JUNE SUCKER RECOVERY IMPLEMENTATION PROGRAM

Post-stocking fate of June sucker in Utah Lake
2015 Final Annual Report

March 2016

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Executive Summary

June sucker *Chasmistes liorus* is an endangered species endemic to Utah Lake, Utah. Historically, Utah Lake supported a unique fish assemblage representing 13 native fishes. Impacts from anthropogenic disturbances and the introduction of non-native fish species have altered the fish assemblage and only two native fishes remain, June sucker and Utah sucker *Catostomus ardens.* June sucker was once abundant in the lake, but a substantial population decline caused by multiple factors including overharvest, habitat degradation, river and stream impoundments, and negative interactions with non-native species reduced the population to less than 1,000 wild individuals in the latter 1990s. Propagation and population augmentation is a primary recovery strategy for June sucker, although post-stocking mortality of hatchery-reared June sucker is poorly understood. In this study, we examined immediate post-stocking mortality and spatial distribution of hatchery-reared June sucker.

In 2015, the third year of this study, 24 June sucker were surgically implanted with acoustic tags. An additional 1,180 PIT tagged fish were released in open water from a boat during two separate stocking events in early summer (June) and early autumn (August). Active tracking was conducted using a programmable acoustic tracking receiver and both directional and omni-directional hydrophones. Submersible ultrasonic receivers (SURs) were strategically placed throughout the study area for continuous passive tracking. Different SUR arrangements were used for both tracking events to respond to a decline in water levels in early autumn. Portable remote PIT scanning antennas were deployed at locations of temporal June sucker aggregations in the lake proper based on past observations, and randomly deployed throughout the study area to examine spatial distribution and survival of PIT tagged fish. Kaplan-Meier survival estimates were derived from the final fate of each acoustic tagged June sucker. Active and passive tracking records were used to assess spatial distribution with ArcGIS®.

Survival was estimated at 0.88 through week 2, and 0.68 through week 3 and for the remainder of the 60-day tracking period for early summer fish. Survival was not estimated for the early autumn tracking period because 7 of 14 fish had an unknown fate (lost contact). Portable remote PIT scanning antennas recorded a total of 2,274 contacts representing 773 unique PIT tags over the five-month study. Since 2007, average size at stocking for June sucker has been 220 mm; however, average release size of June sucker contacted through PIT scanning in 2015 was 307 mm.

Our results revealed that survival was higher for the 2015 early summer (0.68) tracking period compared to the 2014 early summer (0.00) tracking period. In contrast, lack of survival and a large proportion of lost contacts during early autumn in 2015 were consistent with 2014 results. Past observations of immediate post-stocking avian predation suggest this mortality factor may be playing a role, especially in early autumn. Few immediately stocked fish were contacted with portable remote PIT scanning antennas in the lake proper. Cohorts that had the most contacts were released at an average length greater than 220 mm. Increasing size at release of hatchery fish may increase survival and accelerate augmentation of the population with hatchery-reared fish, a primary recovery strategy. Post-stocking survival of fish allowed to grow an additional year at the hatchery (larger fish) will be assessed in 2016.

Introduction

June sucker is a federally endangered, large-bodied catostomid endemic to Utah Lake, Utah (cover photo; Figure 1). Unlike many members of the family Catostomidae, June sucker is one of four members characterized as lake suckers that possess terminal mouths, rather than an inferior mouth position (Miller and Smith 1981). Also, lake suckers are midwater planktivores that utilize pelagic zones. Adults are long-lived, with sexual maturation being reached between 5 and 10 years (Belk 1998). Once mature, adults participate in an annual spawning migration into tributaries of the lake with peak activity occurring in June (Modde and Muirhead 1994). Once emerged, larvae drift downstream and occupy pool habitats before returning to the lake. Juvenile June sucker have not been documented since 2011 (Utah Division of Wildlife Resources [UDWR] 2014b).

Historically, June sucker numbered in the millions (Jordan 1891), but numbers drastically declined and it was estimated that fewer than 1,000 wild individuals persisted into the latter 1990s (US Fish and Wildlife Service [USFWS] 1999). Population decline is attributed to multiple factors including overharvest, habitat degradation, and negative interactions with non-native species. Annual spawning migration occurs in three major tributaries (Hobble Creek, Provo River, and Spanish Fork River), but anthropogenic disturbances (i.e., altered flow regimes, river impoundments, and habitat degradation) have restricted spawning aggregates predominantly to the lower Provo River (UDWR 2014b). These disturbances along with the introduction of a suite of non-native species has resulted in subsequent June sucker recruitment failures (Modde and Muirhead 1994, Belk et al. 2001).

A recovery plan initiated by the U.S Fish and Wildlife Service includes creating a refuge population and habitat improvements, in addition to annual population monitoring and augmentation of the wild population using hatchery-reared fish (USFWS 1999). More than 350,000 individuals with a total length (TL) greater than 200 mm have been stocked into the lake with a target of stocking 2.8 million June sucker (USFWS and Utah Reclamation Mitigation and Conservation Commission 1998). Traditional methods of monitoring June sucker include larval light traps, trap nets, trammel nets, commercial seines, and a combination of weir traps and spotlight sampling surveys during the peak of spawning migrations (USFWS 1999, UDWR 2011). The most recent methods of sampling include trammel netting, commercial fishing observations, and trap nets deployed for monthly sampling (UDWR 2014a, UDWR 2014b). In 2013, this study was initiated to examine immediate post-stocking fate of hatchery-reared June sucker (Ehlo et al. 2013a). This study was initiated because adult June suckers were observed during annual spawning migrations, and larvae were reported, but sampling efforts had not recently recorded juvenile fish in Utah Lake and its tributaries (UDWR 2014b). Recruitment bottlenecks have inhibited natural population growth, despite successful spawning. Therefore, augmentation is an important component, but a better understanding is required to effectively enhance the population and provide a cost-effective recovery plan.

A previous study estimated June sucker post-stocking survival at 5%, noting that survival was strongly correlated to size at stocking and rearing site (Rasmussen et al. 2009). Billman et al. (2011) reported that there were several factors correlated with post-stocking survival: size at release, rearing site, condition, season, and release site. However, both of these studies derived survival estimates from fish that successfully recruited to the adult population. This approach may have been biased due to the time it takes for juveniles to reach maturity, potential site fidelity, and a sampling regime with unequal distribution of sampling effort (Billman et al. 2011).

This report includes results from the third year of an acoustic telemetry and remote portable PIT sensing research project. In this study, we examined immediate post-stocking survival of hatchery-reared June sucker using acoustic telemetry in Utah Lake. This year provided short-term post-stocking survival estimates for fish stocked in early summer (June) and early autumn (August) at one stocking location (open water). Results of this study will provide temporal (seasonal) survival estimates and supplement mark-recapture analysis of passive integrated transponder (PIT) data. These data contribute valuable insight into the survival of hatchery-reared June sucker to guide future stocking endeavors and conservation efforts.

Methods

Intensive acoustic telemetry on Utah Lake was conducted to derive survival estimates and movement patterns of hatchery-reared June sucker. Two short-term (60-day) tracking periods provided survival estimates and movement patterns for each study period. For the early summer telemetry and stocking event, 10 fish were implanted with acoustic and PIT tags. Surgeries were performed two weeks prior to stocking at the Utah Division of Wildlife Resources Fisheries Experiment Station (FES) in Logan, Utah. Additionally, 600 fish were implanted with PIT tags and held at the FES until stocking. For the early autumn telemetry and stocking event, seven fish were implanted with acoustic tags and PIT tagged at the FES and held for two weeks. Once again, 600 fish were implanted with 134.2 kHz PIT tags and held at the FES until stocking. An additional seven fish were implanted with acoustic tags at the stocking site and released one-hour post-surgery (or until stocking tanks were within 2° C). The first stocking and active telemetry tracking began on 22 June 2015 and ended on 21 August 2015. The second study segment began on 31 August 2015 and ended on 30 October 2015. Including surgery fish, 607 June sucker with a mean TL of 177 mm were stocked early summer (June) and 597 June sucker with a mean TL of 213 mm were stocked early autumn (August). In 2015, five post-tagging (PIT) mortalities occurred at the FES during the early summer tagging event, and one mortality occurred during the early autumn tagging event.

Study Area

Utah Lake is one of the largest freshwater lakes west of the Mississippi River situated on the eastern edge of the of the Great Basin physiographic province. The lake is a natural lacustrine system, encompassing a surface area of 38,400 hectares, and a relatively uniform contour with an average depth of 2.8 m and a maximum depth of 4.2 m, respectively (Fuhriman et al. 1981). The area is a semiarid climate and receives little annual rainfall, resulting in a large net evaporation. Historically, Utah Lake's fish assemblage was comprised of 13 native fishes, but has been significantly reduced to two native species, June sucker and Utah sucker. Contemporary fish assemblage composition is predominantly non-natives, all of which negatively interact with native suckers. Belk et al. (2001) examined the predator-prey relationship between white bass *Morone chrysops* and larval June sucker, and concluded larval June sucker were highly susceptible to predation for several weeks after swim-up stage. Commercial fishing data between November 2013 and October 2014 reported white bass as the second most abundant fish in the catch with a relative abundance of 14.5% (UDWR 2014a). However, common carp *Cyprinus carpio* had the greatest relative abundance at 75%. It was also reported that 14 northern pike *Esox lucius* were collected in commercial seines.

Surgical Method

Twenty-four June sucker (10 in early summer and 14 in early autumn; table 1) were surgically implanted with model PT-4 acoustic transmitters (Sonotronics Inc., Tucson AZ; Figure 2) and PIT tagged using slightly different methods from the previous two years (Ehlo et al. 2015a, Ehlo et al. 2015b). Acoustic tags were modified to increase acoustic output in an effort to increase detection range. This resulted in a minor reduction in battery longevity, but nominal battery life was still greater than each study period (60 days). In the early summer acoustic telemetry study, 10 fish were surgically implanted with acoustic tags and PIT tagged at the FES and held for two weeks. To ensure maximum battery life, at the FES on the day of release tags were activated using an external magnet before being loaded into stocking trucks. An omni-directional hydrophone and ultrasonic receiver were used to verify activation. In the early autumn stocking, seven fish were surgically implanted with acoustic tags and PIT tagged, and held at the FES for two weeks. An additional seven fish were surgically implanted with acoustic tags and PIT tagged at Utah Lake and stocked approximately one-hour post-surgery. All surgeries performed followed established procedures (Mueller et al. 2000; Karam et al. 2008).

For surgeries performed at the FES, fish were collected from re-circulating tanks. For lake side surgeries, approximately 15 fish were transferred from the stocking truck into a holding tank and allowed to acclimate for 30 minutes prior to surgery. Before surgery, one individual was immersed into a dark container with approximately 16-L of fresh water and tricaine methanesulfonate (MS222; 125 mg L-1) to anesthetize fish. Successfully anesthetized fish was indicated by lack of operculation, weak muscular movements, and cessation of fin movements. Once met, the fish was removed from the container, measured (TL in mm), weighed (nearest gram [g]), and scanned for a 134.2 kHz PIT tag. Fish were then placed on a surgery cradle ventral side up and covered in a wet towel to minimize desiccation. Anesthesia was maintained by gently pumping MS-222 solution with a small tube (4.77-mm) via the mouth across the gills for the remainder of the surgical procedure. A short (~ 1.5 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). Fish absent of a PIT tag were implanted with a 134.2 kHz tag via the mediolateral incision. 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). Post-surgery fish received additional care to prevent infection (Martinsen and Horsberg 1995): (1) sutured wound was swabbed with Betadine (2) and a 10 mg/kg dosage of Baytril® (enrofloxacin) was injected into the dorsal-lateral musculature. Fish were then placed into an oxygenated recovery tank and monitored until tag retention was confirmed, and full recovery was achieved.

Passive Tracking

In 2015, submersible ultrasonic receiver (SUR) arrangement differed from previous years for both tracking periods (early summer, and early autumn). However, the lake was still divided into three major zones (north, central, and south) by fixed SUR transects. Prior to the release of acoustically tagged fish in early summer, 21 submersible ultrasonic receivers (SURs) were deployed and anchored by weights with attached buoys at fixed sites across the study area as a method of passive tracking (Figure 4). For the early autumn tracking period, 21 submersible ultrasonic receivers were deployed throughout the study area. SURs were concentrated in the central zone, which had a greater depth and fish activity (Figure 5). SUR trials were not conducted in 2015, but detection distance likely increased due to modification of acoustic tags. Data were downloaded from SURs weekly and recently detected fish (< 12 hrs) were manually tracked with an active tracking receiver and directional hydrophone.

Active Tracking

Active tracking was conducted weekly for each 60-day tracking period using a directional or omni-directional hydrophone connected to a programmable ultrasonic tracking receiver (Sonotronics DH-4 and USR-08, respectively; Figure 2). Detection trials for directional and omni-directional hydrophones were conducted at 50 m intervals, indicating a 400 m detection range for the directional and a 300 m detection range for the omni-directional hydrophone. We established a target to contact every fish once per day during the study period. After one-week post-release, SURs were downloaded to determine if any fish left the central zone. We visited up to 316 manual tracking points (1,000 m apart) weekly using a directional hydrophone and the towable hydrophone was used to laterally transect the lake in search of fish between the manual tracking points (Figure 6). However, in 2015, water levels were significantly lower compared to previous years and a large number of tracking points were inaccessible, in areas such as Goshen and Provo Bay.

June sucker were considered missing if they were not contacted during the week. SUR data were incorporated to find fish that were not detected with active tracking. A search was initiated in the zone beyond the SUR transect where the fish was last contacted. A search of the entire lake was initiated if a fish was missing for three tracking periods. A fish contacted in the same location for three subsequent tracking periods was considered a mortality and revisited periodically for confirmation. All individual fish contacted were triangulated using the directional hydrophone and identified by Universal Transverse Mercator (UTM) coordinates. Location of contact was recorded in a boat mounted Global Positioning System (Garmin GPSMAP® 531s). Contact location and tag information were recorded on waterproof paper, which included acoustic tag number and frequency, time and date, general location or site name, water temperature (°C), UTM coordinates, water depth (m), and any additional notes or information. Contact data were incorporated into a Microsoft Access® database to facilitate data analysis and provide a history of each acoustic tagged fish.

Fate and Survival

Immediate post-surgical mortality was assessed by holding fish for two weeks at the FES after surgery. For the summer tracking period, all study fish were held for two weeks. In addition, we attempted to compare the effect of holding fish for two weeks on survival during the early autumn tracking period. Seven fish were held for two weeks and seven fish were released after a short (approximately one hour) recovery period post-surgery. Fish length ranged from 224 to 270 mm TL. Tag weight comprised less than 2% of the body weight for all study fish. All fish that had a surgically implanted acoustic tag survived the two-week period.

PIT Scanning

Portable remote PIT scanning antennas were used to assess survival of PIT tagged fish and spatial distribution of June sucker in the lake proper. Up to 12 PIT scanning units were deployed at localities where congregations of June sucker were reported in the lake proper by UDWR personnel or commercial fishermen, and detected in past remote PIT sensing studies (Ehlo et al. 2015a, Ehlo et al. 2015b). In addition, PIT scanners were deployed haphazardly around the lake to explore June sucker distribution in the lake proper. Typically, PIT scanners were deployed and moved on a weekly basis for the duration of both early summer and early autumn 60-day tracking periods. PIT scanners have evolved and improved from earlier models described by Kesner et al. (2008). Ten PIT scanners were constructed out of water-tight PVC (1.2 x 0.8 m), which housed internal components including a scanner, logger, and a 20.8 amp-hour battery that was capable of continuously scanning for up to 120 hours (Figure 7). These units were slightly buoyant. Weights were attached to the bottom to ensure an upright position in the water column, ostensibly increasing scanning efficiency due to the mid-water behavior of lake suckers. Two PIT scanner units were similar in construction, but their frame was 0.8 m x 0.8 m, and the units were negatively buoyant. Foam pool noodles were attached to the top-side PVC frame to ensure an upright position during deployment, although some deployments were conducted with the antenna flat on the substrate (without foam noodles). Both models were attached to a buoy before deployment and retrieved with a boat hook. Units were deployed early in the week and revisited later in the week (minimum of once a week) to download data. We recorded date and time of deployment, date and time of retrieval, name of location, UTM coordinates, depth (m), distance to shore (m), antenna orientation (flat on substrate or vertical in water column), unit ID, scan time (minutes), and estimated number of contacts.

Data Analysis

Short-term survival estimates using active and passive tracking techniques were derived from hatchery-reared June sucker using methods described by Kaplan and Meier (1958). In order to estimate survival, every individual was assigned to one of three fates: (1) a fish died before the end of the study, (2) a fish survived the study, (3) or a fish was lost to the study (lost signal). A fish lost, but later found dead (after three subsequent tracking periods), was presumed alive up to the point that it was found dead. A fish lost to the study and not contacted within the 60-day tracking period, was determined lost the last time it was contacted (censored). Fish that were re-contacted alive after a period of non-contact (reported missing) were considered alive throughout the missing period (not lost). At the conclusion of the tracking period, fish were considered lost to the study if they were not contacted by active or passive tracking within one week of the end of tracking (from 53 to 60 days post-stocking). Mortalities were determined on the first date discovered after returning to the same location for three consecutive tracking events. Active and passive tracking data were used to assign fish lost to the study once the signal was permanently lost.

PIT scanning data were entered into a Microsoft Access® database. This database included a June sucker stocking table provided by UDWR. Only fish that were stocked with a 134.2 kHz PIT tag were included in the stocking table. To date, 6,183 fish have been stocked at an average length of 220 mm. Additional tagging records for June sucker not tagged at stocking (captured in Utah Lake and tagged with a 134.2 kHz) were included in a separate table if they were scanned during the sample year. All scanning effort and contact data recorded during deployments (see PIT scanning section) were include in the database. Queries were developed to summarize contact data and associate contact records with stocking and tagging data.

Results

Fate and Survival

Submersible ultrasonic receivers continuously scanned for both 60-day tracking periods, and recorded 26,216 contacts representing all 24 acoustic tagged fish. Manual tracking efforts resulted in 93 contacts, also representing all 24 acoustic tagged fish. During early summer, one fish was lost in week 2 and three mortalities occurred (Table 2): one in week 2 (11 days) and two in week 3 (16 and 18 days; Table 1). One mortality was located near Bird Island (Figure 8); an island with an abundant colony of avian predators such as American White Pelican *Pelecanus erythrorhynchos,* Double-Crested Cormorant *Phalacrocorax auritus,* and California Gull *Larus californicus*. Of the 14 fish stocked in early autumn, there were four mortalities, seven lost contacts, and three survivors (Table 2). The first mortality occurred 23 days post-stocking, and three additional mortalities occurred during week 8 (52 days) and week 9 (2 mortalities 59 days post-stocking; Table 1). Survival estimates (95% CI) for early summer fish remained relatively stable from 1.0 (0.65-1.0) in week 1, 0.88 (0.54-0.99) in week 2, dropping to 0.68 (0.33-0.91) in week 3 and remaining constant for the remainder of the 60-day tracking period (Figure 10). Survival estimates were not calculated in early autumn because the fate of half the fish released was unknown (lost fish).

All fish were released in open water (2,284 m offshore) based on observations from Ehlo et al. (2015a) after a significant avian predation event near the Provo River confluence. No avian predation was observed during either stocking event in 2015. One-week post-stocking for the early summer telemetry, fish were predominantly concentrated 1.9 km south of the stocking location, while one fish (tag# 186) dispersed to the southernmost SUR transect, and three fish dispersed north of the stocking location (tag# 168, 170, and 187). Two weeks post-stocking, one fish was dead near Bird Island (tag# 183), four fish (tag# 172, 185, 186, and 187) were contacted approximately 3 km south of the stocking location, and one fish was contacted 12.5 km north of the stocking site. One fish was not contacted in week 2 and lost for the remainder of the study. By week 3, fish were randomly distributed throughout Utah Lake, with two additional mortalities. Both mortalities were within 5 km of the stocking location. There were no additional mortalities or lost contacts for the remainder of the 60-day tracking period. For the early autumn telemetry iteration, all fish were contacted in week 1, but after week 3 and week 4 a large proportion of fish were lost and four mortalities occurred later in the study period. Two of the four mortalities that occurred were lost early in the study, but later found dead on week 9. One-week post-stocking fish were predominantly distributed within 2 km north of the stocking site. One fish dispersed to the north SUR transect and two fish dispersed 3 km south of the stocking site. Three weeks post-stocking fish were randomly distributed throughout Utah Lake. However, during weeks 3 and 4, a total of five fish were lost, and two were found dead on week 9. One fish was dead on the fourth week approximately 5.5 km north of the stocking site. Only six out of the 14 fish were contacted during week 5 and 6, and four were contacted on week 8. One mortality occurred on week 8, 2 km north of the stocking site. Two mortalities occurred on week 9, with one offshore of Bird Island (Figure 10). Ultimately, four mortalities occurred, seven fish were lost, and three fish survived.

All fish that had a surgically implanted acoustic tag survived the two-week holding period prior to stocking and appeared in good health at the time of release. No survival estimate was calculated for fish stocked in early autumn, therefore no statistical comparison of survival could be made between fish held for two weeks prior to release and fish released immediately after surgery. The four confirmed mortalities were equally split between fish held for two weeks (two fish) and those released after surgery (two fish, Table 1). Three of the four mortalities occurred more than 50 days post-release, while the fourth mortality, a fish released after surgery, died within 23 days of release. All three fish that survived the study period were from the group released immediately after surgery. One fish from the group held for two weeks after surgery was lost on day 51 (fish 85, Table 1), two days before the cutoff to be considered a survivor.

PIT Scanning

PIT scanning took place from early June to October 2015, with 336 deployments of submersible PIT scanners and a total scan time of 14,713 hours (Table 3). PIT scanners were predominantly deployed at Long Bar, Bird Island, and near Lincoln Beach (Figure 1). PIT scanning effort resulted in 2,274 contacts (Figure 11), of which 773 were unique PIT tags, and 167 of the 773 unique contacts were June sucker stocked since 2007 with a 134.2 kHz PIT tag. Fish stocked in 2011 represented 83% of the fish within this stocking group (139 of 167, Table 4), with an average length at stocking of 305 mm. Fish stocked in 2013 represented 13% of the total (22 of 167 unique contacts), with an average length at stocking of 339 mm. Of the 1,204 fish stocked (including surgery fish) in 2015, only three were scanned and had an average length at stocking of 195 mm. The greatest proportion (0.76) of unique fish (including all PIT tagged fish) scanned was at Bird Island, representing 586 unique contacts. The second greatest proportion (0.22) of unique fish scanned with PIT scanners was on Long Bar, represented by 169 unique fish. In addition, twelve were contacted near Lincoln Beach, four were contacted near the entrance to Powell Slough, and one was contacted in the pelagic zone of the central zone.

Discussion

The 2015 telemetry study represents the third year where tracking was more successful during the summer compared to autumn, indicated by fewer lost fish, and higher survival through the 60-day period. Lost fish have been a major factor in previous tracking periods; six out of ten fish were lost in late summer 2014, and five out of ten in early autumn 2013. In 2015, acoustic tag modification appeared to enhance tracking success in Utah Lake. Detection range of active tracking equipment was increased by 75% compared to 2014. SUR detection trials were not conducted, but it was assumed that SUR detection also was increased. Even with the increased detection range, 7 of 14 fish were lost in the autumn study. This supports the hypothesis that lost acoustic tagged fish represent fish removals from the lake, likely by avian predators.

Lost fish were removed from Kaplan-Meier survival estimates (censored), but the survival estimates remained lower than expected ranging from zero (summer 2014) to 68% of released fish (summer 2015) for the 60-day post-stocking study period. Negative interactions with non-native fishes may contribute to low June sucker survival during both summer and autumn stocking events. White bass, which readily consume larval June sucker (Belk et al. 2001) are unlikely to contribute to stocked June sucker mortality because the average TL of white bass in Utah Lake is 253 mm (UDWR 2014a). White bass and walleye *Sander vitreus* played a prominent role in reducing the June sucker population by competition and predation in the mid 1950's (USFWS 1999), but contemporary interactions with walleye are unknown. Walleye have a low relative abundance (< 1%) in Utah Lake, but 3,398 walleye were reported from commercial fishing efforts over a year period (UDWR 2014a). Walleye in Utah Lake are robust, with high condition indices and a mean TL of 612 mm (UDWR 2014a). Walleye at this size are likely capable of consuming hatchery-reared June sucker, especially those stocked at lengths of less than 200 mm. Other non-native fishes found in Utah Lake that are capable of preying on hatchery-reared June sucker include northern pike, channel catfish *Ictalurus punctatus*, and largemouth bass *Micropterus salmoides*.

Ehlo et al. (2015a) documented a large California Gull predation event immediately post-stocking near the Provo River confluence in early autumn 2013. In response, an open water stocking strategy was used to reduce avian predation on immediately released June sucker. Even under this strategy two mortalities occurred offshore of Bird Island in 2015. In another study, it was found that American White Pelican predation resulted in 90% mortality of Cui-ui *Chasmistes cujus* lake suckers in Pyramid Lake, Nevada (Scoppettone et al. 2014). Avian predation also has been documented on Warner sucker *Catostomus warnerensis* (Scheerer et al. 2012), which occupies similar aquatic habitats in Oregon. If lost acoustic tagged fish are in fact mortalities due to avian predation, the 60-day estimate of post-stocking survival for June sucker stocked at 250 mm would be less than 25%.

Surgical procedures were examined in 2015 and mortality was not attributed to the tag implantation process during either study period. No study fish died during the two week holding period, and dispersal patterns of fish that were released immediately post-surgery did not differ from fish that were held for two weeks. This comparison was only made in the early autumn tracking period in which seven fish were lost to the study. All three surviving fish in the autumn study came from the lot immediately released after surgery indicates that immediate release did not adversely impact post-stocking survival.

We have repeatedly documented lack of a relationship between surgical tag implant surgery and mortality using the same techniques for other sensitive species (e.g., bonytail *Gila elegans*; Karam et al. 2010).

As knowledge on the distribution of June sucker in the lake proper continues to grow, remote PIT scanning efficiency improves (Figure 13). Increased scanning effort in 2015 resulted in 773 unique contacts compared to 263 unique contacts in 2014. This increase in overall unique contacts did not increase our understanding of post-stocking survival because most of the fish contacted were tagged during netting activities, not prior to release. Of the 1,204 June sucker stocked in 2015 (including acoustic fish), only three were contacted in early summer and none were contacted in autumn. Average length of June sucker stocked in 2015 was 196 mm, while the average stocking length of fish contacted was 307 mm (Figure 13). A majority of fish contacted in 2015 that were PIT tagged prior to release (83%) were released in 2011 at a mean total length of 305 mm compared to a mean total length of 219 mm for the 4,971 records of fish stocked with a 134.2 kHz tag. This provides additional support that size has an effect on post-stocking survival (Billman et al. 2011). However, PIT scanning was conducted predominantly in less than 2 m of water and it remains unclear whether this creates a bias toward adult fish. Our tracking data suggest that juveniles typically utilize pelagic zones away from scanning locations. This potential size survival relationship will be directly tested in 2016 when acoustic and PIT tagged fish will be released concurrently from two different age (size) classes.

Observations from commercial fishing efforts provided insight into PIT scanner placement, which revealed spatiotemporal patterns of June sucker aggregations in the lake proper. Aggregations of June sucker were observed in relatively high numbers at Long Bar and Bird Island (see Figure 1) during early autumn months (August-October). Summer (June-July) scanning only yielded 152 contacts, whereas 2,122 contacts were recorded from August to October. Effort was highest during June with 129 deployments and 3,808 scan hours. August had the highest number of contacts (1,614), and a scan time of 2,596 scan hours. Low contact rates in the lake proper during early summer are likely due to adults spawning in tributaries. Preliminary scanning data suggest fish are randomly distributed throughout the lake during July, and then congregate at Long Bar and Bird Island in August. Other localities of June sucker aggregations in the lake proper currently are unknown.

PIT tagging fish prior to release would also increase opportunities to quantify avian predation. In 2015, a remote hand-held PIT scanner was constructed to scan Bird Island and other exposed areas occupied by American White Pelicans, California Gulls, and Double-Crested Cormorants. Unfortunately, an unusually warm autumn delayed annual migrations and Bird Island was inaccessible for scanning. Scanning Bird Island for expelled PIT tags was conducted in 2013 and 2014, but no tags were recovered or detected there. The lack of recovered or detected PIT tags is likely due to the small portion of June sucker that are PIT tagged prior to release.

In conclusion, early summer telemetry iterations continue to be more successful compared to autumn iterations and suggest that June sucker releases should be concentrated at this time of year. Seasonal acoustic telemetry studies will provide a collective knowledge of post-stocking survival and the continuation and expansion of PIT scanning in the lake proper will greatly increase the knowledge of long-term survival. In 2016, two concurrent stocking events are proposed to compare survival of two age classes (age-1 and age-2). One family lot that was originally intended to be stocked in 2015 will be held over until 2016. Simultaneous stocking events containing age-1 and age-2 fish will allow direct comparisons of post-stocking mortality using intensive acoustic telemetry techniques and portable remote PIT sensing systems.

Recommendations

Additional acoustic telemetry iterations will continue to provide survival estimates and guide stocking endeavors. Past telemetry iterations have provided insight into post-stocking survival for summer and autumn stocking events. However, all fish used were age-1 fish with similar mean lengths among stocking events. The 2011 stocking cohort had an average length at stocking of 303 mm and was the largest proportion of fish scanned, despite a small number of stocked fish. Comparing the relationship between size and survival can definitively test if post-stocking survival is correlated with size at release. Understanding the relationship between size and survival will allow a cost-effective approach at successfully augmenting the June sucker population. We also suggest PIT tagging all fish to derive more robust survival estimates and attempt to quantify avian predation on hatchery-reared fish using a hand-held PIT tag scanner.

Releasing fish in open water appears to reduce the threat of immediate avian predation. We recommend continuing this method, as the threat of post-stocking avian predation increases when fish are released in the Provo River.

Acknowledgements

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Table 1. Fate of 24 individual June sucker surgically implanted with a sonic transmitter and stocked into Utah Lake, UT, in early summer (June) and early autumn (August) 2015. Early autumn releases are denoted as being held at the hatchery for two weeks after surgery (-h) or released immediately after surgery (-r). DPS is days post-stocking.

Tag ID	TL (mm)	Mass (g)	PIT tag #	Season	Surgery Location	Fate	DPS
168	235	143	3D9.1C2D6D086E	Early Summer	FES	Survived	-
169	245	176	3D9.1C2D6C71A6	Early Summer	FES	Survived	-
170	248	161	3DD.003BB21B2D	Early Summer	FES	Survived	-
171	228	136	3D9.1C2D6B8E57	Early Summer	FES	Lost	5
172	250	184	3D9.1C2D6C0B84	Early Summer	FES	Survived	-
183	255	186	3DD.003BB215B0	Early Summer	FES	Mortality	11
184	228	148	3DD.003BB21B44	Early Summer	FES	Mortality	18
185	224	125	3D9.1C2D6D09EB	Early Summer	FES	Survived	-
186	249	177	3D9.1C2D6BC196	Early Summer	FES	Mortality	16
187	242	167	3D9.1C2D6C418D	Early Summer	FES	Survived	-
83	243	173	3DD.003BA2E301	Early Autumn-h	FES	Mortality	59
84	247	163	3DD.003BA2E3C6	Early Autumn-h	FES	Lost	16
85	246	165	3DD.003BA2E37F	Early Autumn-h	FES	Lost	51
86	242	163	3DD.003BA2E3CD	Early Autumn-h	FES	Lost	16
87	243	162	3DD.003BA2E27D	Early Autumn-h	FES	Mortality	52
88	270	226	3DD.003BA2E375	Early Autumn-h	FES	Lost	38
89	251	176	3DD.003BA2E374	Early Autumn-h	FES	Lost	15
98	274	250	3DD.003BA2E449	Early Autumn-r	Utah Lake	Survived	-
99	245	229	3DD.003BA2E2BC	Early Autumn-r	Utah Lake	Lost	8
100	288	309	3DD.003BA2E25A	Early Autumn-r	Utah Lake	Mortality	23
101	267	218	3DD.003BA2E407	Early Autumn-r	Utah Lake	Lost	11
102	257	199	3DD.003BA2E3AE	Early Autumn-r	Utah Lake	Survived	-
103	270	240	3DD.003BA2E2DE	Early Autumn-r	Utah Lake	Survived	-
104	245	165	3DD.003BA2E27E	Early Autumn-r	Utah Lake	Mortality	59

Table 2. Fate of telemetry tagged June sucker stocked into Utah Lake, UT, in early summer and early autumn 2015.

	Week									
Early Summer 2015	1	2	3	4	5	6	7	8	9	Total
Survivors	10	8	6	6	6	6	6	6	6	6
Mortalities	0	1	2	0	0	0	0	0	0	3
Lost Fish	0	1	0	0	0	0	0	0	0	1
Early Autumn 2015[1]										
Survivors	14	14	12	8	8	8	7	6	3	3
Mortalities	0	0	0	1	0	0	0	1	2	4
Lost Fish	0	0	2	3	0	0	1	0	1	7

[1]Three fish were temporarily lost to the study and later found dead in the lake for Early Autumn 2015. For the purpose of the Kaplan-Meier estimate, one fish was labeled dead on week 8, and two fish were labeled dead the last week of the 60-day tracking period.

Table 3. Summary of PIT scanning performed in Utah Lake, UT, 2015. 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 (2015)	Deployments	Total scan time (hours)	Contacts	Unique	Study Unique
June	129	3808	121	56	1
July	42	2632	31	28	0
August	61	2596	1614	484	1
September	100	3128	351	147	3
October	34	2550	157	58	0
total	366	14713	2274	773	5

Table 4. List of 2015 remotely scanned unique June sucker that were stocked and tagged with a 134.2 kHz PIT tag. Date is the day of stocking. FES is the UDWR Fisheries Experiment Station in Logan, UT.

PITHEX	Date	Length	Weight	Origin
3D9.1C2C46E3D3	04-May-11	338	420	Camp Creek via Springville
3D9.1C2C91F63A	04-May-11	318	340	Camp Creek via Springville
3D9.1C2C48AB80	11-Aug-11	379	560	Camp Creek via Springville
3D9.1C2CAAF56F	11-Aug-11	356	500	Camp Creek via Springville
3D9.1C2CD47D4A	11-Aug-11	375	580	Camp Creek via Springville
3D9.1C2CCE69A4	11-Aug-11	377	600	Camp Creek via Springville
3D9.1C2CAC60EE	11-Aug-11	381	580	Camp Creek via Springville
3D9.1C2CAC5949	11-Aug-11	317	320	Camp Creek via Springville
3D9.1C2CAAFC3C	11-Aug-11	346	440	Camp Creek via Springville
3D9.1C2CABBE55	11-Aug-11	404	680	Camp Creek via Springville
3D9.1C2C456F0F	15-Aug-11	410	740	Camp Creek via Springville
3D9.1C2CAAF7E4	15-Aug-11	380	540	Camp Creek via Springville
3D9.1C2CAC6182	17-Aug-11	435	780	Camp Creek via Springville
3D9.1C2CAC55A6	17-Aug-11	386	580	Camp Creek via Springville
3D9.1C2C46902E	18-Aug-11	423	760	Camp Creek via Springville
3D9.1C2CD46B29	18-Aug-11	347	420	Camp Creek via Springville
3D9.1C2C92142B	22-Aug-11	380	600	Camp Creek via Springville
3D9.1C2C434923	22-Aug-11	374	570	Camp Creek via Springville
3D9.1C2C867C13	22-Aug-11	353	470	Camp Creek via Springville
3D9.1C2C880ED5	22-Aug-11	406	620	Camp Creek via Springville
3D9.1C2C4894AA	22-Aug-11	343	440	Camp Creek via Rosebud
3D9.1C2C92210F	22-Aug-11	374	530	Camp Creek via Springville
3D9.1C2C9229A4	22-Aug-11	365	480	Camp Creek via Springville
3D9.1C2C929570	22-Aug-11	317	350	Camp Creek via Springville
384.1B795B0FF5	20-Sep-11	292	254	Camp Creek via Rosebud
384.1B795B1350	20-Sep-11	294	236	Camp Creek via Rosebud
384.1B795B1337	20-Sep-11	280	220	Camp Creek via Rosebud
384.1B795B0FFF	20-Sep-11	260	184	Camp Creek via Rosebud
384.1B795B1359	20-Sep-11	295	246	Camp Creek via Rosebud
384.1B795B0FF7	20-Sep-11	307	294	Camp Creek via Rosebud
384.1B795B1348	20-Sep-11	306	264	Camp Creek via Rosebud
384.1B795B0FF1	20-Sep-11	273	202	Camp Creek via Rosebud
384.1B795B0FEA	20-Sep-11	325	336	Camp Creek via Rosebud
384.1B795B135D	20-Sep-11	307	288	Camp Creek via Rosebud
384.1B795B0FE0	20-Sep-11	304	332	Camp Creek via Rosebud
384.1B795B1377	20-Sep-11	285	206	FES via Rosebud
384.1B795B0FD7	20-Sep-11	300	282	Camp Creek via Rosebud
384.1B795B0FD4	20-Sep-11	265	172	Camp Creek via Rosebud
384.1B795B0FD3	20-Sep-11	285	204	Camp Creek via Rosebud

384.1B795B0FBF	20-Sep-11	302	252	Camp Creek via Rosebud
384.1B795B0FE1	20-Sep-11	305	272	Camp Creek via Rosebud
384.1B795B144D	20-Sep-11	290	247	Camp Creek via Rosebud
384.1B795B1459	20-Sep-11	285	238	Camp Creek via Rosebud
384.1B795B1461	20-Sep-11	298	230	Camp Creek via Rosebud
384.1B795B1463	20-Sep-11	280	216	Camp Creek via Rosebud
384.1B795B1465	20-Sep-11	205	260	Camp Creek via Rosebud
384.1B795AA69C	20-Sep-11	308	261	Camp Creek via Rosebud
384.1B795B1466	20-Sep-11	288	226	Camp Creek via Rosebud
384.1B795B1370	20-Sep-11	275	206	Camp Creek via Rosebud
384.1B795B144F	20-Sep-11	288	222	Camp Creek via Rosebud
384.1B795B135E	20-Sep-11	297	244	Camp Creek via Rosebud
384.1B795B1467	20-Sep-11	287	214	Camp Creek via Rosebud
384.1B795B1383	20-Sep-11	310	290	Camp Creek via Rosebud
384.1B795B1455	20-Sep-11	289	244	Camp Creek via Rosebud
384.1B795B1375	20-Sep-11	328	320	Camp Creek via Rosebud
384.1B795B1452	20-Sep-11	320	313	Camp Creek via Rosebud
384.1B795B1365	20-Sep-11	305	238	Camp Creek via Rosebud
384.1B795B135F	20-Sep-11	281	204	Camp Creek via Rosebud
384.1B795B0FB3	20-Sep-11	282	200	Camp Creek via Rosebud
384.1B795AA5E4	20-Sep-11	275	204	Camp Creek via Rosebud
384.1B795AA6A9	20-Sep-11	310	290	Camp Creek via Rosebud
384.1B795AA60C	20-Sep-11	305	260	Camp Creek via Rosebud
384.1B795AA600	20-Sep-11	267	190	Camp Creek via Rosebud
384.1B795AA5F8	20-Sep-11	290	236	Camp Creek via Rosebud
384.1B795AA5F5	20-Sep-11	308	280	Camp Creek via Rosebud
384.1B795AA5EE	20-Sep-11	273	186	Camp Creek via Rosebud
384.1B795AA619	20-Sep-11	290	218	Camp Creek via Rosebud
384.1B795AA5E5	20-Sep-11	302	262	Camp Creek via Rosebud
384.1B795AA621	20-Sep-11	289	238	Camp Creek via Rosebud
384.1B795AA5E2	20-Sep-11	326	334	Camp Creek via Rosebud
384.1B795AA5DD	20-Sep-11	330	338	Camp Creek via Rosebud
384.1B795AA5D8	20-Sep-11	290	234	Camp Creek via Rosebud
384.1B795AA5D6	20-Sep-11	281	222	Camp Creek via Rosebud
384.1B795AA5D5	20-Sep-11	307	278	Camp Creek via Rosebud
384.1B795AA5D3	20-Sep-11	270	184	Camp Creek via Rosebud
384.1B795AA5D1	20-Sep-11	300	218	Camp Creek via Rosebud
384.1B795AA5E7	20-Sep-11	308	282	Camp Creek via Rosebud
384.1B795AA6B3	20-Sep-11	281	201	Camp Creek via Rosebud
384.1B795B0FAB	20-Sep-11	316	290	Camp Creek via Rosebud
384.1B795B0FA5	20-Sep-11	289	220	Camp Creek via Rosebud
384.1B795B0F9D	20-Sep-11	281	210	Camp Creek via Rosebud
384.1B795AA6E1	20-Sep-11	310	290	Camp Creek via Rosebud

384.1B795AA6DA	20-Sep-11	308	263	Camp Creek via Rosebud
384.1B795AA6C8	20-Sep-11	302	247	Camp Creek via Rosebud
384.1B795AA60E	20-Sep-11	290	252	Camp Creek via Rosebud
384.1B795AA6BB	20-Sep-11	265	179	Camp Creek via Rosebud
384.1B795B0FAE	20-Sep-11	287	210	Camp Creek via Rosebud
384.1B795AA6AA	20-Sep-11	321	308	Camp Creek via Rosebud
384.1B795B146B	20-Sep-11	301	294	Camp Creek via Rosebud
384.1B795AA6A5	20-Sep-11	310	260	Camp Creek via Rosebud
384.1B795B1654	20-Sep-11	285	254	Camp Creek via Rosebud
384.1B795AA699	20-Sep-11	280	219	Camp Creek via Rosebud
384.1B795AA690	20-Sep-11	280	212	Camp Creek via Rosebud
384.1B795AA622	20-Sep-11	300	262	Camp Creek via Rosebud
384.1B795AA6C6	20-Sep-11	298	260	Camp Creek via Rosebud
384.1B795B1801	20-Sep-11	293	230	Camp Creek via Rosebud
384.1B795B16A2	20-Sep-11	320	339	Camp Creek via Rosebud
384.1B795B17D2	20-Sep-11	295	237	Camp Creek via Rosebud
384.1B795B17D5	20-Sep-11	305	262	Camp Creek via Rosebud
384.1B795B17D6	20-Sep-11	269	192	Camp Creek via Rosebud
384.1B795B17DA	20-Sep-11	285	230	Camp Creek via Rosebud
384.1B795B17DD	20-Sep-11	273	184	Camp Creek via Rosebud
384.1B795B17E5	20-Sep-11	304	272	Camp Creek via Rosebud
384.1B795B17EB	20-Sep-11	320	314	Camp Creek via Rosebud
384.1B795B16A1	20-Sep-11	254	174	Camp Creek via Rosebud
384.1B795B17F0	20-Sep-11	264	181	Camp Creek via Rosebud
384.1B795B180B	20-Sep-11	315	280	FES via Rosebud
384.1B795B1480	20-Sep-11	277	224	Camp Creek via Rosebud
384.1B795B180F	20-Sep-11	285	229	Camp Creek via Rosebud
384.1B795B1646	20-Sep-11	270	182	Camp Creek via Rosebud
384.1B795B181E	20-Sep-11	301	209	Camp Creek via Rosebud
384.1B795B1832	20-Sep-11	282	226	Camp Creek via Rosebud
3D9.1C2C433FFC	20-Sep-11	281	198	Camp Creek via Rosebud
3D9.1C2C458A6A	20-Sep-11	327	338	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
384.1B795B17EE	20-Sep-11	296	253	Camp Creek via Rosebud
384.1B795B14A8	20-Sep-11	285	212	Camp Creek via Rosebud
384.1B795B1813	20-Sep-11	301	260	Camp Creek via Rosebud
384.1B795B1692	20-Sep-11	275	192	Camp Creek via Rosebud
384.1B795B149E	20-Sep-11	303	231	Camp Creek via Rosebud
384.1B795B1490	20-Sep-11	288	224	Camp Creek via Rosebud
384.1B795B148D	20-Sep-11	268	182	Camp Creek via Rosebud
384.1B795B1485	20-Sep-11	252	136	Camp Creek via Rosebud
384.1B795B14A6	20-Sep-11	299	265	Camp Creek via Rosebud

384.1B795B14AA	20-Sep-11	280	134	Camp Creek via Rosebud
384.1B795B14AF	20-Sep-11	272	188	Camp Creek via Rosebud
384.1B795B1640	20-Sep-11	277	206	Camp Creek via Rosebud
384.1B795B1665	20-Sep-11	270	290	Camp Creek via Rosebud
384.1B795B168D	20-Sep-11	303	308	Camp Creek via Rosebud
384.1B795B1688	20-Sep-11	267	194	Camp Creek via Rosebud
384.1B795B167B	20-Sep-11	309	265	Camp Creek via Rosebud
384.1B795B14A2	20-Sep-11	288	219	Camp Creek via Rosebud
384.1B795B1669	20-Sep-11	267	190	Camp Creek via Rosebud
384.1B795AA5CC	20-Sep-11	290	216	Camp Creek via Rosebud
384.1B795B1658	20-Sep-11	300	260	Camp Creek via Rosebud
384.1B795B1656	20-Sep-11	276	200	Camp Creek via Rosebud
384.1B795B164B	20-Sep-11	280	206	Camp Creek via Rosebud
384.1B795B166D	20-Sep-11	292	253	Camp Creek via Rosebud
3D9.1C2CD485B7	30-May-12	400	780	Camp Creek via Springville
3D9.1C2CAC3618	22-May-13	376	500	Camp Creek via Springville
3D9.1C2CAC27D1	22-May-13	353	440	Camp Creek via Springville
384.342770EED1	22-May-13	390	620	Camp Creek via Springville
384.342770EE60	22-May-13	312	300	Camp Creek via Springville
384.3427710AF2	22-May-13	346	400	Camp Creek via Springville
384.3427710AB4	22-May-13	374	520	Camp Creek via Springville
384.3427710A9A	22-May-13	412	760	Camp Creek via Springville
384.3427710A74	22-May-13	377	480	Camp Creek via Springville
384.3427710A6E	22-May-13	365	480	Camp Creek via Springville
384.342770EE37	22-May-13	268	180	Camp Creek via Springville
384.342770EE18	22-May-13	353	480	Camp Creek via Springville
384.342770EE82	22-May-13	366	520	Camp Creek via Springville
384.342770EE36	22-May-13	298	240	Camp Creek via Springville
384.342770EEC8	22-May-13	310	300	Camp Creek via Springville
384.342770EE3E	22-May-13	266	200	Camp Creek via Springville
384.342770EE5B	22-May-13	309	240	Camp Creek via Springville
384.342770EE62	22-May-13	350	400	Camp Creek via Springville
384.342770EE99	22-May-13	414	700	Camp Creek via Springville
384.342770EEA0	22-May-13	342	400	Camp Creek via Springville
384.342770EEB1	22-May-13	328	340	Camp Creek via Springville
384.342770EEB5	22-May-13	326	300	Camp Creek via Springville
384.342770EE2B	22-May-13	321	300	Camp Creek via Springville
3DD.003BB9181D	02-Jun-14	235	172	Fisheries Experiment Station
3DD.003BCF09CC	29-Sep-14	264	174	FES via Rosebud
3DD.003BB21547	22-Jun-15	185	75	Fisheries Experiment Station
3DD.003BB215DC	22-Jun-15	164	70	Fisheries Experiment Station
3DD.003BB2161D	22-Jun-15	175	60	Fisheries Experiment Station

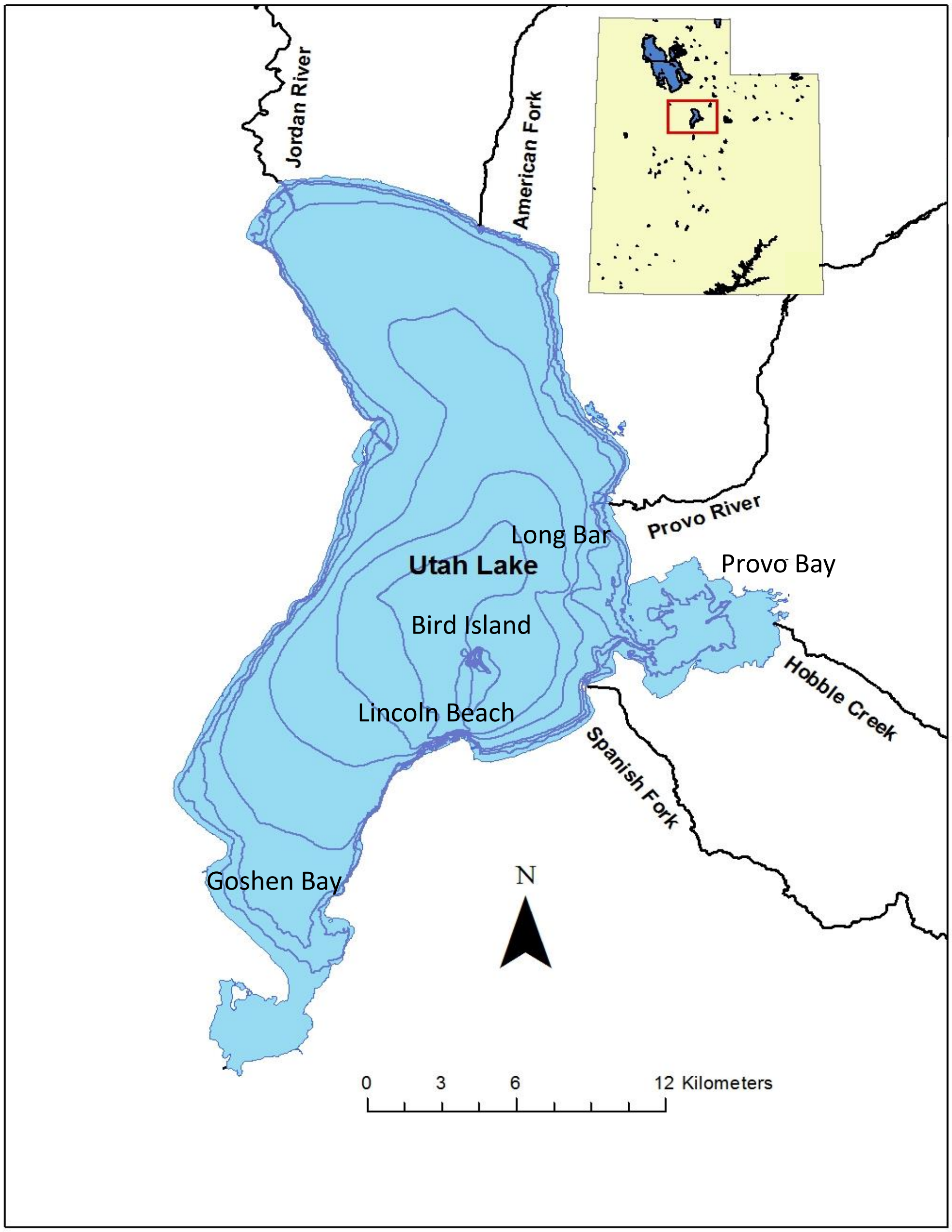

Figure 1. Map of the study area, Utah Lake, UT, and notable place names. The inset map provides the location of Utah Lake in relation to the state of Utah.

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

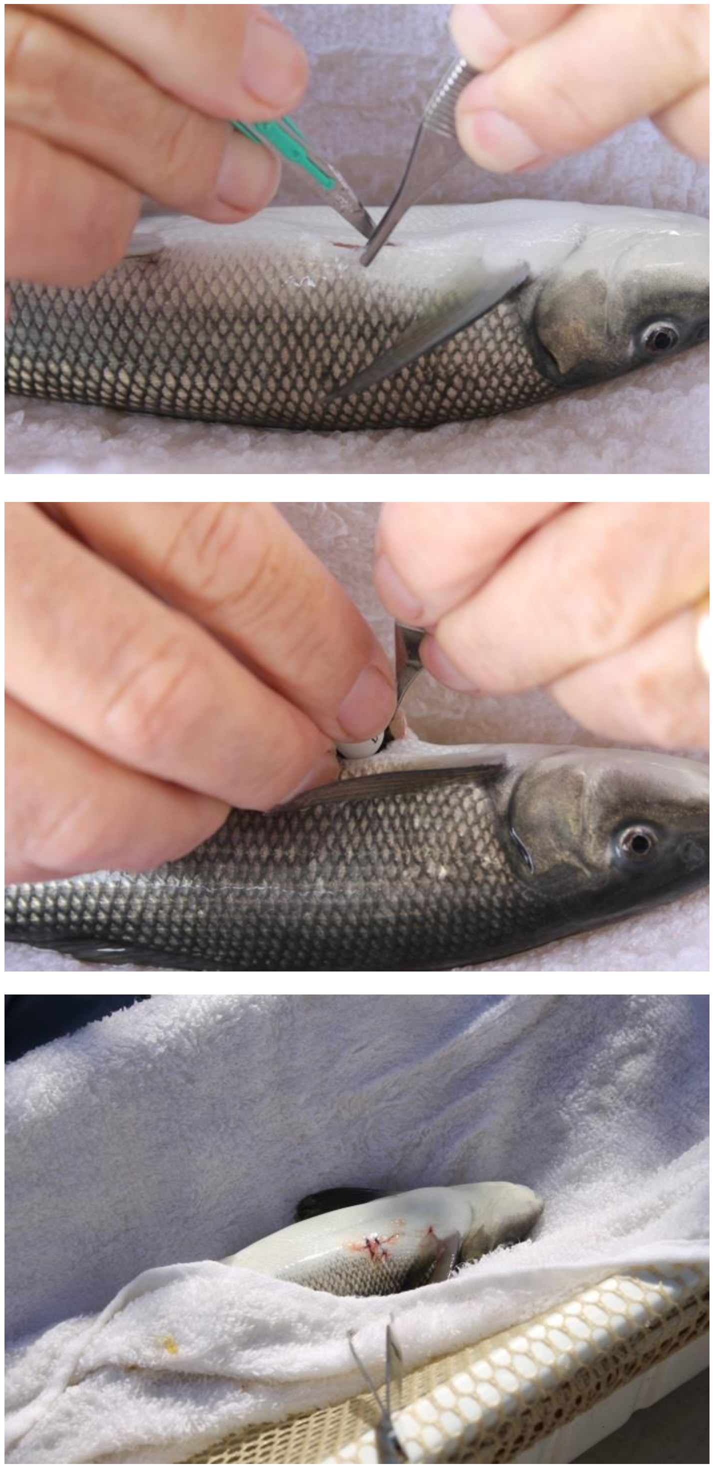

Figure 3. Pictures of the June sucker acoustic tag implantation procedure. Once the mediolateral incision is made (above), the tag is inserted into the abdominal cavity (middle), and then the incision is sutured (bottom). Next Betadine is swabbed on the closed would and surrounding region and a dosage of Baytril® (enrofloxacin) is injected into the dorsal-lateral musculature.

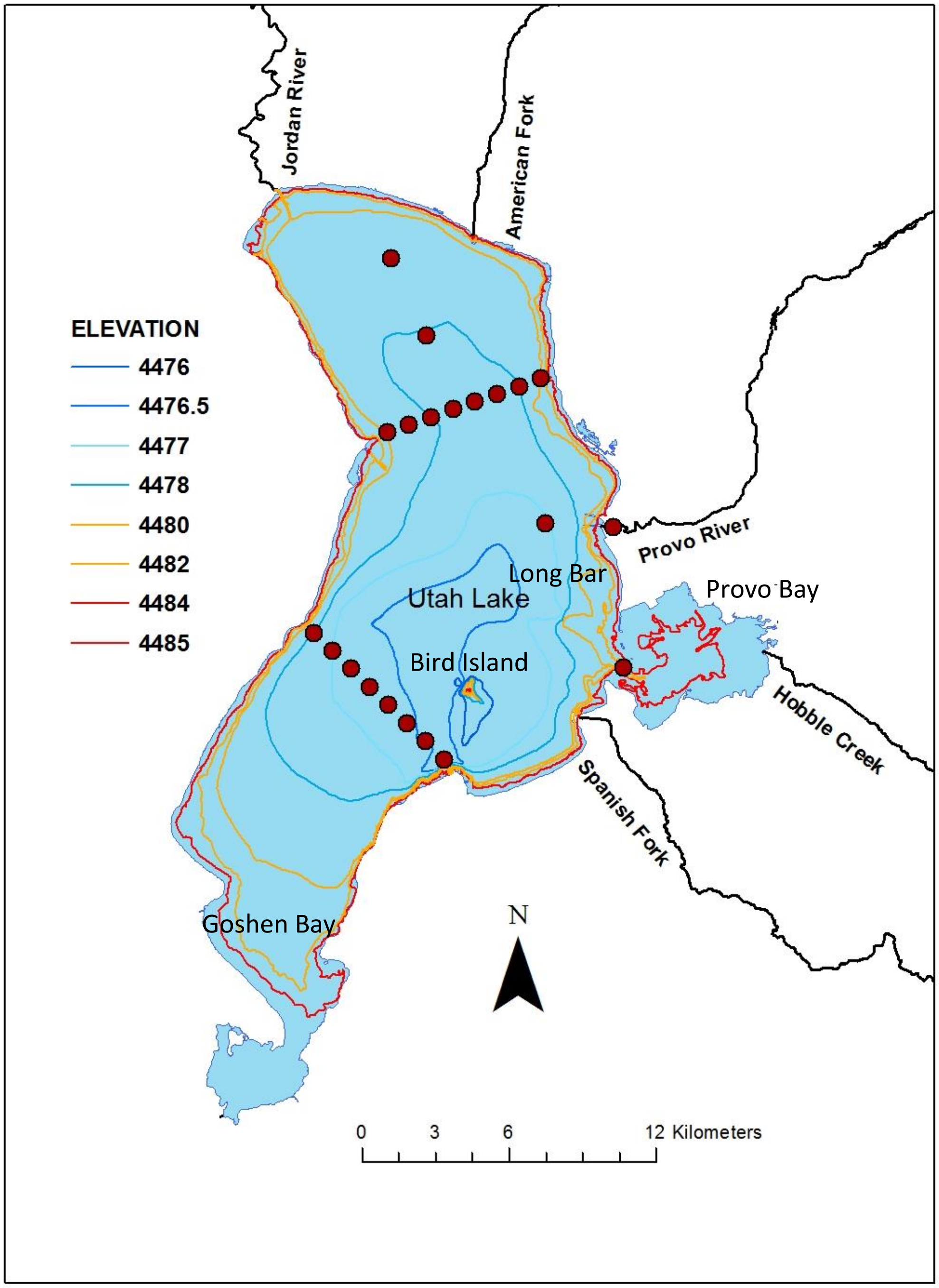

Figure 4. Bathymetric map of Utah Lake, UT, and SUR placements represented by red circles during the 2015 early summer June sucker telemetry study. Elevations greater than 4,484 m were inaccessible during the latter half of the study period.

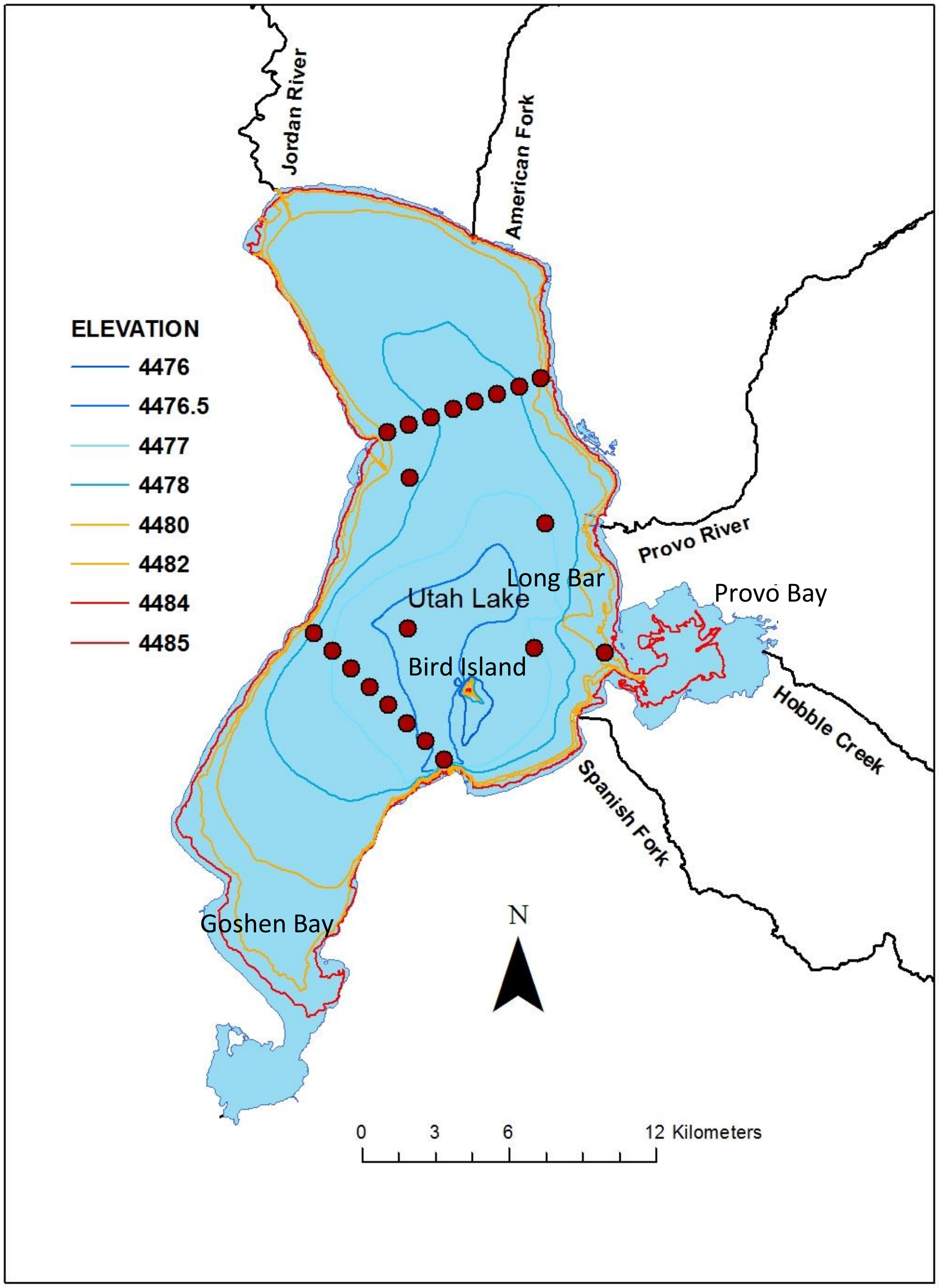

Figure 5. Map of Utah Lake, UT, and SUR placements represented by red circles during the 2015 early autumn June sucker telemetry study. Elevations greater than 4,482 m were inaccessible during this time due to low water levels.

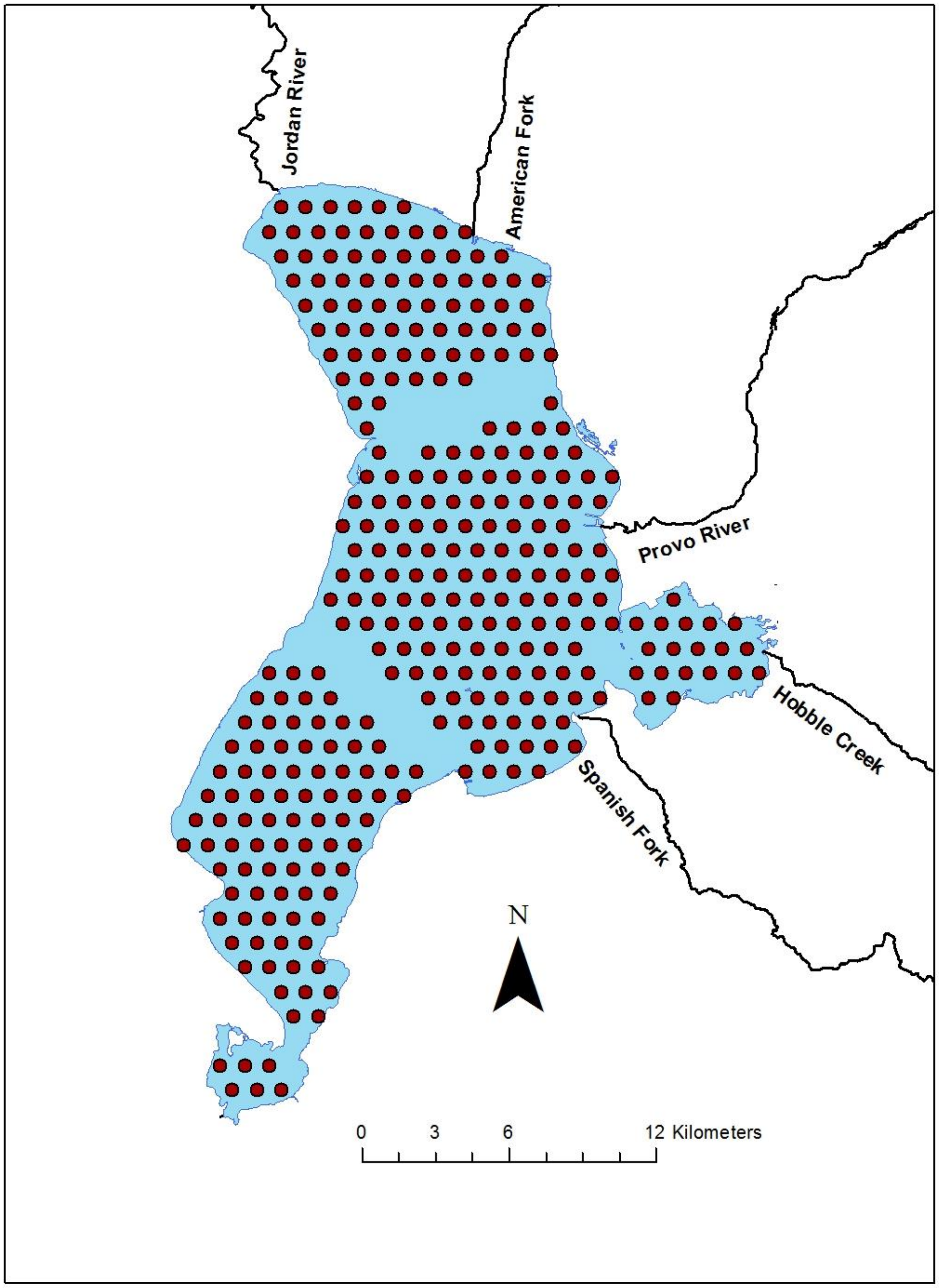

Figure 6. Map of Utah Lake, UT, showing locations of the 316 manual tracking points during the 2015 June sucker telemetry study.

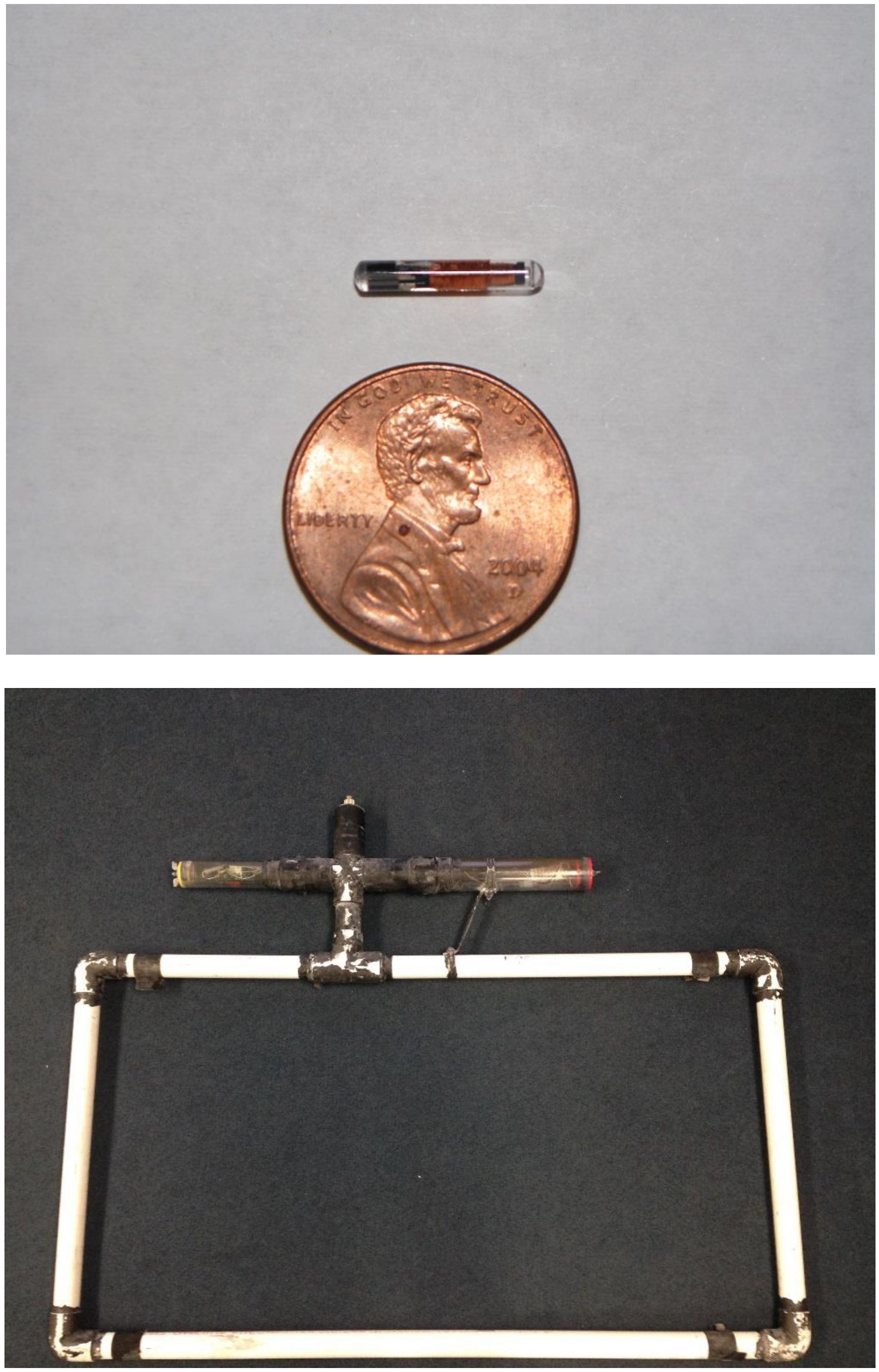

Figure 7. Remote PIT scanning equipment used during the 2015 June sucker study. Top photo is an example of the 134.2 kHz PIT tag that was implanted in the study fish. Bottom photo is an example of the submersible PIT scanning units deployed throughout the lake.

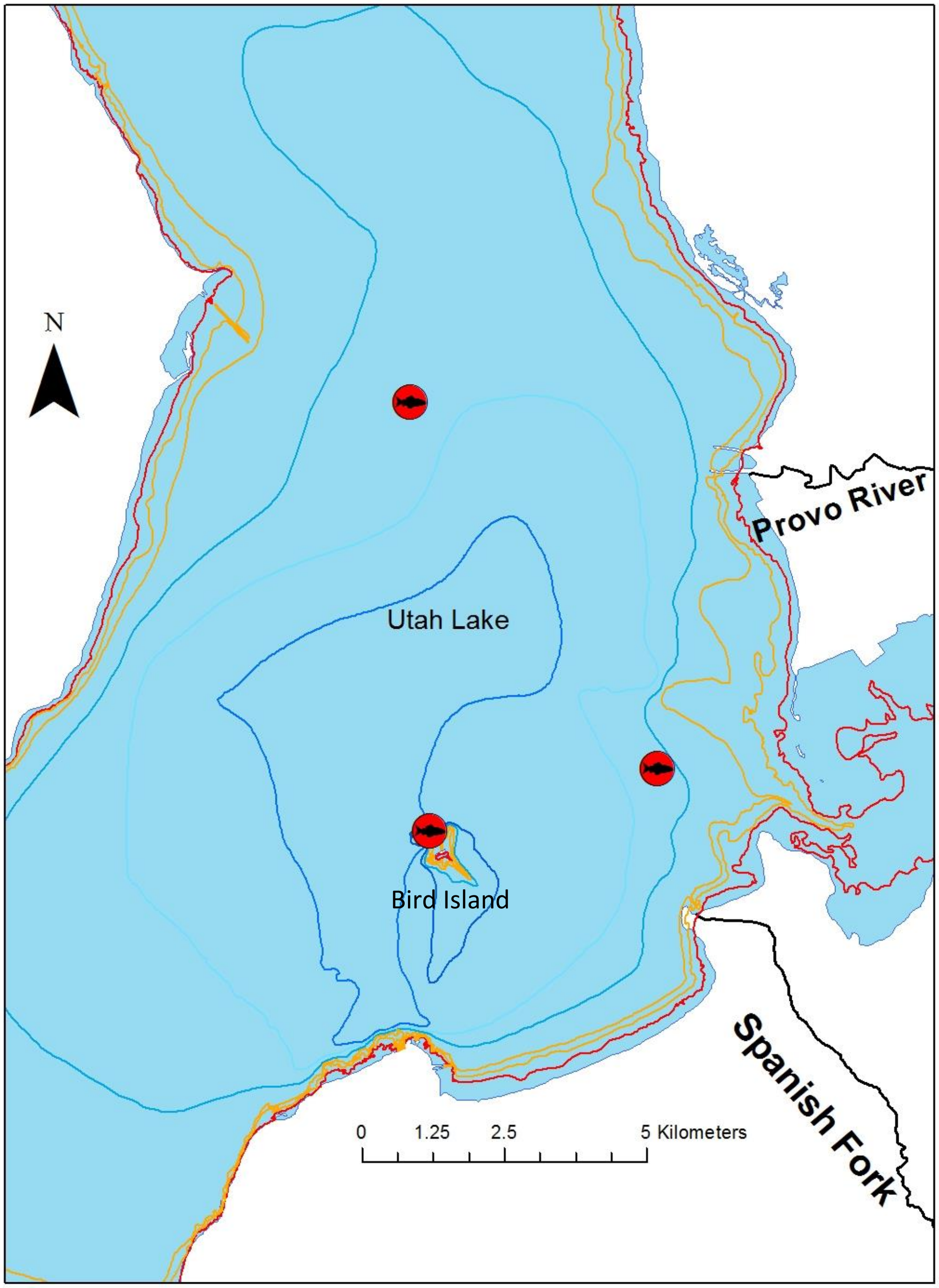

Figure 8. Locations (red circles) where three mortalities occurred during the 2015 early summer tracking period in Utah Lake, UT.

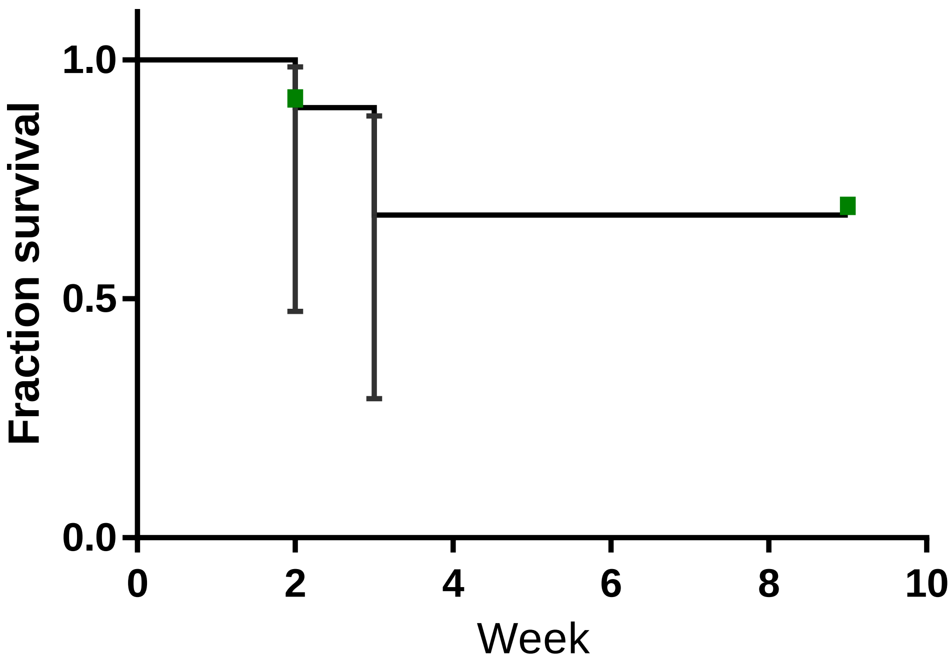

Figure 9. Weekly Kaplan-Meier June sucker survival estimates for early summer fish in 2015. Error bars represent 95% confidence intervals. Green squares represent censored individuals.

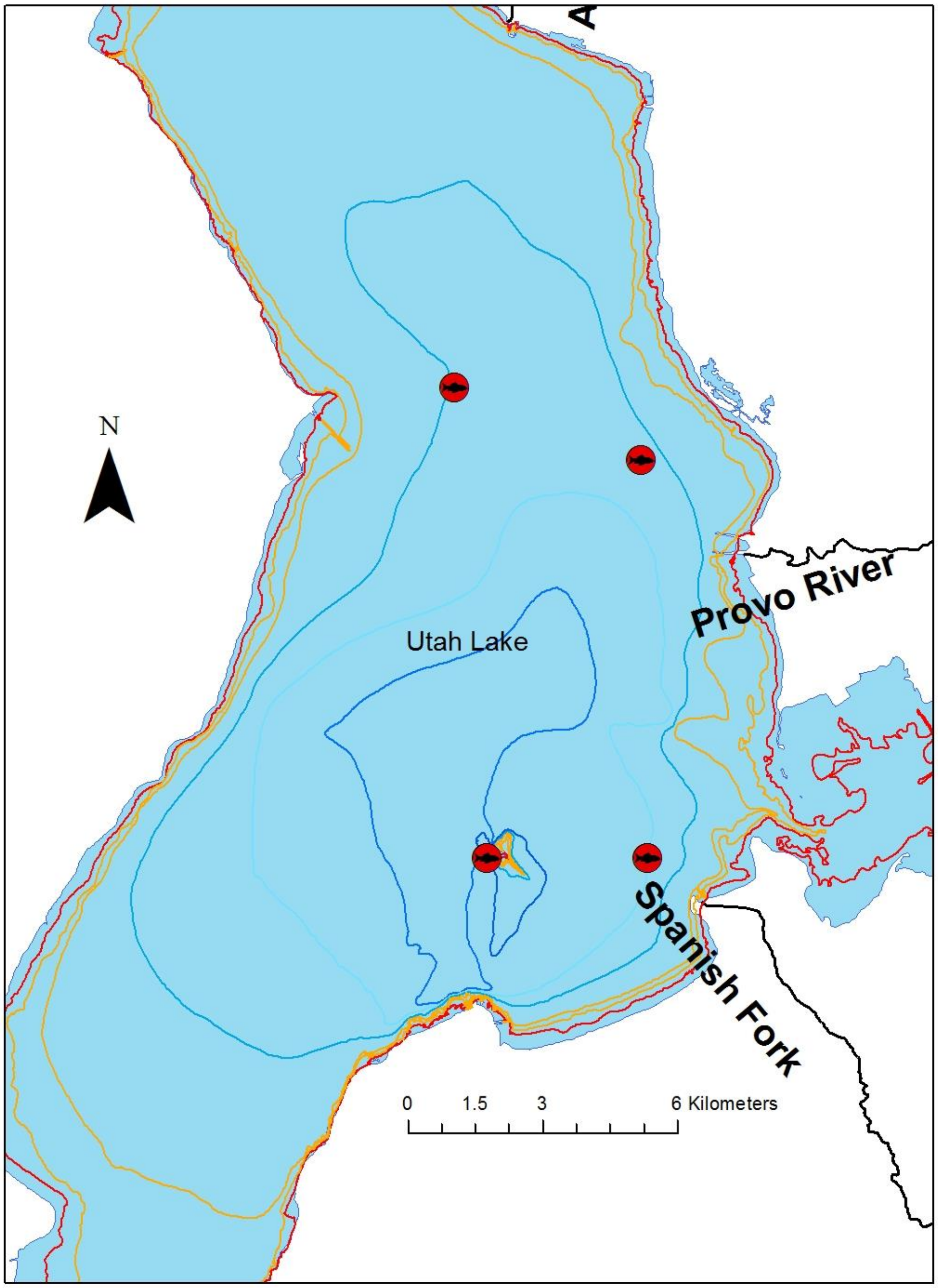

Figure 10. Locations (red circles) where four mortalities occurred during the 2015 early autumn tracking period in Utah Lake, UT.

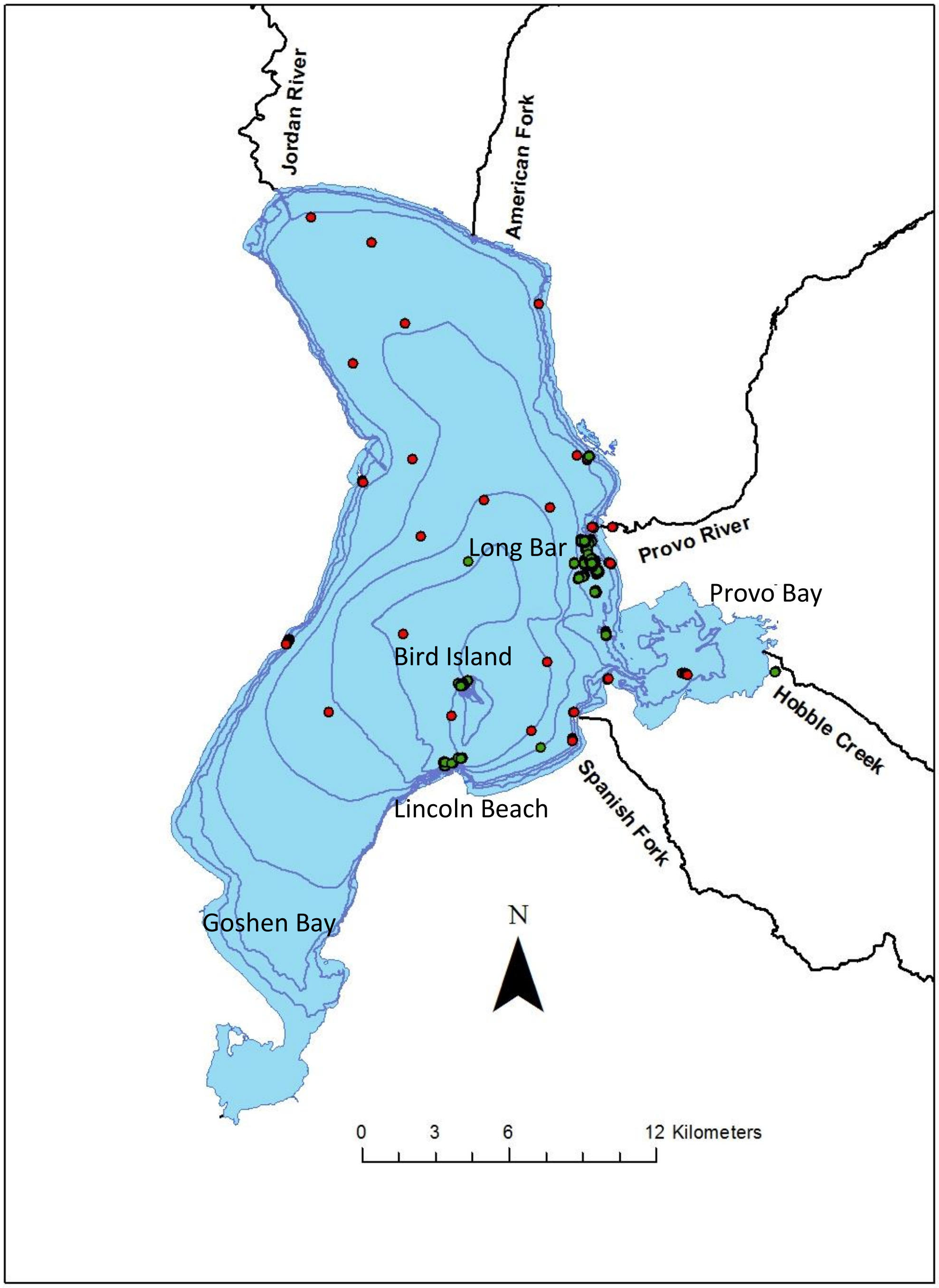

Figure 11. Deployment distribution of portable remote PIT scanners throughout the study area represented by contacts (green circles) and no contacts (red circles).

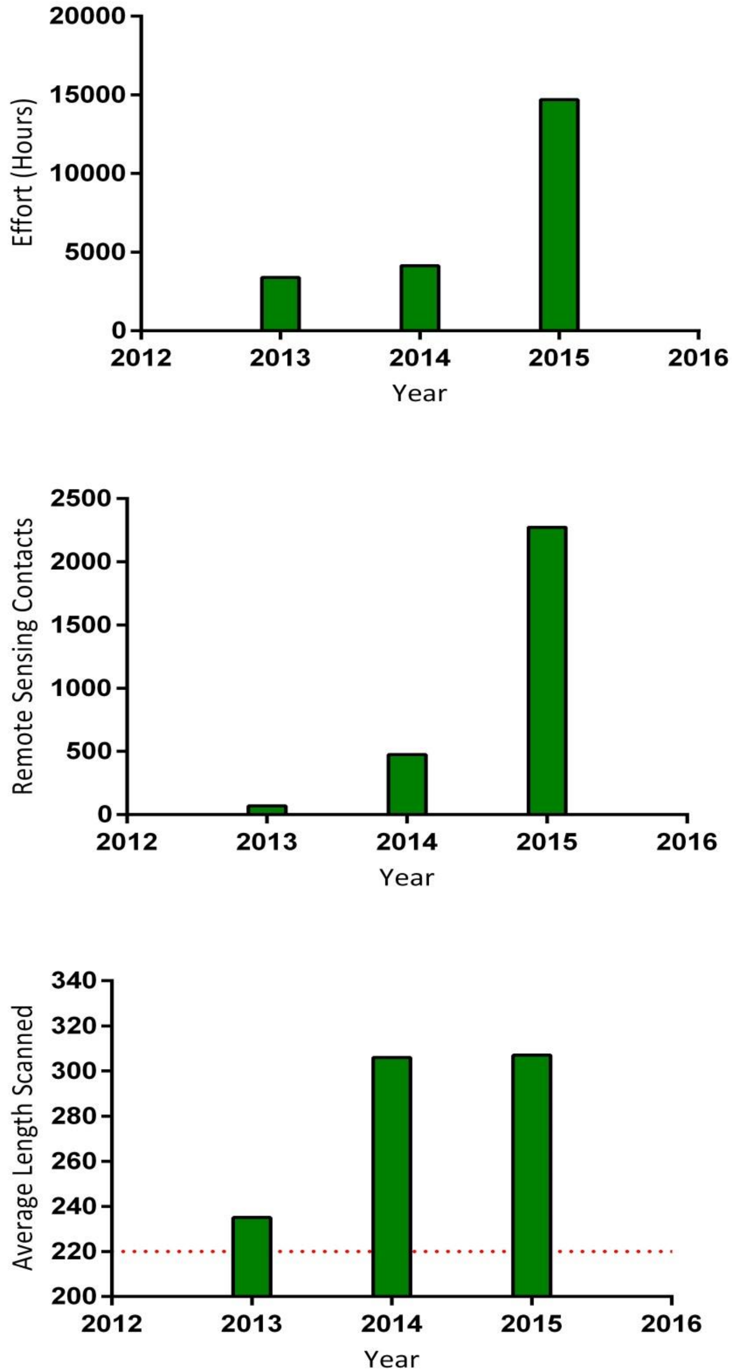

Figure 12. Portable remote PIT scanning effort (top), number of contacts (middle), and average total length in mm of fish scanned (bottom) from 2013 – 2015. Remote sensing contacts (middle) include all of the fish scanned during the given year including fish that were sampled and implanted with a 134.2 kHz PIT tag. The average length at stocking scanned (bottom) includes fish that were stocked since 2007. The red tick line represents the average length of fish stocked since 2007.