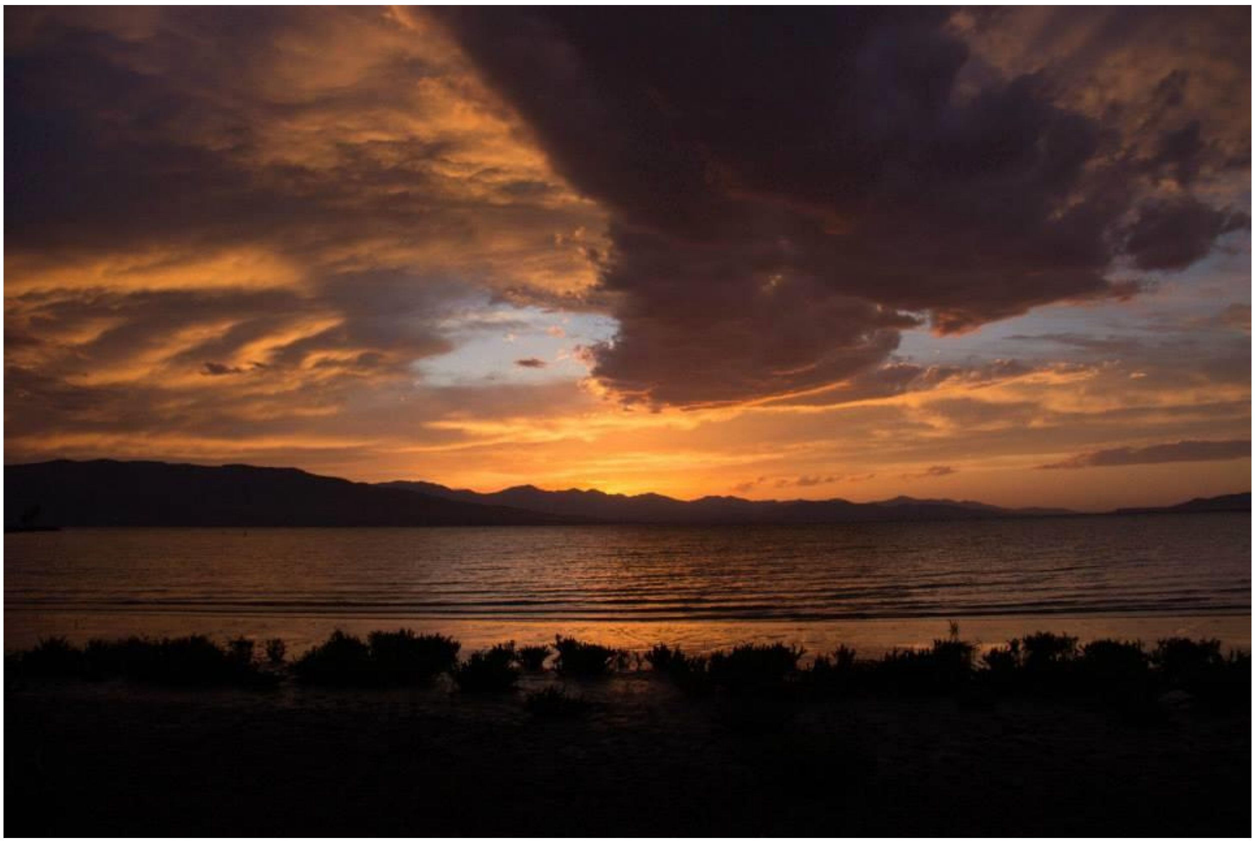
JUNE SUCKER RECOVERY IMPLEMENTATION PROGRAM

Post-stocking fate of June sucker in Utah Lake
2014 Draft Annual Report



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March 2015

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2014 Draft Annual Report

Prepared by: Chase A. Ehlo, Brian R. Kesner, and Paul C. Marsh

Marsh & Associates, LLC
5016 South Ash Avenue, Suite 108
Tempe, Arizona 85282
(480) 456-0801

June Sucker Recovery
Implementation Program
1594 West North Temple, Suite 3310
Salt Lake City, Utah 84114
www.junesuckerrecovery.org

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Executive Summary

June sucker *Chasmistes liorus* is an endangered species endemic to Utah Lake, UT. The lake historically supported 13 native fishes, but due to human interactions it now supports a suite of non-native species and only two natives, June sucker and Utah sucker *Catostomus ardens*. June sucker was once numerous throughout the lake, but numbers declined in the late 1990s to as few as 300 wild individuals. Many factors contributed to its decline including overharvest, habitat degradation, and predation and competition by non-native species. Repatriation of hatchery produced fish is a primary recovery strategy for June sucker, but fate of stocked fish is not well known. The purpose of this study is to detail immediate post-stocking survival and dispersal of hatchery reared June sucker in Utah Lake.

In the second year of this nominal three-year study, 20 June sucker were surgically implanted with acoustic telemetry tags. The acoustic tagged fish along with 1165 PIT tagged fish were released from the shoreline and in open water from boat in two separate stocking events in early and late summer. Both directional and omnidirectional hydrophones with a receiver were used to actively track fish. Multiple submersible ultrasonic receivers that continuously scanned for acoustic tags were placed throughout the study area for passive tracking. Remote PIT scanners were utilized in the lake to scan PIT tagged fish. Survival estimates for each telemetry study were calculated using Kaplan-Meier survival based on the final fate of each acoustic tagged June sucker. Patterns of dispersal were assessed for individual fish by mapping active and passive tracking records in ArcView®.

Kaplan-Meier survival estimates were 0.20 at 8 weeks and 0.00 at the end of the 60 day tracking period for early summer fish. Contact was permanently lost (unknown fate) with six out of ten fish released in late summer, and as a result survival estimates were not calculated. A total of 477 PIT tag contacts representing 263 unique fish were recorded over the four month study period using remote PIT scanners. Average size at stocking since 2007 has been 227 mm, whereas average stocking size of fish scanned in 2014 was 306 mm.

Overall, estimated survival in 2014 was lower than in 2013. The cause of the additional mortality in 2014 was unclear. American white pelican as well as other piscivorous birds are abundant at Utah Lake and may play a role in post-stocking survival of the fish. In addition, remote PIT scanning suggests that post-stocking survival is positively related to size at release. With continued efforts these data coupled

with PIT scanning will help to support informed stocking decisions and ultimately ensure the long term persistence and conservation of the species.

Introduction

June sucker *Chasmistes liorus* is an endangered species endemic to Utah Lake, UT (cover photo; Figure 1). June sucker is one of four species of the genus characterized as lakesuckers (Miller and Smith 1981). Lakesuckers are mid-water planktivores that differ from other members of the family Catostomidae by having a large, terminal mouths rather than the typical ventral one. June sucker is believed to become sexually mature at 5 to 10 years of age (Belk 1998) and adults generally make an annual spawning migration into tributary streams including the Provo River toward the end of June (Modde and Muirhead 1994). Larvae then drift downstream and make their way back into the lake where they grow to adulthood.

Historically, June sucker was numerous throughout the lake, but numbers declined in the latter 1990s to as few as 300 wild individuals with little or no recruitment in the population (US Fish and Wildlife Service [USFWS 1999). The decline was attributed to many factors including overharvest, habitat degradation, and predation and competition by non-native species. Spawning occurs in major tributaries, but the majority is restricted to the lower portion of the Provo River (Utah Division of Wildlife Resources [UDWR] 2011). Due to habitat alterations in the Provo River, most age-0 fish do not successfully transition from larvae to juveniles, and those that do are susceptible to predation by non-native fish (Modde and Muirhead 1994, Belk et al. 2001).

Habitat improvements, creation of a refuge population, and augmentation of the wild population with hatchery propagated and captive reared fish all are part of the June sucker recovery plan (USFWS 1999). More than 350,000 individuals longer than 200 mm total length (TL) have been stocked into the lake with a goal of stocking 2.8 million fish (USFWS and Utah Reclamation, Mitigation and Conservation Commission 1998). Monitoring of June sucker includes use of trap nets, trammel nets, commercial seines, and trawls in the lake proper and a combination of spotlighting and weir operations during spawning runs in the Provo River (USFWS 1999, UDWR 2011). Although hundreds of adult June sucker are captured in the river during spawning each year, juvenile suckers are rarely encountered in the river or in extensive efforts in the lake proper (UDWR 2011).

There is little information on post-stocking survival because of the paucity of encounters with juvenile fish. Rasmussen et al. (2009) estimated survival of stocked June sucker at 5% and found that survival was strongly correlated to size at release and rearing site. In addition, Billman et al. (2011) reported that probability of recruitment of stocked fish into the adult population was correlated to multiple factors including size at release, rearing site, condition factor, season, and release site. Both of these studies based their results on fish recruited to the adult population, which occurs several years after release and may result in bias due to potential site fidelity and unequal distribution of sampling effort (Billman et al. 2011).

This report presents results from year two of a multi-year, acoustic telemetry and remote sensing research project. The purpose of this study is to evaluate immediate post-stocking survival and dispersal of hatchery reared June sucker in Utah Lake. This year provided initial estimates of post-stocking survival for fish stocked in early summer (June) and late summer (August) at two stocking locations (shoreline and open water). Results of the study will provide a range of estimates among different stocking conditions and will supplement mark-recapture analysis of passive integrated transponder (PIT) data. This information will be incorporated into a cost-benefit analysis that will provide guidance for future stocking efforts and assist the June sucker program as it works toward recovery.

Methods

To obtain survival estimates and movement patterns for captive reared June sucker, intensive acoustic telemetry studies were conducted on Utah Lake. Each discrete segment of the study provided short-term (60 day) survival rates as well as post-stocking dispersal patterns. Twenty fish (10 for each stocking event) were implanted with acoustic tags (see *Surgical Method*, below) at the stocking site and 1200 additional fish (600 for each stocking event) were implanted with 134.2 kHz PIT tags and held in the UDWR Fisheries Experiment Station (FES) in Logan, UT until stocking. Thirty-five of the latter fish died while being held in the FES, a mortality rate of 2.9%. The first stocking and telemetry investigation was in early summer and ran from 2 June 2014 to 3 August 2014. The second study segment was in early autumn and ran from 31 July 2014 to 29 October 2014. Including surgery fish, 583 June sucker at a mean TL of 181 mm were stocked in early summer and 582 June sucker at a mean TL of 197 mm were stocked in late summer.

Study Area

Utah Lake (Figure 1) is a natural lacustrine system on the eastern edge of the Great Basin physiographic province. It is a large, shallow, eutrophic water body with a surface area of 38,400 hectares and mean and maximum depths of 2.8 and 4.2 m respectively (Fuhriman et al. 1981). The system historically supported 13 native fish species, but is now home to only two (June sucker and Utah sucker *Catostomus ardens*), plus a suite of non-native fishes. All of these non-natives are potential predators on one or more life stages of June sucker and some (channel catfish *Ictalurus punctatus*, white bass *Morone chrysops*, largemouth bass *Micropterus salmoides*, northern pike *Esox lucius*, and walleye *Sander vitreus*) have the potential to consume even the largest adult suckers.

Surgical Method

Twenty June sucker (10 in early summer and 10 in late summer; Table 1) were surgically implanted with model PT-4 acoustic transmitters (Sonotronics Inc., Tucson AZ) at the release site each sample period (Figure 2). This tag is small, reliable, and has a battery life of approximately three months. An additional five June sucker were implanted with PT-4 "dummy" tags, which are the same weight and size as the live tags. These latter fish were held simultaneously with five untagged fish in a live cage placed in Utah Lake for the same 60-day period as fish released in the lake to evaluate the surgical method. The 10 early summer fish had a mean TL of 236 mm, the 10 late summer fish had a mean TL of 245 mm, and the 10 fish held in the live cages had a mean TL of 241 mm. Each surgery was performed generally as follows (Mueller et al. 2000; Karam et al. 2008).

> Approximately 20 fish were transferred from the stocking truck into a holding tank and allowed to acclimate for at least 30 minutes prior to surgery. Each fish was anesthetized by immersion in approximately 16-L of fresh water with tricaine methanesulfonate (MS222; 125 mg L-1) in a dark container. Once anesthesia had progressed to the desired depth, indicated by cessation of all fin and muscular movements other than weak operculation, the fish was removed from the container, measured (TL in mm), weighed (nearest gram [g]), and scanned for a 134.2 kHz PIT tag. The fish then was placed on its dorsum on a wetted towel in a specially-constructed cradle and covered with a damp lightweight cloth. Fresh MS-222 from a 20-L reservoir was gently pumped through a 4.7-mm inner diameter tube and onto the exposed gills to maintain

anesthesia for the duration of the procedure. A short (< 2 cm) mediolateral incision was made slightly anterior and dorsal to the left pelvic fin and an acoustic transmitter sanitized in 70% ethanol was inserted into the abdominal cavity (Figure 3). A PIT tag was placed into the cavity if none was detected. The incision was sutured with 2-3 knots using 3-0 blue monofilament polypropylene and NRB-1, 17 mm, ½ taper cutting needle (CP Medical, Portland OR). Following surgery, the wound was swabbed with Betadine, a 10 mg/kg dosage of Baytril® (enrofloxacin) was injected into the dorsal-lateral musculature to prevent infection (Martinsen and Horsberg 1995), and the fish was placed in a recovery tank with fresh circulated water. Following surgery, fish were monitored to ensure proper health and transmitter retention and allowed to recover for up to one hour before being stocked.

Passive Tracking

Prior to stocking, 20 submersible ultrasonic receivers (SURs) equipped with weights and buoys were deployed throughout the lake in permanent locations as a method of passive tracking (Figure 4). Initial trials indicated a detection range of approximately 500 meters (m) from the SURs. Taking this nominal range into account, 16 SURs were used to section the lake into three zones with eight SURs deployed 1000 m apart across the lake along two transect lines. Two SURs were also placed at the mouth of Provo Bay and two were placed in the Provo River to detect any movement into and out of these areas (Figure 4). Additionally, another four to five SURs were placed at random locations in the lake for approximately 24-hour time periods (Figure 5). Random SUR locations were determined using Hawth's Tools v 3.27, a free open-source tool for ArcView®. Data from SURs were downloaded weekly and any fish detected on the SUR within 12 hours of the time the SUR was downloaded were manually tracked using active methods outlined below.

Active Tracking

During each 60-day release period, fish were manually tracked using an omni-directional (towable) and directional hydrophone connected to a programmable active tracking receiver (Sonotronics DH-4 and USR-08, respectively; Figure 2). Initial trials in Utah Lake indicated a detection range of approximately 200 m. Immediately after release, an attempt was made to contact each fish at least once per day during the study period. As the fish left the release area, SURs were downloaded to determine if any fish left the central zone. Up to 316 manual tracking fixed points 1000 m apart were visited weekly to pinpoint fish locations using the directional hydrophone (Figure 6) and the towable hydrophone was used to laterally transect the lake.

June sucker that were not contacted while visiting the fixed points were recorded as missing. If missing fish were recorded on an SUR along a zone transect, the zone beyond that SUR transect was targeted for the next tracking period. If a fish was recorded missing for more than three tracking periods, a search of the entire lake was initiated. Fish recorded in the same location for three tracking periods without any noted activity were considered mortalities. When an individual was contacted, fish location was determined by triangulation using the directional hydrophone and identified by Universal Transverse Mercator (UTM) coordinates. Location and tag information was recorded on waterproof paper as follows: acoustic tag number and frequency, time and date, general location or site name, water temperature (°C), UTM coordinates, and water depth (m). Contact data were incorporated into a Microsoft Access® database to create an accurate and complete history of each acoustic tagged fish.

PIT Scanning

Deployments of six remote PIT scanning units at potential locations of juvenile June sucker concentrations were conducted in 2014. Deployments were completed biweekly over the course of both early and late summer 60-day tracking periods. Submersible PIT scanners were modified from earlier models described in Kesner et al. (2008). Five submersible PIT scanners were comprised of a 1.2 x 0.8 m PVC frame antenna attached to a scanner, logger and a 10.4 amp-hour battery contained in water-tight PVC and ABS piping (Figure 7). One submersible PIT scanner was comprised of a 1.2 x 0.8 m PVC frame antenna attached to a scanner, logger and equipped with a longer battery tube in water-tight PVC piping that could be fitted with a 20.8 amp-hour battery. Both types of units were completely submersible and scanned continuously for up to 72 hours for 10.4 amp-hour batteries and up to 120 hours for the 20.8 amp hour battery. Antennas were also equipped with weights so that units could be oriented to lie flat along the bottom of the lake (bottom flat) or to stand upright in the water column (bottom long). On the first day of a scanning sample period, crews set out antennas and then revisited the units the following day (with exception to the 20.8 amp hour unit which was deployed and left for the week). After units had been deployed for approximately 24 hours, crews replaced scanner batteries and downloaded data to a handheld device. During each effort the following information was recorded:

date and time of deployment and pick-up, general location, UTM coordinates, depth (m), distance to shore (m), antenna orientation (antenna oriented perpendicular or parallel to the substrate), unit and battery ID, scan time (minutes), and estimated number of contacts.

Data Analysis

Kaplan-Meier estimates (Kaplan and Meier 1958) of post-stocking survival from each telemetry study were based on the final fate of each acoustic tagged June sucker. To calculate the estimate, each fish was assigned to one of three fates: a fish died before the end of the study, a fish survived the study, or a fish was lost to the study (lost signal). If a fish was lost to the study and later found dead, the fish was presumed alive up to the point that it was found dead. This occurred for two fish in the early summer tracking period. For fish that died or for which the signal was lost, the timing of the death or lost signal was determined. The first date of three consecutive tracking events that a fish was found at the same location was determined as its time of death. The time of the last recorded active or passive (SUR) contact with a fish whose signal was permanently lost during the 60 days was determined as the time the fish was lost to the study.

Results

Fate and Survival

Permanent SURs recorded a total of 6657 telemetry tag contacts representing 11 of the 20 fish and random SURs recorded a total of 2019 contacts representing 14 of the 20 fish. Manual tracking resulted in 57 contacts representing 16 of the 20 fish. Of the 10 fish stocked in early summer, there were eight mortalities and two lost contacts (Table 2). Seven mortalities for early summer fish occurred 4-45 days post-stocking (Table 1) and the last mortality occurred 86 days post-stocking outside of the study timeframe. However, this fish was lost to the study 8 days post-stocking and likely died earlier in the tracking period but was only found later through intensive tracking. The two lost contacts occurred 2-4 days post-stocking. Of the 10 fish stocked in late summer, there were four mortalities and six lost contacts (Table 2). Mortalities for late summer fish occurred 5-21 days post-stocking (Table 1). Of the six lost contacts, contact was immediately lost for three fish and contact was lost 1 day post-stocking for three fish (Table 1). There was complete mortality among the fish held in a live cage on Utah Lake within two days of stocking. There were avian wounds present on the carcasses of caged fish, but it is unclear if avian predation was the cause of mortality. Efficacy of our surgical protocol has been verified with June sucker (Ehlo et al. 2015) and is not implicated in loss of these fish. Another factor (for example, poor water quality) may have been the cause of mortality and birds simply scavenged on the fish afterward they had died. Survival estimates (95% CI) for early summer fish decreased steadily from 0.90 (0.54-0.99) in week 1 to 0.40 (0.14-0.73) from weeks 2-6 to 0.20 (0.04-0.56%) in weeks 7 and 8 and finally to 0 (0-0.34) in week 9 (Figure 8). Kaplan-Meier estimates were not calculated for late summer fish due to censuring of the majority (six of ten) of fish after the first week of tracking.

Early summer stocking fish were released in the Provo River. All 10 of the telemetry fish moved out of the river 1-3 day post-stocking. One fish was detected on the northern transect of SURs (Figure 9) but was not contacted by active tracking and was not passively tracked after 4 days post-stocking. The eight mortalities were all found within 5 km of the stocking site. In the late summer stocking, fish were released 2 km offshore in Utah Lake. Four SURs were placed around the stocking location to verify when the fish left the stocking area. All fish were initially recorded on these SURs and five fish were found with active tracking 1 day post-stocking. However, six fish soon disappeared for the duration of the study and the four mortalities all occurred within 5 km of the stocking location.

PIT Scanning

Because Utah Lake is shallow and often rough due to prevailing winds, safe locations for PIT scanner deployments were limited. Submersible units were generally placed in or near the following locations (Figure 1): Provo River, the boulder jetty sheltering Utah Lake State Park Marina, Bird Island (a small rocky island in the southern area of the lake), Long Bar (a sandy area just south of the Provo River mouth), American Fork River mouth, entrance to Powell Slough (a wetland north of the Provo River mouth), Pelican Point (a rocky point on the west shoreline of Utah Lake), and Goose Point (a small rocky point just south of Pelican point).

Stocking records were compiled from a database provided by UDWR. Because this is a post-stocking survival project, only fish stocked with a 134.2 kHz tag were included in the stocking table (i.e., fish that were captured in Utah Lake and tagged with a 134.2 kHz tag were excluded). The stocking table had a total of 4035 fish at an average length of 227 mm.

From late May to September 2014, crews made a total of 144 deployments of submersible PIT scanning units, resulting in 4148 hours of scanning (Table 3). Scanners were generally placed in the same vicinity each sampling week (i.e., Bird Island, Provo River mouth, etc.). A total of 477 PIT contacts were recorded over the four month study period, 263 of these represented unique June sucker, and 45 of the fish were stocked in the lake with a 134.2 kHz tag at an average length of 306 mm (Table 4). Of these last 45 fish only four were June sucker that were stocked for this study. Three of those four were stocked in 2014 and one was stocked in 2013 and scanned on Long Bar (Table 4). The majority of fish (34) with a stocking record were stocked in 2011. The greatest proportion of fish, 0.627 (165 fish), was contacted on Long Bar, 53 fish were contacted at Bird Island, 49 in the Provo River, two in the Provo River Mouth, and one was contacted at Goose Point (seven fish were contacted in multiple locations).

Discussion

Overall, tracking was less successful in 2014 than 2013 as evident by the number of fish lost to the study and lower survival rates. The cause(s) of post-stocking mortality of June sucker in Utah Lake is unknown. Avian predation appeared to be a major factor in post-stocking survival of fish in 2013, as evidenced by presence and documentation of California gulls *Larus californicus* consuming fish immediately post-stocking (Ehlo et al. 2015). Avian predation has been documented on other endangered suckers such as the Warner sucker *Catostomus warnerensis*, a species that utilizes similar lake habitats in Oregon, and another species of lakesucker, the Cui-ui *Chasmistes cujus* in Lake Tahoe, Nevada (Scheerer et al. 2012; Scoppettone et al. 2014). More specifically, Scoppettone et al. (2014) found that American white pelicans *Pelecanus erythrorhynchos* had taken 90% of the Cui-ui deployed with tags during the study. American white pelicans are found in abundance at Utah Lake and in the nearby Great Salt Lake, and the effect of these and other piscivorous birds are unknown and warrant future investigations.

Due to the low statistical power, the loss of fish, and other limits of the Kaplan-Meier survival model, a mark-recapture known fate model (Pollock et al. 1989) was investigated but not included in this report. This known fate model is more versatile in that it will allow direct comparisons between different grouping factors such as season, year, and stocking location; it will improve statistical power, and allows for covariates such as size or condition of fish. This model will be further explored and included in the final report alongside Kaplan-Meier survival estimates.

Remote PIT scanning in 2014 contacted almost four times as many fish as were contacted by scanners in 2013. The mean stocking size of fish contacted by PIT scanners (306 mm TL) was larger than the mean size of fish stocked in the lake with a 134.2 kHz tag (227 mm TL). In a previous study, Rasmussen et al. (2009) found that survival was strongly correlated to size at release. In addition, Billman et al. (2011) stated that total length has an apparently strong effect on the probability of stocked June sucker recruiting into the spawning population. Although data from this project and others suggest that there is a positive relationship between stocking size and survival, it is unclear whether the remote PIT scanning is biased toward bigger fish. Scanners were generally placed within a few kilometers of shoreline in places where June sucker are known to aggregate (i.e., Long Bar and Bird Island). Tracking data suggest that newly stocked sub adults utilize the pelagic areas of the lake, but it is unknown whether smaller fish are not contacted due to differing habitat utilization or general rarity brought about by increased mortality at smaller size classes.

In conclusion, acoustic telemetry was met with more difficulty this year as compared to the previous year's tracking, particularly in the late summer stocking where more than half of the fish were lost to the study. However, telemetry continues to provide short term post-stocking survival estimates, and remote PIT scanning is beginning to provide insight on longer-term survival of June Sucker. Two additional telemetry iterations and remote PIT scanning are scheduled for the next year, completion of which will build on the current dataset and will ideally provide more insight into release factors and the impact they have on the immediate post-stocking survival.

Recommendations

Release of acoustic tagged fish should continue because it provides a means to further study release factors such as time of year and location. Other factors that may affect post-stocking survival such as avian predation, size at release, and environmental factors (i.e., water quality and quantity) should also be explored. A portion of June sucker stocked in Utah Lake should continue to be PIT tagged, and other remote PIT scanning locations throughout the lake should be identified. These approaches collectively will be beneficial in determining long-term survival of the species as the surviving fish become sexually mature and move up the tributaries to spawn.

Acknowledgements

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Table 1. Fate of 20 individual June sucker surgically implanted with a sonic transmitter and stocked into Utah Lake, UT in early summer and late summer 2014. DPS is days post-stocking.

Tag ID	TL (mm)	Mass (g)	Pit tag #	Season	Fate	DPS
3	227	130	3DD.003BC50DF9	Early Summer	Lost contact	3
4	232	140	3D9.1C31E2718E	Early Summer	Mortality	9
5	249	170	3D9.1C2C857408	Early Summer	Lost contact	2
6	235	142	3DD.003BB917B8	Early Summer	Mortality	45
7	241	148	3DD.003BC50DF3	Early Summer	Mortality	4
63	237	154	3D9.1C2C85230E	Early Summer	Mortality	9
64	232	152	3D9.1C2C843FE9	Early Summer	Mortality	9
65	238	140	3D9.1C2C845017	Early Summer	Mortality	86
66	243	150	3D9.1C2C857457	Early Summer	Mortality	9
67	230	124	3D9.1C2C845313	Early Summer	Mortality	10
38	233	140	3D9.1C2D6C08FF	Late Summer	Lost contact	1
39	232	136	3D9.1C2D6D0B98	Late Summer	Mortality	6
40	256	156	3D9.1C2D6BBE10	Late Summer	Lost contact	1
41	249	158	3D9.1C2D6C3E87	Late Summer	Lost contact	0
42	248	150	3D9.1C2D6C3DD8	Late Summer	Lost contact	0
68	242	140	3D9.1C2D6C0AE1	Late Summer	Mortality	5
69	237	146	3D9.1C2D6C40AC	Late Summer	Lost contact	1
70	244	152	3D9.1C2D6C0B79	Late Summer	Mortality	6
71	259	180	3D9.1C2D6BCF30	Late Summer	Mortality	21
72	264	160	3D9.1C2D6C32FC	Late Summer	Lost contact	0

Table 2. Fate of telemetry tagged June sucker stocked into Utah Lake, UT, in Early Summer and Late Summer 2014.

	Week									
	1	2	3	4	5	6	7	8	9	Total
Early Summer 2014[1]										
Survivors	9	0	0	0	0	0	0	0	0	0
Mortalities	1	5	0	0	0	0	1	0	1	8
Lost fish	0	2	0	0	0	0	0	0	0	2
Late Summer 2014										
Survivors	7	0	0	0	0	0	0	0	0	0
Mortalities	3	0	0	1	0	0	0	0	0	4
Lost fish	0	6	0	0	0	0	0	0	0	6

[1]There were two fish temporary lost to the study and later found dead in the lake for Early Summer 2014. One fish in the Early Summer 2014 sample was lost for the duration (60 days) of the tracking period and later found. For the purpose of the Kaplan-Meier estimate this fish was labeled dead on the last week of the 60 day tracking period.

Table 3. Summary of PIT scanning performed in Utah Lake, UT, 2014. Contacts is the total number of contacts, Unique is the number of individual June sucker that were contacted, and Study unique is individual fish contacted that were stocked specifically for this study.

Month (2014)	Deployments	Total scan time (hours)	Contacts	Unique	Study unique
May	1	133	9	9	0
June	42	1288	52	45	1
July	19	409	3	3	0
August	41	1110	89	48	2
September	40	1208	324	166	1
Totals	143	4148	477	263	4

Table 4. List of remotely scanned June sucker that were stocked with a 134.2 kHz tag. Date is the day of stocking. FES is the UDWR Fisheries Experiment Station in Logan, UT.

PITHEX	Date	Length	Weight	Origin
3D9.1C2C867CAA	06-Jun-10	191	60	FES via Springville
3D9.1C2C921635	26-Apr-11	391	700	Camp Creek via Springville
3D9.1C2C91F63A	04-May-11	318	340	Camp Creek via Springville
3D9.1C2CAB079F	11-Aug-11	351	460	Camp Creek via Springville
3D9.1C2CAB1E72	11-Aug-11	327	400	Camp Creek via Springville
3D9.1C2CAC55A6	17-Aug-11	386	580	Camp Creek via Springville
3D9.1C2CAC197F	18-Aug-11	372	540	Camp Creek via Springville
3D9.1C2CD46B29	18-Aug-11	347	420	Camp Creek via Springville
3D9.1C2C880ED5	22-Aug-11	406	620	Camp Creek via Springville
3D9.1C2C920CF2	22-Aug-11	385	580	Camp Creek via Springville
384.1B795AA5D1	20-Sep-11	300	218	Camp Creek via Rosebud
384.1B795AA5D5	20-Sep-11	307	278	Camp Creek via Rosebud
384.1B795AA5E1	20-Sep-11	291	218	Camp Creek via Rosebud
384.1B795AA5E7	20-Sep-11	308	282	Camp Creek via Rosebud
384.1B795AA5F8	20-Sep-11	290	236	Camp Creek via Rosebud
384.1B795AA600	20-Sep-11	267	190	Camp Creek via Rosebud
384.1B795AA6B9	20-Sep-11	280	212	Camp Creek via Rosebud
384.1B795AA6C1	20-Sep-11	309	278	Camp Creek via Rosebud
384.1B795B134C	20-Sep-11	291	236	Camp Creek via Rosebud
384.1B795B1355	20-Sep-11	318	340	Camp Creek via Rosebud
384.1B795B1361	20-Sep-11	335	346	Camp Creek via Rosebud
384.1B795B136E	20-Sep-11	304	280	Camp Creek via Rosebud
384.1B795B137F	20-Sep-11	335	380	Camp Creek via Rosebud
384.1B795B144D	20-Sep-11	290	247	Camp Creek via Rosebud
384.1B795B1461	20-Sep-11	298	230	Camp Creek via Rosebud
384.1B795B149E	20-Sep-11	303	231	Camp Creek via Rosebud
384.1B795B14AA	20-Sep-11	280	134	Camp Creek via Rosebud
384.1B795B1651	20-Sep-11	325	310	Camp Creek via Rosebud
384.1B795B17D6	20-Sep-11	269	192	Camp Creek via Rosebud
384.1B795B17F2	20-Sep-11	270	200	Camp Creek via Rosebud
384.1B795B17FE	20-Sep-11	-	-	Camp Creek via Rosebud
384.1B795B182B	20-Sep-11	313	247	Camp Creek via Rosebud
3D9.1C2C459B48	20-Sep-11	259	181	Camp Creek via Rosebud
3D9.1C2C45B410	20-Sep-11	282	226	Camp Creek via Rosebud
3D9.1C2C46CE7A	20-Sep-11	276	216	Camp Creek via Rosebud
3D9.1C2CD485B7	30-May-12	400	780	Camp Creek via Springville
384.342770EE19	22-May-13	311	240	Camp Creek via Springville
384.342770EE32	22-May-13	339	360	Camp Creek via Springville
384.342770EE63	22-May-13	317	340	Camp Creek via Springville
384.342770EE99	22-May-13	414	700	Camp Creek via Springville
384.342770EECE	22-May-13	296	260	Camp Creek via Springville
384.342770F7B6	29-Jul-13	225	160	Fisheries Experiment Station
3DD.003BB9177C	02-Jun-14	187	78	Fisheries Experiment Station
3DD.003BCE5DD7	31-Jul-14	196	77	Fisheries Experiment Station
3DD.003BCE5E3E	31-Jul-14	211	105	Fisheries Experiment Station

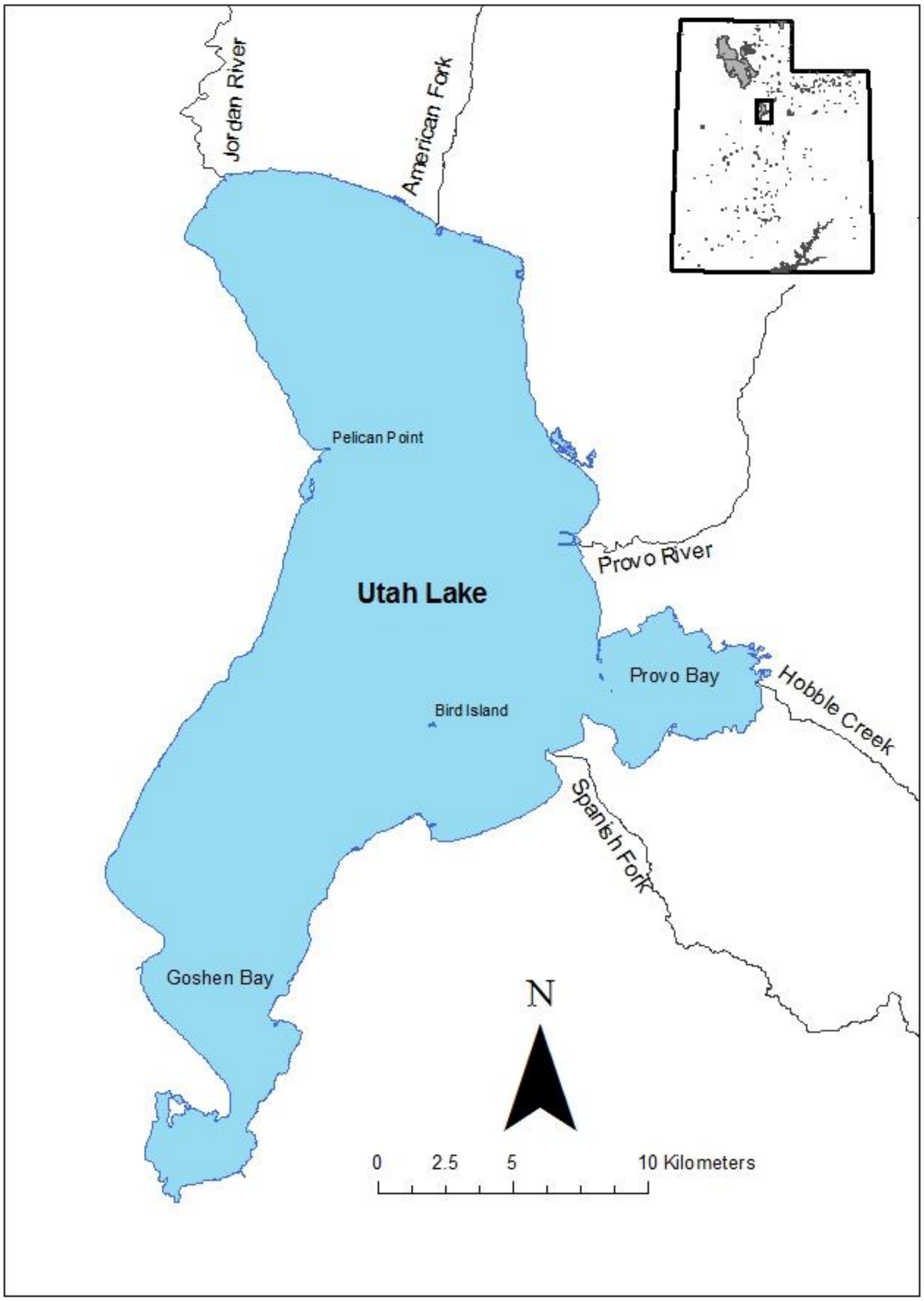

Figure 1. Map of Utah Lake, UT, showing main tributaries and place names throughout the lake, and location map (inset).

Figure 2. Telemetry equipment used for the June sucker study. Upper left photo is the Sonotronics Inc. (Tucson, Arizona) model PT-4 acoustic tag. Upper right photo is the directional hydrophone (Sonotronics model DH-4). Lower left photo is the omni-directional towable hydrophone (Sonotronics model TH-2). Lower right photo is the Sonotronics Inc. (Tucson, Arizona) Submersible Ultrasonic Receiver.

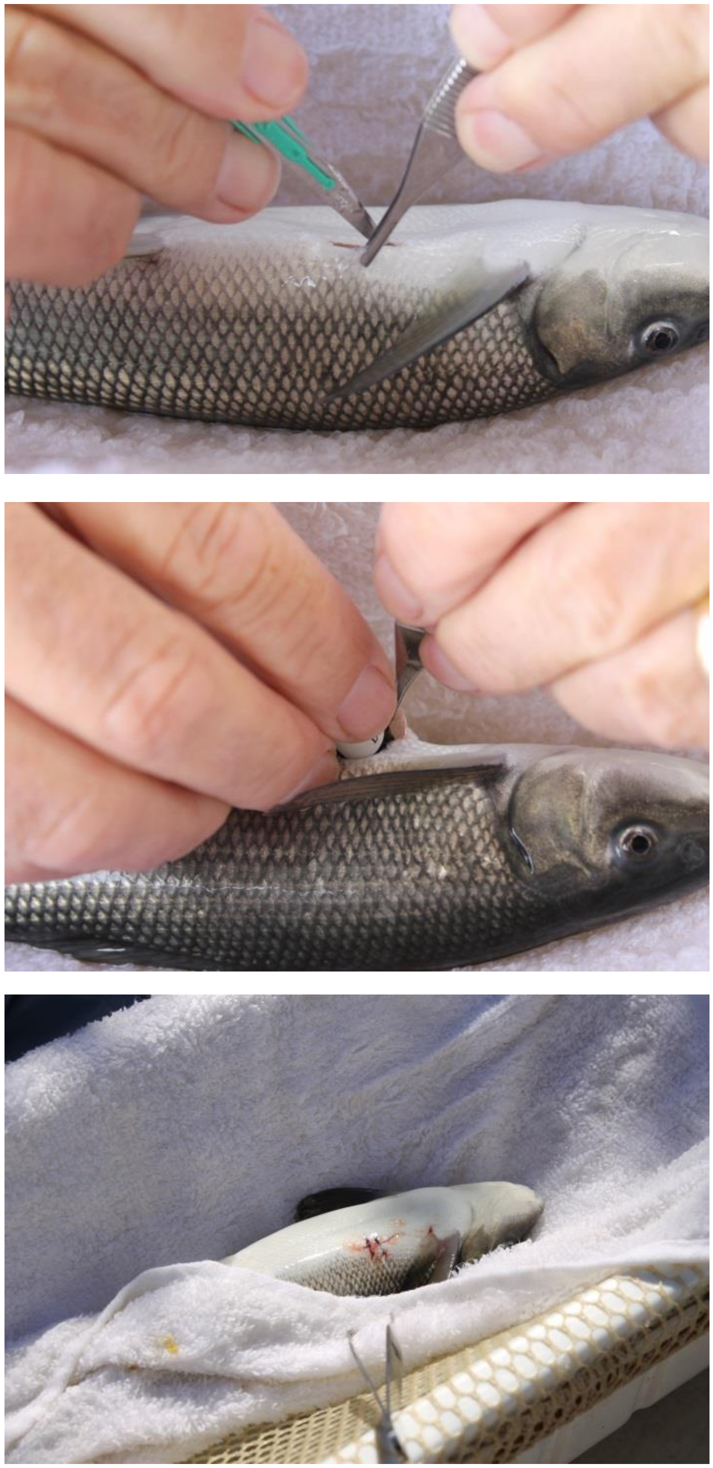

Figure 3. June sucker telemetry tag implantation procedure. The top picture is the mediolateral incision being made. The middle picture is the tag being inserted, and the bottom picture depicts the suturing of the incision.

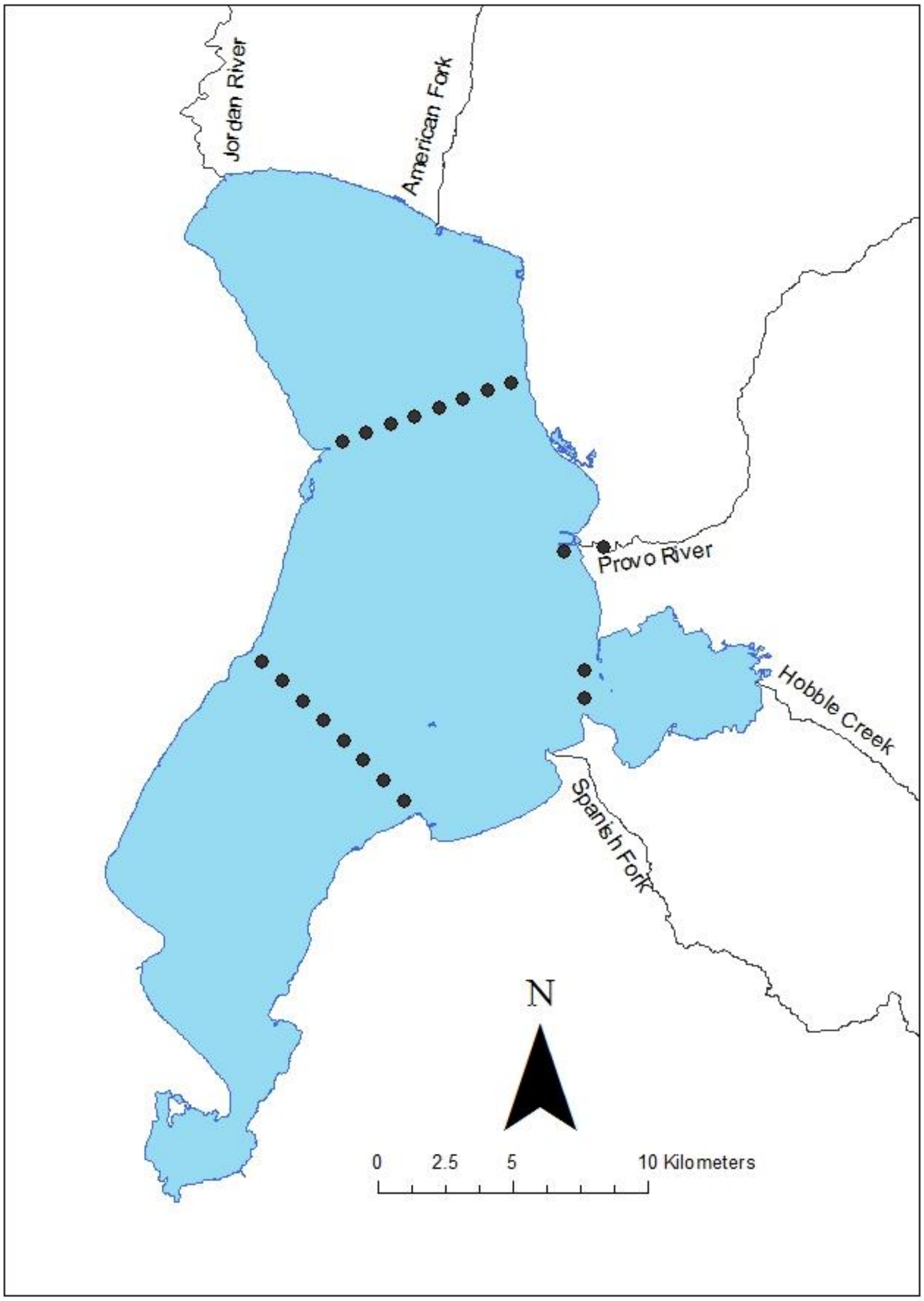

Figure 4. Map of Utah Lake, UT, showing locations of the seasonally permanent SUR placements during the 2014 June sucker telemetry study.

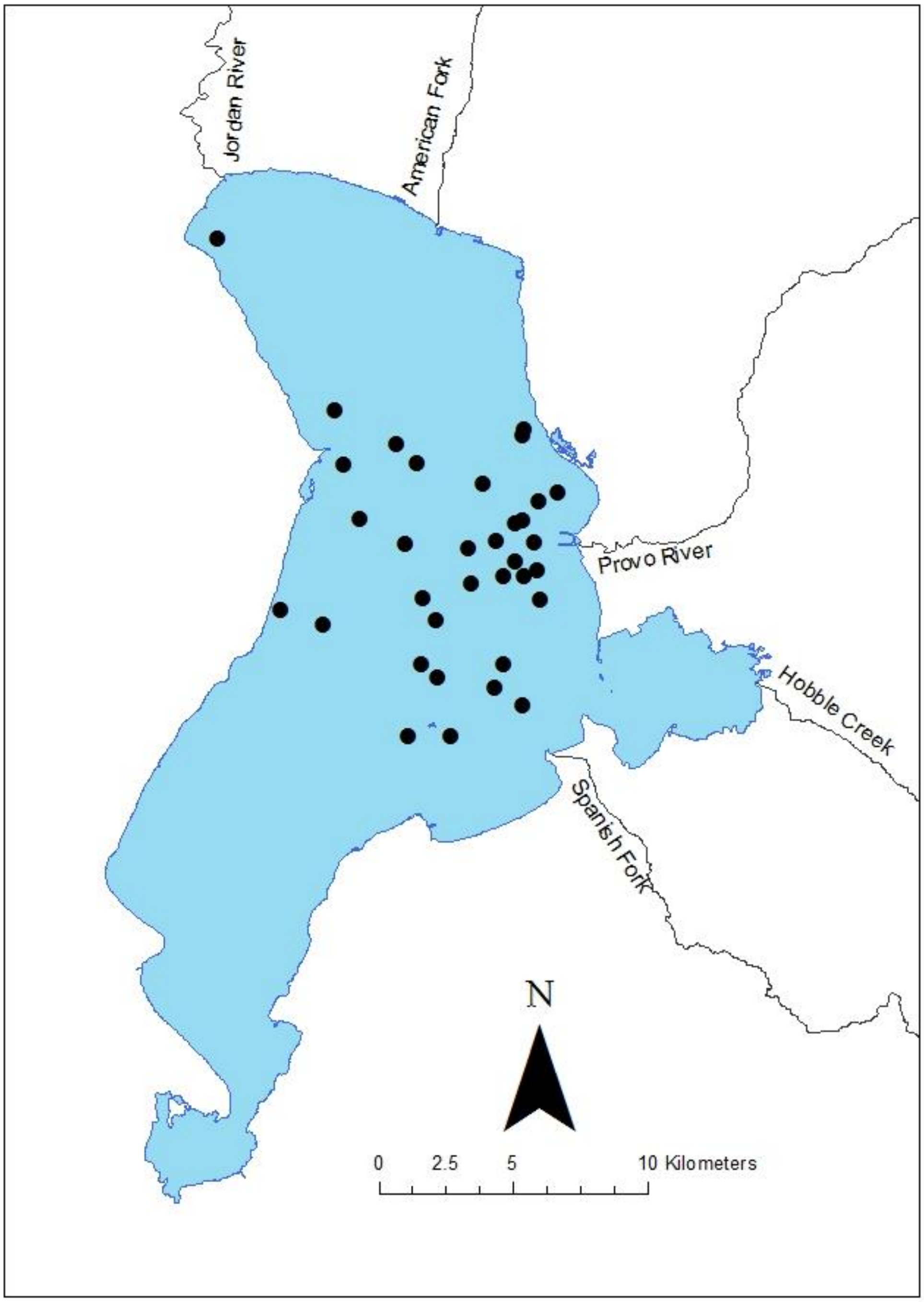

Figure 5. Map of Utah Lake, UT, showing locations of the random SUR placements during the 2014 June sucker telemetry study.

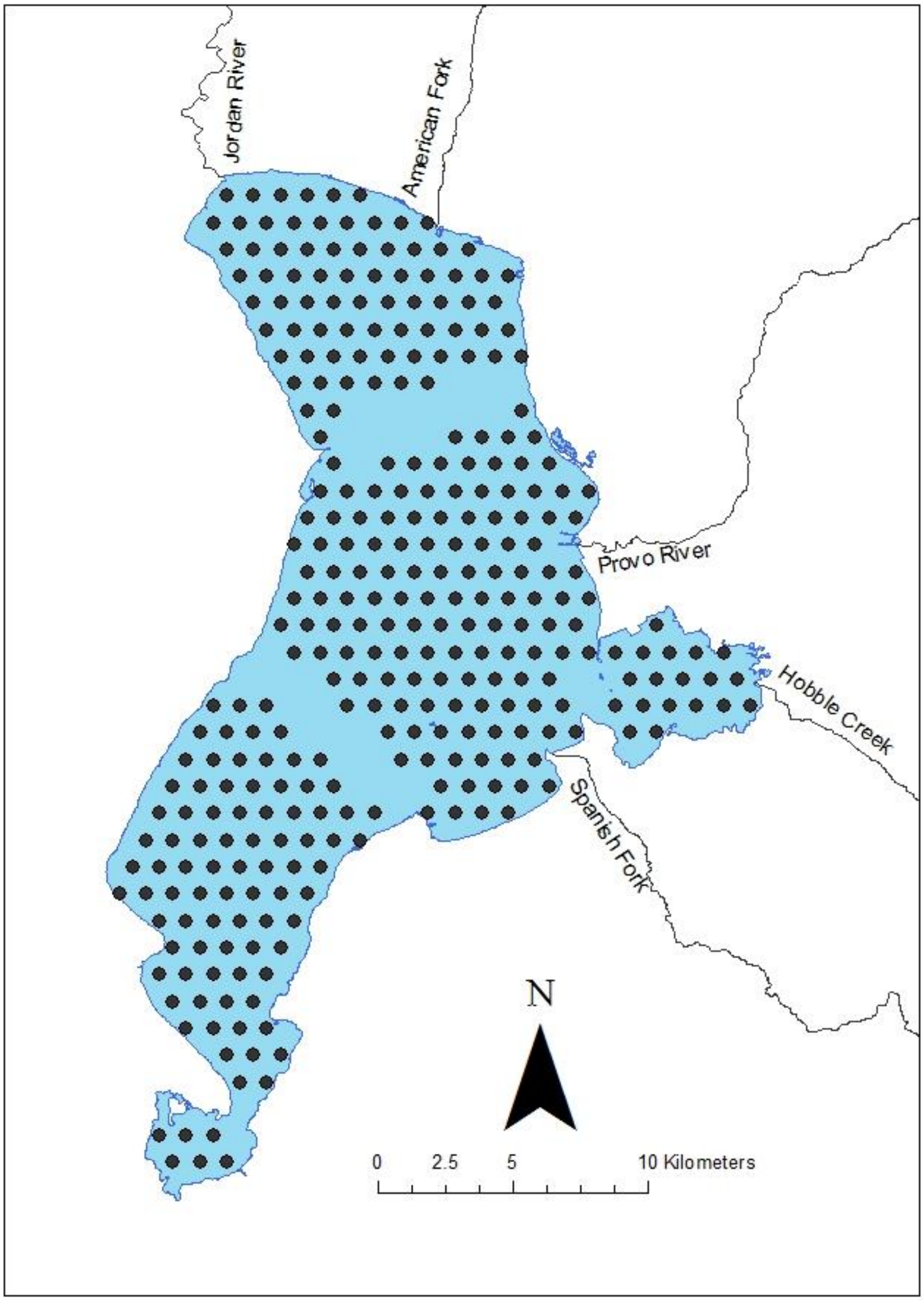

Figure 6. Map of Utah Lake, UT, showing locations of the 316 manual tracking points during the 2014 June sucker telemetry study.

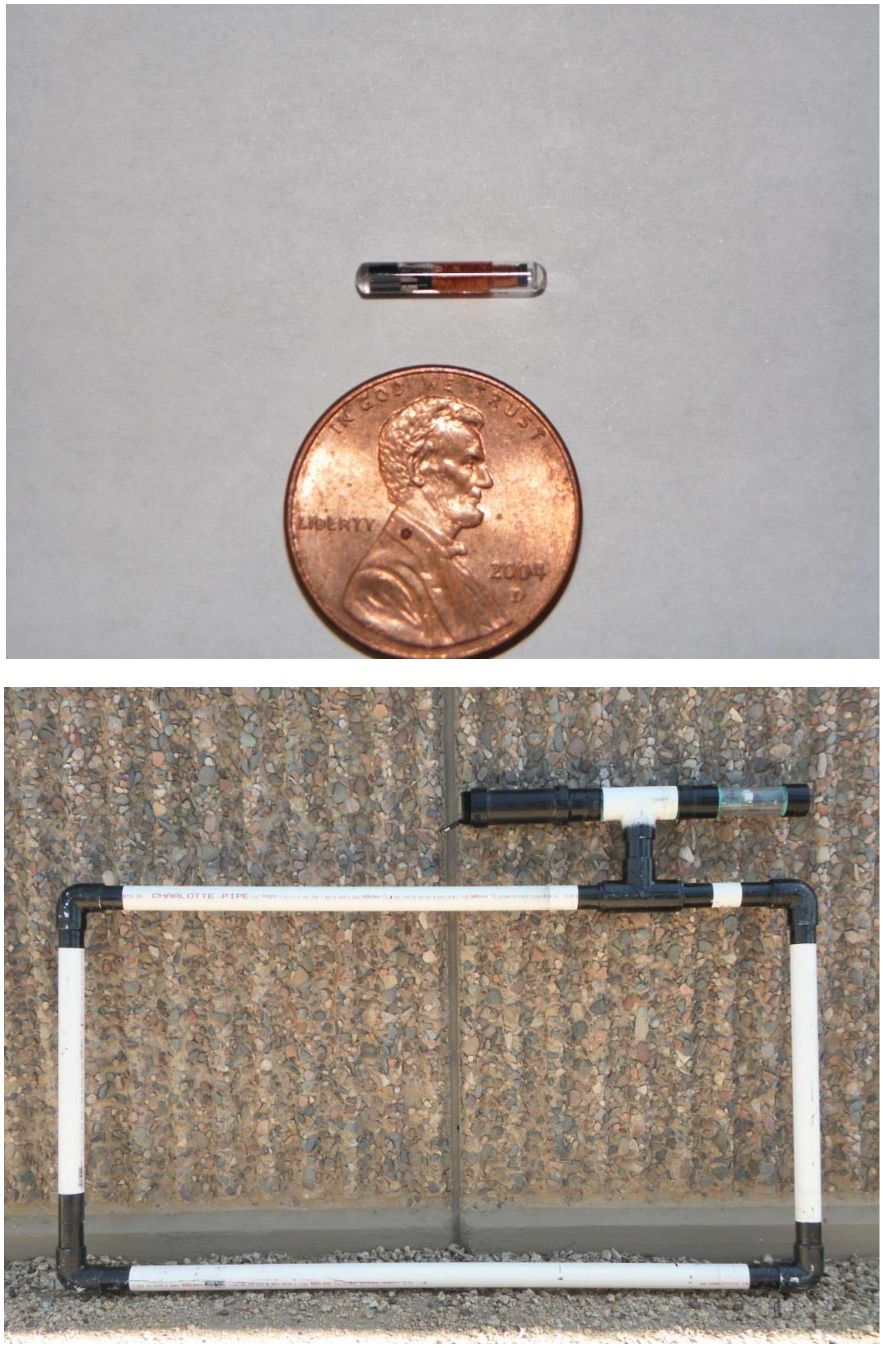

Figure 7. Remote PIT scanning equipment used during the 2014 June sucker study. Top photo is an example of the 134 kHz PIT tag that was implanted in the study fish. Bottom photo is the submersible PIT scanning unit deployed throughout the lake.

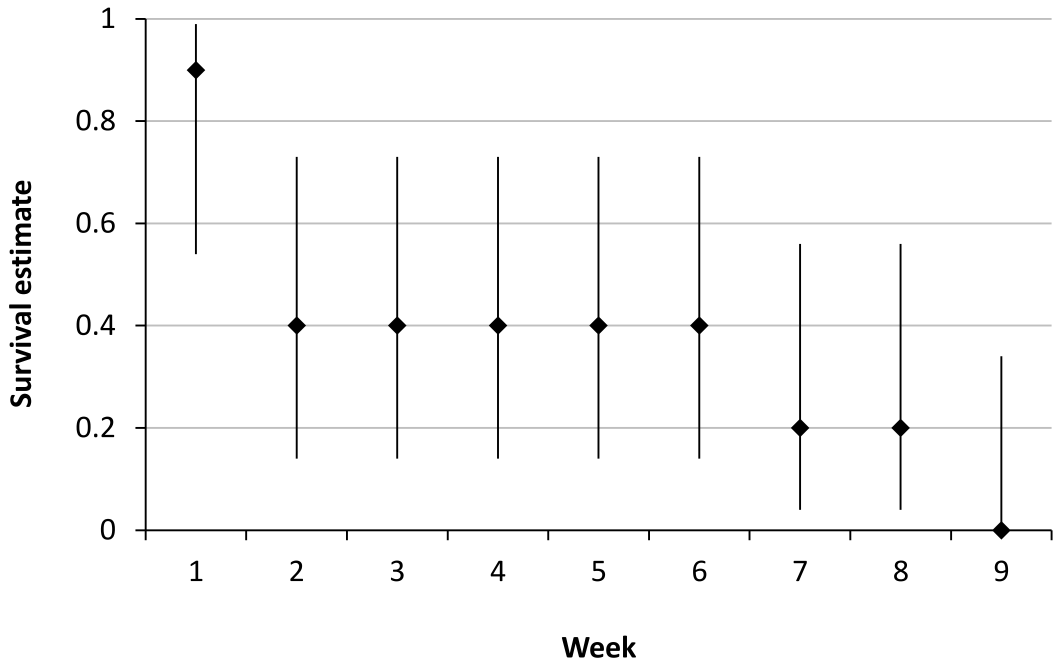

Figure 8. Weekly Kaplan-Meier June sucker survival estimates for early summer fish in 2014. Error bars represent 95% confidence intervals.

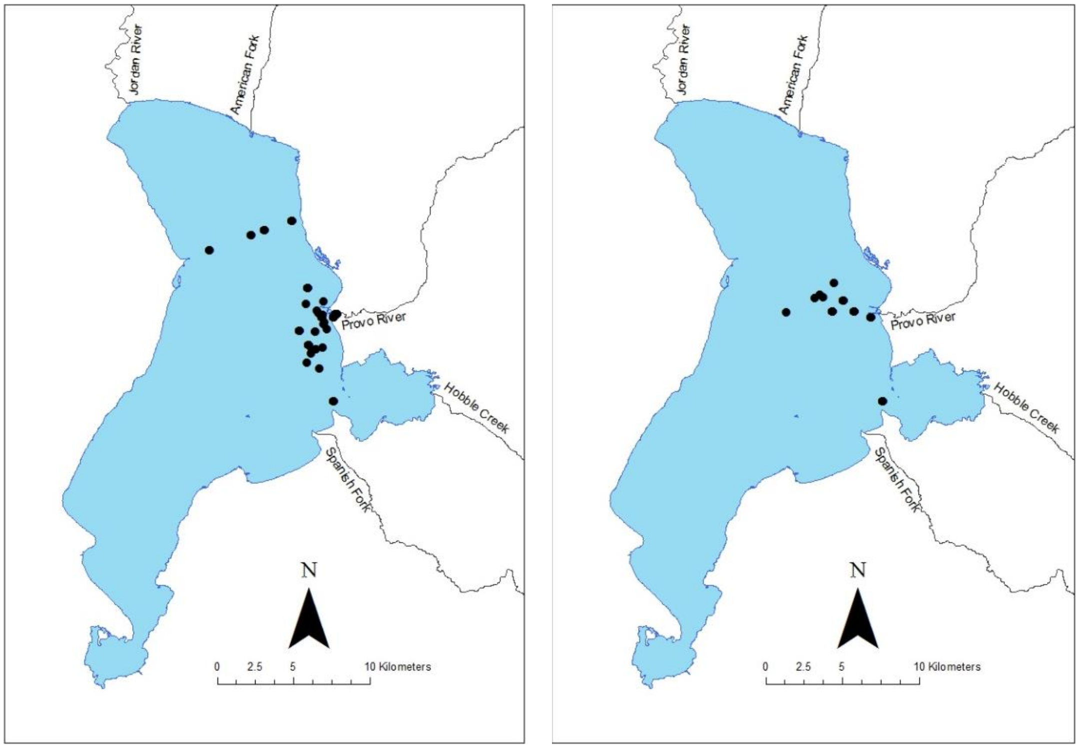

Figure 9. Manual and passive June sucker contacts for early summer (left) and late summer (right) 2014 telemetry fish.