than their counterparts that emigrated in the spring (Figure 7).

Average spring discharge (measured from May 15th through July 15th) was higher in 2010 than all other tagging years due to an unusually cold and wet spring. Other green sturgeon tagging years were 2002, 2003, 2004, 2005, and 2009 (Figure 8). A substantially larger proportion of tagged green sturgeon exited the river during the spring and summer of 2010 compared to other tagging years. This behavior was also observed in 2005 when spring discharges were nearly as high as 2010 flows (Table 3; Figures 8 and 9).

DISCUSSION

Twenty green sturgeon were captured and tagged in the Klamath River in 2010 between May 10th and June 24th as river flows were declining and river temperatures were increasing with the descending limb of the snowmelt peak. Past observations have shown that this is generally the time period when green sturgeon undertake their spawning migrations up the Klamath River.

Green sturgeon tagged between May 10th and May 17th were larger on average than fish tagged between May 29th and June 24th. These early run fish also migrated further up the river, and resided longer than later running green sturgeon. Data collected in 2010 also shows that most green sturgeon that migrated past rkm 70 exited the Klamath River in the fall. This is presumably due to the inflow of the Trinity River as it adds large amounts of flow, and the lower flows of the Klamath River above its confluence with the Trinity could inhibit spring outmigration due to shallow riffles for example. The exact flows and mechanisms involved would be useful to determine with higher confidence, which would likely require a long term data set developed through additional years of data collection.

In 2010, YTFP green sturgeon captures occurred slightly later than in previous tagging years. This is most likely due to the higher than average flows that were present during the spring of 2010 due to the usual weather conditions. These high flows made fishing for green sturgeon very challenging during the months of April and early May. Some Tribal subsistence fisherman reported normal catches in April; however these individuals were able to fish in locations where high river flows did not hinder their effort. We do not believe that higher spring flows inhibit green sturgeon from migrating up the Klamath River; nevertheless the increased flows can make fishing more difficult.

In 2010, six green sturgeon were captured and tagged after June 10th. In all of the previous tagging years, no fish were tagged after this date. Tribal subsistence fisherman also reported that the green sturgeon run extended later than normal. We believe this extended upstream migration period was due to usually protracted high spring flows that lasted into early July. We found that over 60% of our tagged green sturgeon left the Klamath River during the spring in 2010. This behavior was also observed in 2005 when over 60% of tagged green sturgeon also out-migrated in spring. Discharge levels in the spring of 2005 were also higher and more protracted than average. This finding emphasizes the significant role that river flows play in the migration behaviors of green sturgeon, and has significant implications as the bioenergetic and physiological stress endured by sturgeon over summering in the hot, toxic mainstem Klamath River is undoubtedly significantly greater than over-summering in marine feeding habitats. These spring out-migrating fish are often detected in bays and estuaries along the West Coast of North America just weeks after leaving the Klamath River. Green sturgeon that do not leave the river until the fall must spend up to six months in the riverine environment. The Klamath River's water quality is severely impaired during this time period and there is little or no food for green sturgeon. Our findings in 2010 (and 2005) show that higher spring flows later into the year can be valuable to green sturgeon by allowing a greater proportion of fish to exit the river in the spring after spawning and thereby avoid over-summering in the river. It has been well established that the first significant increase in river discharge of the fall leads to a mass exodus of all green sturgeon that have held in the river over the summer suggesting they are behaviorally

locked in place by low flows. As more fish are tagged and observed in years of varying water types, it becomes clear that river discharge, both the amount and the timing, is a crucially important factor in the green sturgeon spring out-migration.

Eight of the twenty tagged green sturgeon from 2010 were detected by our receiver at Dolans Bar. This receiver is located at rkm 98 and is the furthest upstream unit of our array. Six of these fish migrated past the receiver, presumably to spawning grounds located upstream, before passing by the receiver again on their exit from the river. Two of the tagged green sturgeon spent the entire summer in the vicinity of the receiver and were detected thousands of times before leaving the river in fall. The Dolans Bar receiver has been deployed since 2002 and the eight fish detected in 2010 are by far the most of any year.

Our in-river acoustic receiver array did not detect any green sturgeon from other studies outside the Klamath River basin in 2010. No tagged green sturgeon from previous study years on the Klamath were detected either. This has been the case in previous years also, and is probably because many of the acoustic tags used in previous studies are no longer operational due to battery life constraints. We envision green sturgeon detections increasing in the future as more fish are tagged with Vemco's 10 year acoustic tags. Green sturgeon tagged in Washington's Grays Harbor or Willipa Bay are frequently detected or captured in the Klamath River (as evidenced by the two green sturgeon capture from these areas in 2010 with non-functioning tags). It is believed that Klamath River green sturgeon spend their juvenile and non-spawning summers in productive marine and estuarine habitats such as these bays and estuaries. More research is needed in regards to appropriate management actions to protect sturgeon when residing in these areas from hazards such as broad spectrum pesticides used in oyster aquaculture to by-catch in various fisheries.

No tagged green sturgeon were detected by our acoustic receiver located in the Trinity River, which is a known spawning tributary of the Klamath River, but the Trinity is well documented to receive substantially less sturgeon annually than the mainstem Klamath River based on harvest and biotelemetry records. All captured green sturgeon were tagged and released downstream of the Trinity River confluence. This situation has not been common and we predicted that at least one of twenty tagged green sturgeon would enter the Trinity River. Hoopa Tribal subsistence fishermen reported high catches of green sturgeon on the lower Trinity River in 2010 but none of our tagged green sturgeon entered the Trinity River so it is impossible to estimate the proportion of the run the went up the Trinity River based on tagging data.

The YTFP will continue to install our acoustic receiver array in the Klamath River in future years and tag green sturgeon annually as funding levels allow. It has been our experience that the more fish we tag, the more knowledge we gain about these ancient, revered creatures.

ACKNOWLEDGEMENTS

The YTFP would like to acknowledge Mr. Thomas Wilson for his invaluable contributions to this project. Mr. Wilson selflessly donated a number of green sturgeon to the YTFP for tagging purposes. This study's success can be directly contributed to Mr. Wilson's generosity. We

would also like to acknowledge the USGS Cook, WA office for contributing 5 acoustic tags for this project. This study was funded by the Bureau of Reclamation's Klamath Basin Area Office.

TABLES AND FIGURES

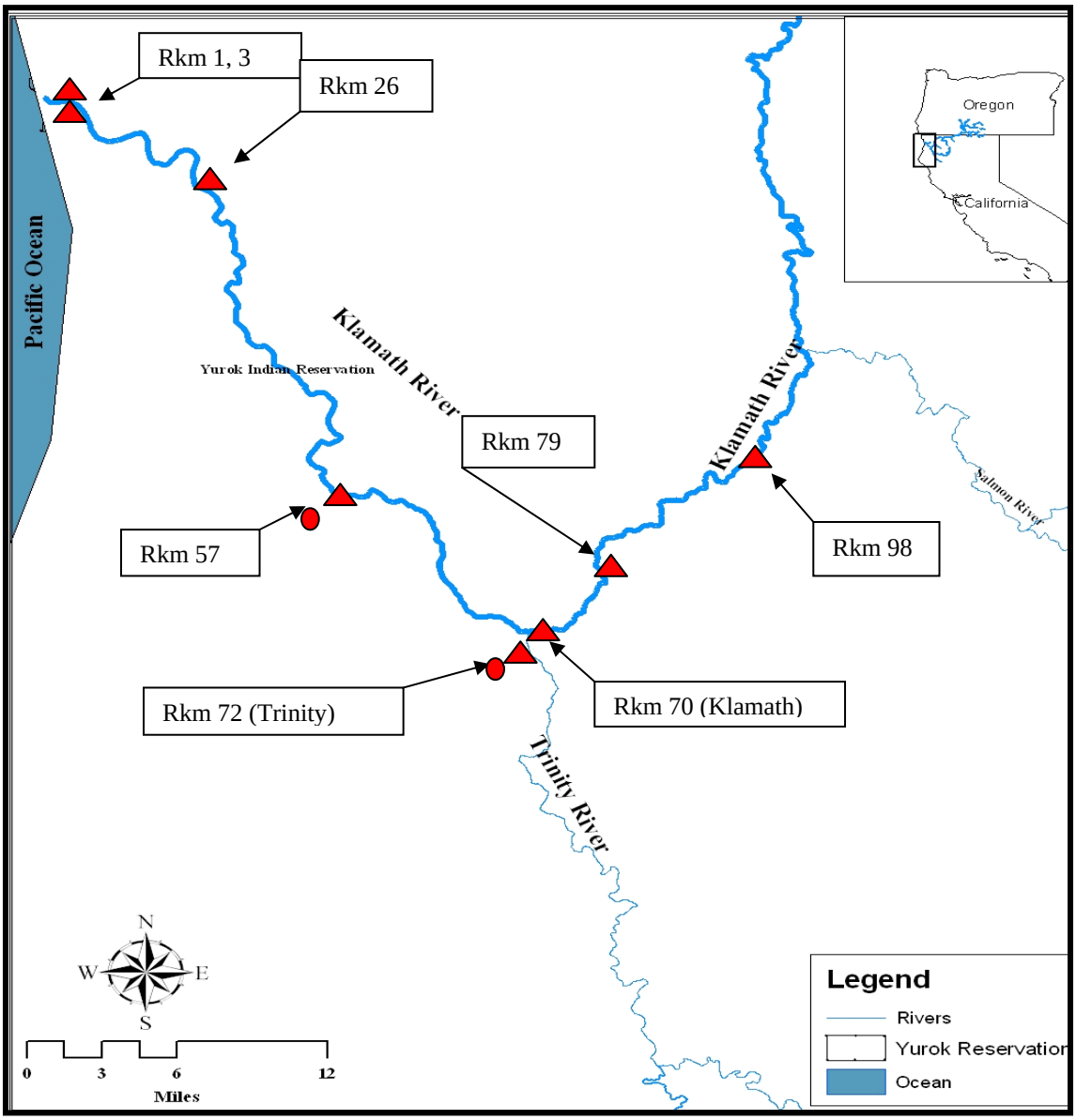

Figure 1: Map of the lower Klamath and Trinity rivers showing acoustic receiver locations during the green sturgeon acoustic tagging and biotelemetry monitoring project of 2010. Coon Creek (rkm 57) and Weitchpec (rkm 69) are represented by circles and were also capture and tagging locations.

Table 1: Tagging and residency data for the 2010 green sturgeon acoustic tagging and monitoring project. Tagging location is expressed in river kilometers (rkm), lengths are shown in centimeters (cm), and weights are shown in kilograms (kg). Exit date is the last date that the tagged individual was detected by our acoustic receiver at rkm 1 as it left the Klamath River system. The individuals labeled as unknowns were not detected by the receiver at rkm 1.

Number	Date Tagged	Tagging Location (rkm)	Tag Code	Sex	Length (cm)	Weight (kg)	Exit Date	Days in River
1	5/10/2010	69	63213	F	218	61.2	unknown	unknown
2	5/10/2010	69	63214	M	175	43	10/29/2010	172
3	5/10/2010	69	63215	M	170	38.5	unknown	unknown
4	5/11/2010	69	63216	M	175	34	10/24/2010	166
5	5/11/2010	69	63217	M	188	49.8	10/27/2010	169
6	5/11/2010	69	58691	F	196	56.6	5/28/2010	17
7	5/11/2010	69	58692	M	193	52.1	10/24/2010	166
8	5/12/2010	69	58693	M	175	38.5	6/25/2010	44
9	5/12/2010	69	58694	F	224	72.5	10/25/2010	166
10	5/14/2010	69	58695	F	198	58.9	unknown	unknown
11	5/17/2010	69	58696	F	216	56.6	11/3/2010	170
12	5/29/2010	69	58697	M	165	31.7	7/2/2010	34
13	5/29/2010	57	58698	M	168	31.7	6/20/2010	22
14	5/29/2010	57	58699	M	152	24.9	6/25/2010	27
15	6/13/2010	69	58701	F	211	63.5	10/25/2010	134
16	6/14/2010	69	58700	F	185	45.3	7/3/2010	19
17	6/14/2010	69	48742	F	185	47.6	7/1/2010	17
18	6/24/2010	69	48743	M	177	38.5	7/7/2010	13
19	6/24/2010	69	48744	M	190	43	7/29/2010	35
20	6/24/2010	69	48745	M	147	20.4	7/2/2010	8

Table 2: Acoustic receiver locations and detections from the YTFP 2010 green sturgeon tagging and monitoring project. Locations are show with place names and river kilometers (rkm). No tagged fish were detected in the Trinity River and the Blue Creek receiver had a malfunction.

Station Site	RKM	Number of Tags Detected
Requa	1	15
Jet Boat Tours	3	12
Blue Creek	26	0
Coon Creek	57	8
Weitchpec	70	16
Trinity River	72	0
Aikins Hole	79	7
Dolans Bar	98	8

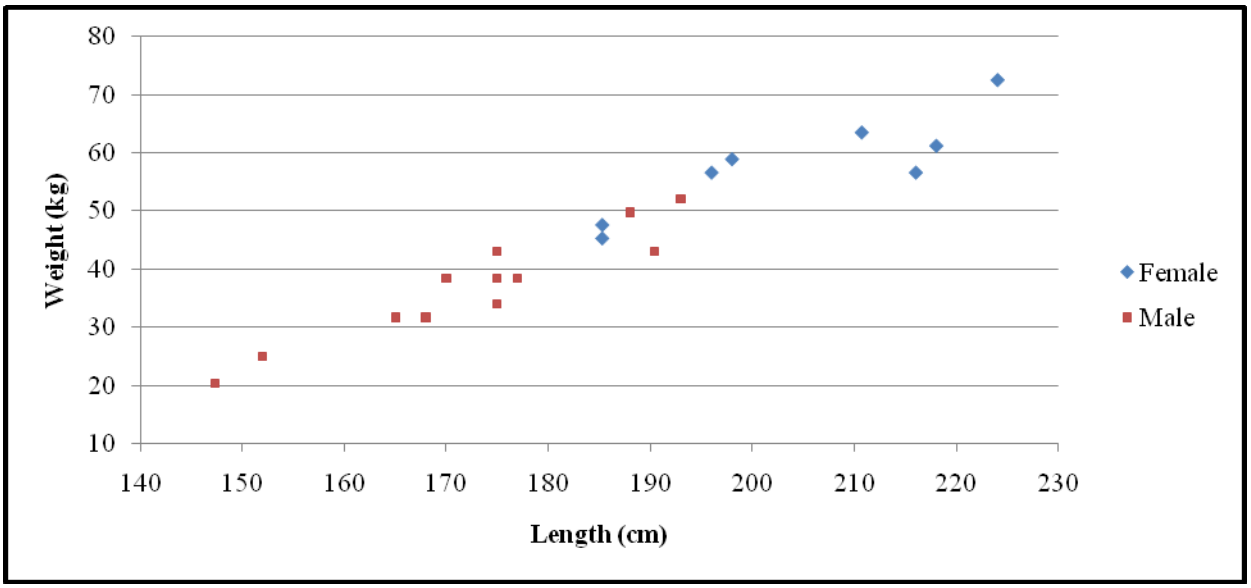

Figure 2: Weights and lengths of male and female green sturgeon tagged in the YTFP 2010 acoustic tagging and monitoring project.

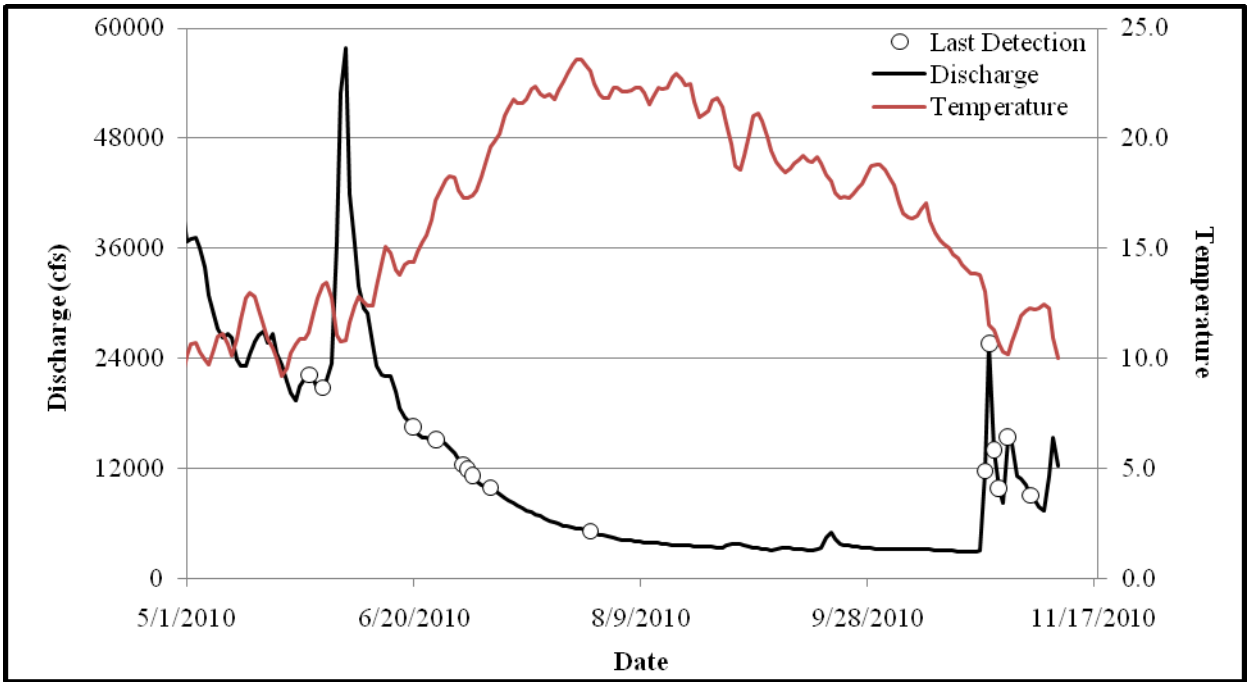

Figure 3: Klamath River discharge and temperature during the YTFP 2010 green sturgeon acoustic tagging and monitoring project. Discharge is shown in cubic feet per second (cfs) and was recorded by the USGS at rkm 13. Temperature is shown in degrees Celsius and was monitored by the YTFP at rkm 72. Circles on the discharge line represent the last time a tagged individual sturgeon was detected by our acoustic receiver at rkm 1 before exiting the Klamath River.

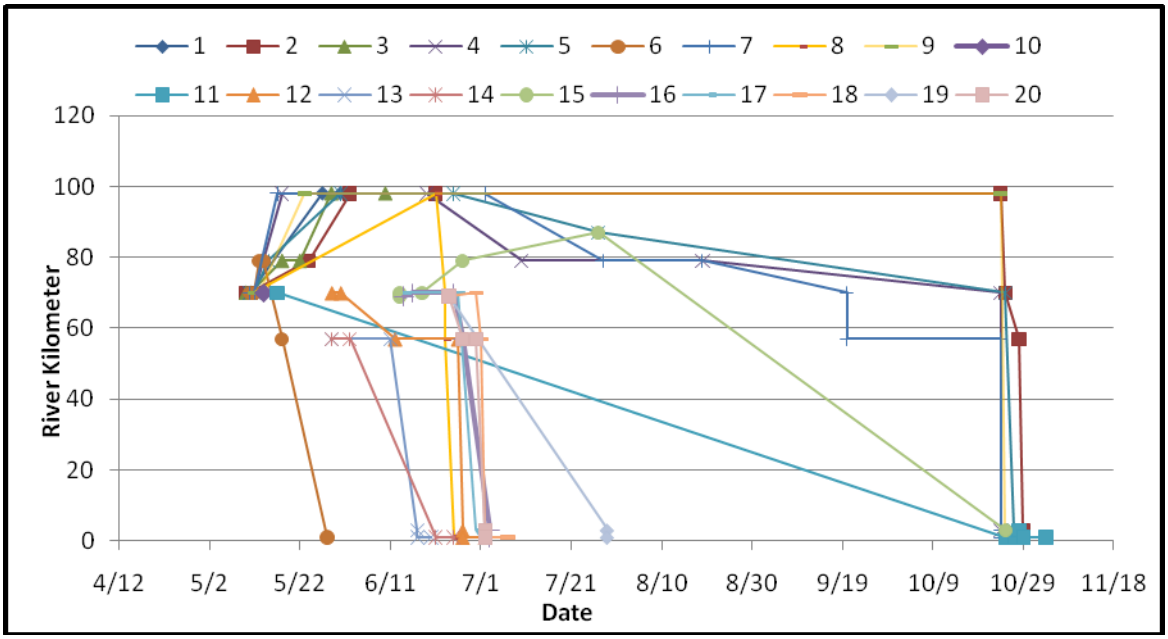

Figure 4: Movement summary of all tagged fish during the YTFP 2010 green sturgeon acoustic tagging and monitoring project. Each line represents and individual tagged green sturgeon and each mark on the line is an individual detection. For some fish the line between marks does not represent actual movements since the resolution of the movement data was low in some cases.

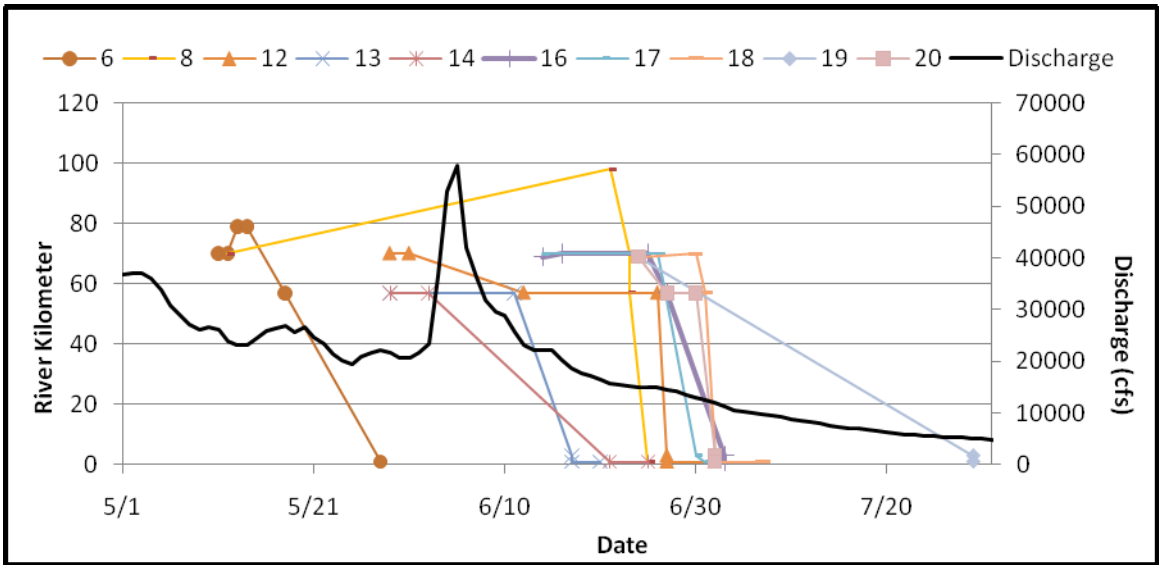

Figure 5: Movement summary for tagged green sturgeon that emigrated from the Klamath River during the spring and summer of the YTFP 2010 green sturgeon acoustic tagging and monitoring project. Also shown is Klamath River discharge for this time period which was measured by the USGS at rkm 13.

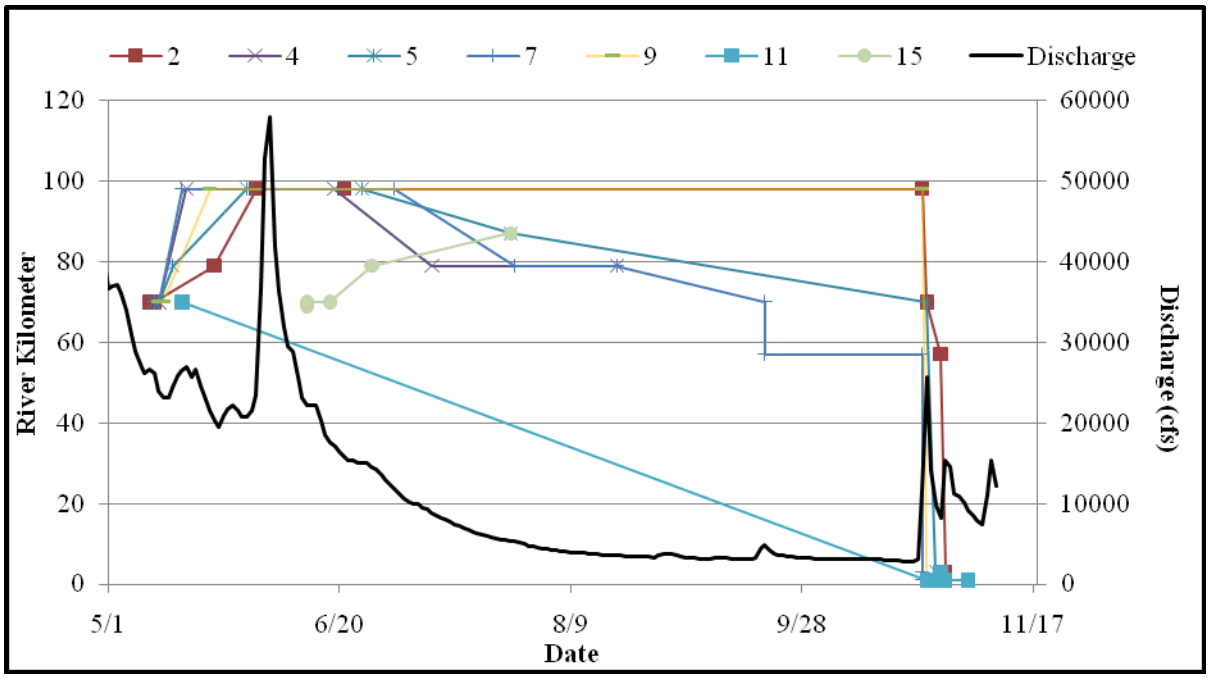

Figure 6: Movement summary for tagged green sturgeon that emigrated from the Klamath River during the fall of the YTFP 2010 green sturgeon acoustic tagging and monitoring project. Also shown is Klamath River discharge for this time period which was measured by the USGS at rkm 13.

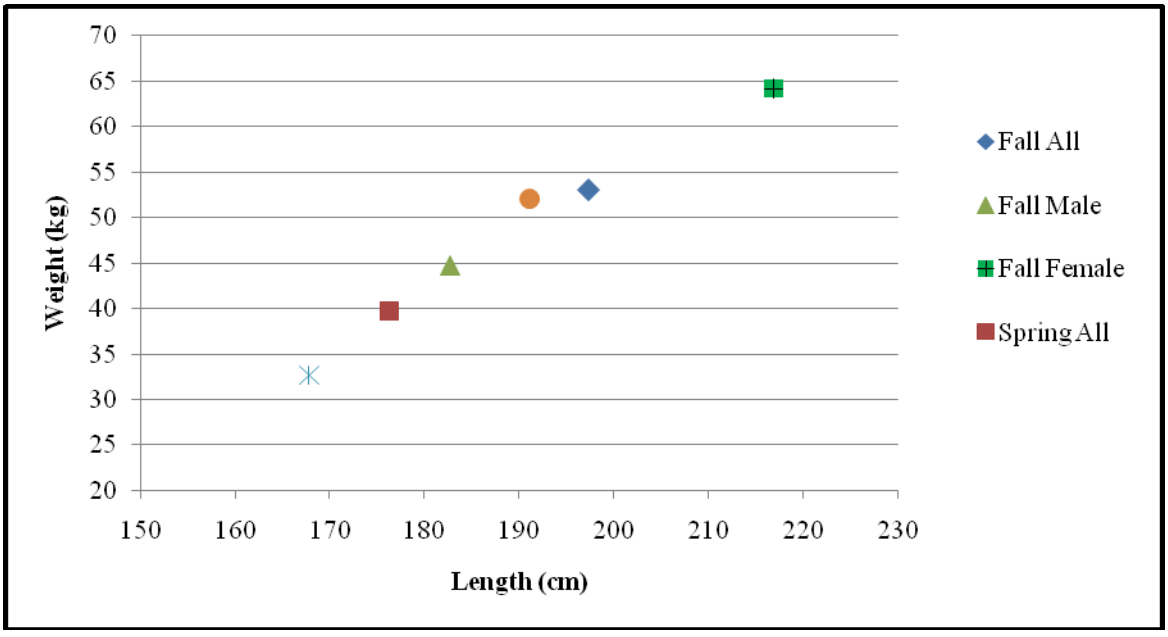

Figure 7: Average sizes of tagged emigrating green sturgeon from the YTFP 2010 green sturgeon acoustic tagging and monitoring project. "Fall All" encompasses both male and female fish that exited the river during fall and "Spring All" represents both male and female green sturgeon that left the river during spring or summer 2010.

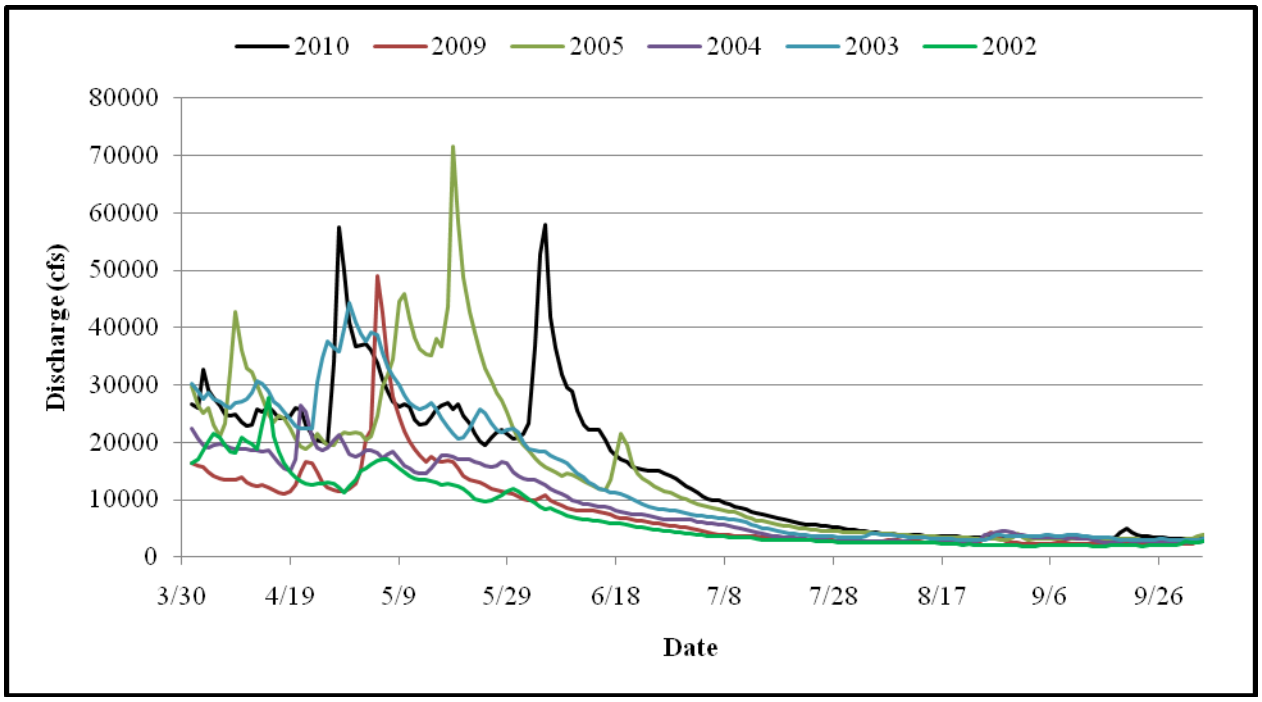

Figure 8: Klamath River discharge for all years that the YTFP has tagged green sturgeon. Discharge measurements were taken by the USGS at rkm 13.

Table 3: Average spring Klamath River discharge for all years that the YTFP has tagged green sturgeon. Spring discharge was calculated by finding the mean of the daily average flow for the time period between May 15th and July 15th and was measured by the USGS at rkm 13. Spring % represents the percent of individual tagged green sturgeon that emigrated from the Klamath River during spring or summer. Note that the low sample size in 2009 may have biased the data on the percentage of fish that exited in the spring as opposed to the fall.

Year	Sample Size	Spring Outmigrants	Fall Outmigrants	Spring %	Avg. Spring Flow
2010	18	11	7	61%	20,157
2009	4	2	2	50%	8,472
2005	8	5	3	62%	19,235
2004	8	3	5	38%	10,271
2003	22	7	15	32%	14,175
2002	13	1	12	8%	7,165

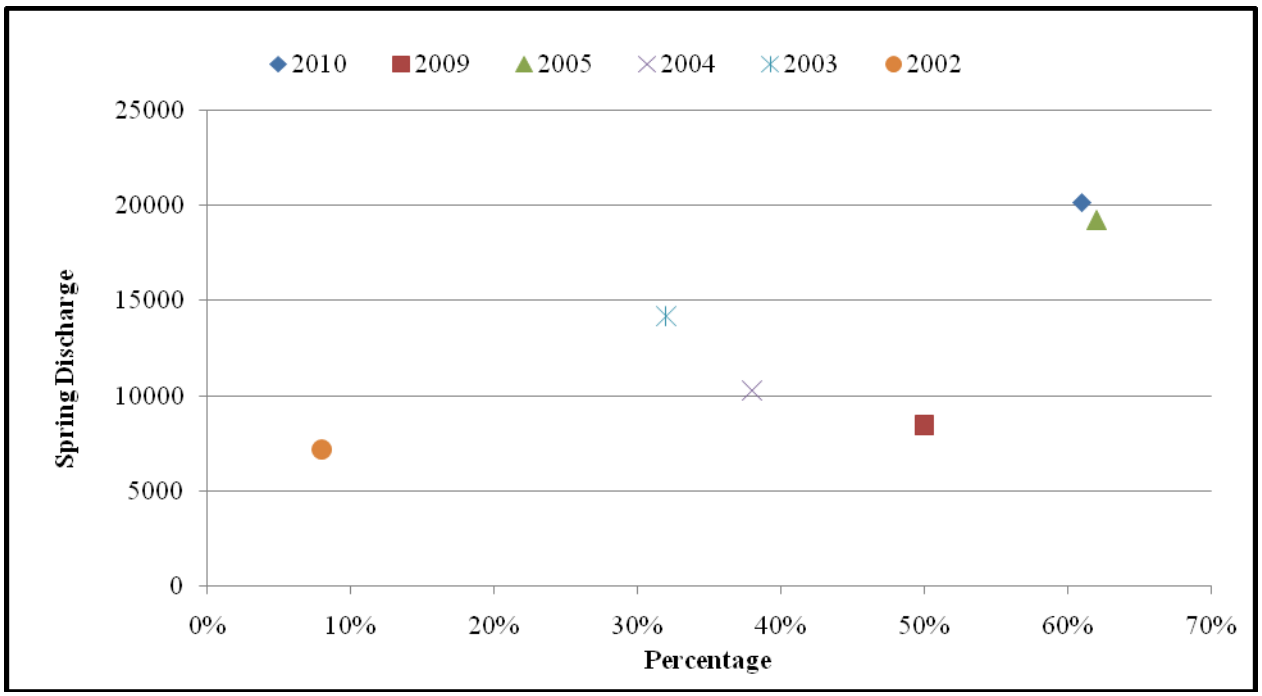

Figure 9: Klamath River spring discharge and percent of tagged fish that emigrated during spring or summer for all years that the YTFP has tagged green sturgeon. Spring discharge was calculated by finding the mean of the daily average flow for the time period between May 15th and July 15th and was measured by the USGS at rkm 13. Percentage represents the percent of individual tagged green sturgeon that emigrated from the Klamath River during spring or summer per individual year.

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