Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Imperial Ponds Native Fish Monitoring October 2008 – August 2011 Final Report

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

May 2012

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Multi-Species Conservation Program

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Prepared by: Brian R. Kesner, Jane S. Fencl, Guillermo Ley, and Paul C. Marsh

Marsh & Associates LLC
5016 S Ash Ave
Tempe, Arizona 85282

Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada

http://www.lcrmscp.gov

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Executive Summary

Imperial Ponds is a 19 hectare pond complex designed to provide habitat for two endangered native fish, bonytail (*Gila elegans*) and razorback sucker (*Xyrauchen texanus*). The ponds are part of the 50 year Lower Colorado River Multi-Species Conservation Program (LCR MSCP) goal to develop 146 hectares of backwater habitat along the Colorado River. Monitoring and research at Imperial Ponds is also funded by the LCR MSCP program under work task C-25 This is the final report of native fish monitoring and research efforts conducted at Imperial Ponds from October 2008 to September 2011. Monitoring during this period focused on bonytail and razorback sucker abundance, growth, reproduction, recruitment, and habitat association of resident razorback sucker.

Over the study period, 1,105 Passive Integrated Transponder (PIT) scanner deployments resulted in 1,673 bonytail and 98,829 razorback sucker contacts. Few PIT tagged bonytail survived into this reporting period, and none were stocked during the study. However, untagged bonytail from natural recruitment in Pond 2 persisted throughout the period and 109 individuals were captured and PIT tagged in 2011. These fish account for 1,547 of the total bonytail contacts. Totals of 59, 272, and 198 razorback sucker were stocked into ponds 2, 4, and 6 respectively, and populations persisted throughout the study period. Mortality was low except for acute die-offs in ponds 4 and 6; monthly survival was estimated at 98.5, 96.6 and 97.4% for ponds 2, 4, and 6, respectively, in months without acute die-offs. There was a summer mortality event in Pond 4 between August and October, 2009, during which an estimated 74.0% of the population perished. A die-off occurred in the first two months post-release in Pond 6, with an estimated loss of 64.5% of the population within the time period. Totals of 49, 26, and 49 razorback sucker were moved from ponds 2, 4, and 6 to Pond 1 respectively. Two razorback sucker from each source pond were captured without PIT tags, and therefore could not have been included in the last population estimates for these ponds, which were 47, 30, and 52 for ponds 2, 4, and 6 respectively.

Razorback sucker habitat association shifted significantly across seasons. Populations in different ponds had different seasonal associations except in summer and during the spawning season. During summer when water temperatures exceed 32 °C, deep open water areas were preferred and little activity was detected. Razorback sucker spawning activity appeared to peak in late winter/spring on the gravel boat ramps of ponds 2, 4, and 6, and the artificial spawning beds in ponds 1 and 6, with nearly all members of the population visiting these areas during the period January through March (in 2010 for ponds 2, 4, and

6, and 2011 for Pond 1). Radio telemetry conducted in ponds 2 and 4 during the summer months in 2010 and acoustic telemetry conducted in Pond 1 in 2011 provided additional support to the hypothesis that razorback sucker spend their summer days in deeper (>3 m), open water locations.

Individual growth and recruitment success for native species was evaluated through sampling activities (nets, traps, and electrofishing) in the autumn of each year. A total effort of 10,892.27 hours of netting and trapping resulted in 305 bonytail and 168 razorback sucker captures and a total catch of 6,529 non-native fish. Individual growth for razorback sucker was comparable to fish from Lake Mohave, AZ/NV and females grew faster than males. All but one of the bonytail captured were young recruited fish from Pond 2.

In 2009 and 2010 a total of 733, 417, 519 minutes of active (lighted) larval netting effort was conducted in ponds 2, 4, and 6 respectively to detect spawning success of native fishes. This effort resulted in the capture of 11, 1, and 0 razorback sucker larvae for ponds 2, 4, and 6 respectively. One bonytail larva was also collected from Pond 2 in 2010. In 2011, 917 minutes of larval collection effort in Pond 1 resulted in the capture of 0 bonytail and 60 razorback sucker larvae.

Threadfin shad (*Dorosoma petenense*), common carp (*Cyprinus carpio*), bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), warmouth (*Lepomis gulosus*), and western mosquitofish (*Gambusia affinis*), persisted throughout the study period in most ponds. In addition to these previously documented species, black crappie (*Pomoxis nigromaculatus*) was captured in ponds 3, 4, and 6 during autumn sampling in 2009 and one striped bass (*Morone saxatilis*), 430 mm total length, was captured on April 12, 2010 in Pond 2. Renovations were implemented in ponds 1 and 3 in 2009 and 2010. Attempts to eliminate non-native fishes from Pond 1 were not successful in removing western mosquitofish, but the renovation appeared completely successful in Pond 3.

Water physico-chemistry parameters in all ponds have generally remained within acceptable limits established by the Imperial Ponds work group, i.e., pH <9.0, DO > 4 mg/l, and temperature < 33.3° C. During summer months (June – September) maximum values of pH and temperature and minimum values of DO exceeded limits, and mean values exceeded limits for ponds without active water management.

Introduction

The Lower Colorado River Multi-Species Conservation Program (LCR MSCP) is a 50-year conservation program intended to address the biological needs of at least 26 species through implementation of the Habitat Conservation Plan (LCR MSCP 2004), while accommodating current water diversions and power production on the Colorado River. This program is a partnership of Federal and non-Federal stakeholders, of which the U. S. Bureau of Reclamation (Reclamation) is the implementing partner. One component of the program is to restore or create 146 hectares of backwater habitat along the lower Colorado River “that contain the physical, chemical, and biological conditions required to support native LCR fishes in a healthy condition” (LCR MSCP 2004). Imperial Ponds located on Imperial National Wildlife Refuge (INWR) adjacent to the Colorado River north of Yuma, Arizona was designed and built to provide 19 hectares of habitat for two LCR MSCP fish species, bonytail (*Gila elegans*) and razorback sucker (*Xyrauchen texanus*), and as a testing ground for habitat features that may aid in both species persistence (LCR MSCP 2008).

Bonytail and razorback sucker are two critically imperiled, endemic fishes of the Colorado River basin; both are federally listed as endangered. Stocking of bonytail throughout the lower Colorado River basin has failed to establish new populations and wild populations may be extirpated (Mueller 2006). Razorback sucker stocked into the lower basin have met with a similar fate (Schooley and Marsh 2007, Schooley et al. 2008, Schooley 2010), although stocking more than 200,000 razorback sucker into Lake Mohave has resulted in a small, persistent repatriate population of approximately 3,000 individuals (Kesner et al. 2011). Throughout the basin, predation by non-native fishes has played a major role in decimating populations of stocked fish of either species (Karam et al. 2008; Kesner et al. 2005), and the creation of backwater habitat free of non-native piscivores is critical to the long-term perpetuation of both species (Minckley et al. 2003).

An important component of the Imperial Ponds LCR MSCP work task (C-25) is research and monitoring for bonytail and razorback sucker abundance, growth, reproduction, recruitment, and habitat association of resident razorback sucker. The first period of monitoring, August 2007 through June 2008 was used to test a range of techniques for monitoring population status, recruitment, and habitat association (Kesner et al. 2008b). Guided by previous research conducted by Bond et al. (2007) remote Passive Integrated Transponder (PIT) scanning units were designed and built for Imperial Ponds and determined to be the most effective method to monitor stocked populations of PIT tagged native fish throughout the year. These units were used to assess habitat association in the following years.

Initial native fish stockings occurred in November and December of 2007. Abundance of bonytail declined dramatically within two months of stocking. Although the cause was unknown, avian predation may have played a role (Kesner et al. 2008b; see also Schooley 2010). Razorback sucker numbers declined at a steady rate with survivorship of approximately 75% through early summer (May 2008). A small collection of razorback sucker larvae indicated at least limited spawning, but recruitment to the juvenile stage was undocumented.

This is the final report of native fish monitoring and research efforts conducted at Imperial Ponds from October 2008 to September 2011. Research on the two native fishes at Imperial Ponds under work task C-25 is expected to end in federal fiscal year 2018, while monitoring is expected to continue throughout the nominal 50-year span of the LCR MSCP. Annual reports of these activities have been submitted to Reclamation, Boulder City, Nevada, and are available on the LCR MSCP website (www.lcrmscp.gov).

Study Area

INWR is located approximately 30 miles north of Yuma, Arizona (Figure 1). The six ponds that comprise Imperial Ponds are adjacent to the Colorado River less than one mile west of the refuge headquarters. The ponds range in size from 3.3 to 9.2 surface hectares. Features built into the ponds are gravel-lined boat ramps, one rip-rap (boulder) lined shoreline, a water inlet and outlet, and hummocks (LCR MSCP 2008). Hummocks are submerged mounds of silt-sand with gravel-cobble sides. These mounds were designed for planting emergent native vegetation such as hardstem bulrush (*Schoenoplectus acutus*) and three-square bulrush (*Scirpus pungens*). Shorelines also were planted or invaded by cattail (*Typha* sp.), phragmites (*Phragmites australis*), three-square bulrush, and coyote willow (*Baccharis salicifolia*). Additional features added since 2007 include one spawning bed in Pond 6 (an approximately 3 x 6 m cobble area along the shoreline in water 1-2 m deep) in February 2009, and six spawning beds in Pond 1 (approximately 3 x 6 to 4 x 8 m of gravel) added in May 2010. Three artificial habitats in Pond 2 (PVC tables with mesh tops) were installed between January and April 2009 and removed in June 2011.

Methods

Monitoring activities during routine trips included deploying remote PIT scanners and downloading data, snorkeling, minnow trapping, hoop netting, larvae collecting, and acquiring water physico-chemistry data. PIT scanners were deployed to monitor stocked bonytail and razorback sucker abundance and more recently to monitor bonytail and razorback sucker habitat association. Attempts to collect bonytail and razorback sucker larvae were made to detect spawning success and collect material for genetic analysis. Minnow trapping and hoop netting were conducted to assess native fish recruitment and non-native fish invasion. In addition to routine trips, an intensive sampling effort was conducted each autumn to assess health, individual growth, and abundance of stocked native fish, to detect native fish recruitment, and to acquire additional information on presence and status of invasive non-native fishes. Water physico-chemistry data were collected to detect if and when measured parameters exceeded limits considered inhospitable for bonytail and razorback sucker, and to direct pumping activities to specific ponds when they were exceeded (Kesner et al. 2008b). Digital photographs were taken quarterly from designated locations and compass directions around the ponds to capture long-term changes in the visual aspects of the shoreline and pond (e.g., bank degradation, shoreline, and aquatic vegetation development). Monthly and annual progress reports were submitted to Reclamation and to the Imperial Ponds fishery coordination team during the contract period.

Population and Habitat Association Monitoring

PIT Scanning

PIT scanning units were designed and built in 2007 and 2008 (Kesner et al. 2008b), modified in the first year of this study October 2008 to July 2009, and used extensively in the last two years of study, August 2009 through September 2011, to monitor native fish populations in Imperial Ponds. The basic design was based on units described in Bond et al. (2007), relying on an Allflex® scanner which can detect full duplex (FDX) and half duplex (HDX) PIT tags. Their design was described in detail in Kesner et al. (2010a) and repeated below:

> "The scanner antennas consisted of 12 AWG stranded copper wire encased in 38 mm PVC pipe (2.3 m by 0.7 m). Each antenna was connected to an Allflex® scanner. Each scanner unit was powered by a Power-Sonic® (Power-Sonic Corporation, San Diego, California) 12 volt, 26 Amp-Hr. battery or similar battery. The Allflex® scanner was stored in a model 1520, Pelican™ case

(Pelican Products, Torrance, California) which also contained a data logger. Allflex® scanners sent tag data to the loggers via a serial cable. Data loggers recorded tag numbers and a date-time stamp. Data loggers used were provided by Cross Country Consulting Inc. (Phoenix, Arizona). Revisions to the logger design and programming allowed for long-term deployment of the scanners with an on-off cycling of the scanner from one to 48 hours. Coleman solar panels (model CL-600) were mounted to the top of pelican cases and connected to the battery to provide daily recharging and extend deployment period of each scanner unit."

All native fish initially stocked into Imperial Ponds were tagged with an FDX PIT tag prior to stocking, and PIT scanning for the first year was conducted to monitor survival of the stocked fish. After the initial year, two stockings were conducted with 32 mm HDX tagged razorback sucker; 59 into Pond 2 on December 10, 2008, and 198 into Pond 6 on January 15, 2009. HDX tags typically have a longer read range compared to standard 12 mm FDX tags, up to 2 meters (Bond et al. 2007). HDX tags are also less dependent on antenna tuning than FDX tags (antennas can be slightly out of tune with respect to the scanner and still be successfully detected). For these reasons, HDX tagged razorback sucker were stocked to obtain habitat association data.

PIT scanner deployments were standardized during sampling trips in August 2009 to collect comparable habitat association data for ponds 2, 4, and 6. Four scanners were deployed randomly among four habitats; rip-rap shore, mud shore, hummock, and open water (one scanner per habitat). Habitat delineation in ArcGIS® software (ESRI, Redlands, California) and randomization of deployment sites were described in Kesner et al 2010a:

"Beginning in February 2009, PIT scanner deployment was standardized during sampling trips to collect comparable habitat use data for ponds 2, 4, and 6. Ponds 1 and 5 were excluded from standardized habitat scanning since native fish were absent from these ponds, and Pond 3 was excluded because routine scanning from July 2008 to February 2009 failed to contact a single tag. Four scanners were deployed randomly among four habitats; rip-rap shore, mud shore, hummock, and open water (one scanner per habitat). Aerial photographs were geo-referenced to bathymetry data taken by Reclamation personnel using ArcGIS® software (ESRI, Redlands, California). Aerial photographs were manually fitted to bathymetry shapefiles and all contour lines except for the 185 ft elevation contour line were deleted. Each pond was then split into polygons representing their corresponding habitats. Shoreline habitats (rip-rap and mud shore)

> extended from the 185 ft elevation contour line out into the pond for five meters. Hummocks were outlined by the 185 ft contour line and their gravel-cobble sides were accounted for with a five meter buffer around each hummock. Open water was considered any area not categorized as shoreline or hummock habitat. Boat ramps in each pond were initially considered a separate habitat. However, given the small size of the boat ramps, it was determined that this along with artificial habitats and spawning beds would be defined as “hot spots” (a single sampling point instead of an area). Artificial habitats are PVC framed nylon webbing “tables”, three of which were deployed into Pond 2 between January and March 2009. One spawning bed was created in Pond 6 in February 2009.”

Three to four random points (replicates) were generated for each of the four designated habitats per sampling trip, and one or two ponds were sampled per sampling trip. Effort and the number of ponds scanned per trip were scheduled to ensure that each pond with PIT tagged native species was scanned at least once per month. Effort hours for the last (typically fourth) replicate on trips prior to April 2010 were generally 10 hours less than the nearly 24 hour cycle of most replicates because scanners were pulled or moved the morning of the last sampling day. Since April 2010, this fourth partial replicate was eliminated from the protocol, leaving three complete replicates per habitat, pond, and sample month. No adjustment was made to account for the discrepancy in effort for the partial replicates because the majority of contacts occurred between sunset and sunrise. This standardized methodology continued in Pond 1 from November 2010 to May 2011 as native fishes were being transferred, but in May 2011 habitat association scanning was changed. For each trip, one random point was generated for the four designated habitats. Scanners were deployed at the random locations on a 48 hour cycle (24 hours on, 24 hours off) until the following trip to INWR when they were moved to a new location. This change was made because sampling trips were reduced in duration from 4 or 5 days to 3 days to allow more time for data analysis and final report writing. Although the PIT scanners were deployed among the four habitat types during this period, these data were collected to ensure population estimates remained accurate and were not used for habitat association analysis.

Data from PIT scanner units were downloaded to a PDA or laptop computer at the end of each effort cycle, and entered and stored in a Microsoft Access 2003 database. All contact data were initially entered, then pared to one unique PIT contact per minute per deployment. This was necessary to avoid inflation of total contacts because razorback sucker were double tagged with one HDX and one FDX tag in ponds 2 and 6. Scanners had built-in delays to avoid repeated records of individual PIT tags in the field at any given minute, but multiple contacts were recorded when two individual tags were in the scanning field at the same time. The presence of two tagged fish in the antenna's field resulted in duplication as well. The reduced data set still contained duplicate fish records within a given minute if both tags (FDX and HDX) within the same fish were recorded. Although these records were retained in the database, all habitat association analyses were conducted based on a unique fish identification number (FID) so that only one record per unique fish was used in any given minute for any given scanner deployment.

After native fish were consolidated into Pond 1, antenna orientation also was varied to determine its effect on contacts. From May through July 2010, two antennas were deployed side-by-side approximately 1 m apart; this spacing was to avoid interference between adjacent antennas. One antenna was placed in a bottom long orientation (traditional orientation) and the second was deployed in either a bottom flat, surface flat, or bottom tall orientation (Figure 2). Antennas were placed at random locations within the four designated habitats as described above for habitat association deployments. Total contacts by FID were analyzed using a matched-pairs signed-rank Wilcoxon test and the corresponding statistical table from Sokal and Rohlf (1995).

When sufficient remote sensing data were acquired for a pond between two routine monitoring trips, a mark-recapture population estimate was calculated using the single-census modified Peterson formula, $\frac{(M+1)(C+1)}{(R+1)}$ (Ricker 1975).

The number of fish marked (M) or captured (C) during a sampling trip was calculated from unique PIT scanner contacts within a sampling trip and pond. Recaptures (R) were calculated as the number of PIT tags in common between consecutive sampling trips to the same pond. Survival estimates were calculated from the single census population estimates and the total number of fish stocked.

Monthly survival for razorback sucker was also estimated using a generalized Cormack Jolly Seber (CJS) mark-recapture model; open population, recaptures (PIT scanning contacts) only. Contact histories, a series of 0s (non-contact) and 1s (contact) for individual fish over sampling periods, were assembled based on habitat association data for ponds 2, 4, and 6. For each pond contact histories and time intervals between scanning events were inputted into the computer program MARK (White and

Burnham 1999). Although time intervals varied from 0.4 to 5.4 months (including time period between stocking and first scanning effort), MARK standardizes parameter estimates to a single unit of time (month in this case). For ponds 2 and 6, survival was based on data starting immediately after stocking, December 2008 and January 2009, respectively, and ending in August 2010. Survival in Pond 4 was based on mark-recapture data from April 2008 to August 2010. Potential model parameterizations numbered in the thousands given the number of capture intervals, but only a small subset of these potential models were tested based on information from mark-recapture population estimates provided in monthly reports (e.g. survival parameters (ϕ) were fixed for most time periods, but were set to vary across months when population estimates declined dramatically). Encounter probability (p) was varied over all contact occasions for all models, because PIT scanner encounter probability varied with seasonal changes.

In Pond 2, no dramatic declines were observed based on population estimates (see results, below), so only two models were assessed; constant survival and time varying recapture rates (model ϕ, p_t) and time varying survival and recapture rates (model ϕ_t, p_t). In Pond 4, population estimates declined during the summer of 2009 (June through October, 2010). To assess the time period in which the die-off occurred, and quantify the rate of decline, two parameters for survival were tested, one for the time period when the die-off occurred and the other for the rest of the time. Four models were tested, each with a different range of sample intervals that included the potential die-off; October, August through October, July through August, and June through August. Intervals with separate parameters of survival were designated by the month the sampling interval ended (e.g., $\phi_{jul\ 2009}$, $p_{t\ indicates}$ a die-off period between the most recent previous sampling period prior to July and the July sampling event in 2009). One additional model with time varying survival and recapture rates was used for comparison (model ϕ_t, p_t). Population estimates in Pond 6 declined in the months immediately following stocking (January-March 2009), and a similar analysis of mark-recapture models was done using combinations of post-stocking months as die-off periods. Maximum likelihood estimates of survival were chosen for each pond from the best fit model based on the lowest Akaike's Information Criterion (AIC) provided by MARK.

Investigation of diel patterns of habitat preference began in autumn 2009; habitat association deployments were divided into day and night contacts. This was accomplished by replicating the deployment information for a given replicate (season, habitat, pond, UTM coordinates, etc), denoting one as the daytime replicate and one as the nighttime replicate (hereon referred to collectively as diel replicates), and associating contacts with the appropriate replicate. Daytime contacts were defined as any contact occurring between sunrise and sunset as reported by the US Navy for the Yuma, Arizona area (http://www.usno.navy.mil/USNO/astronomical-applications/data-services/rs-one-year-us). All other contacts were considered to occur at night. Nighttime contacts therefore included contacts made during the crepuscular period, a period previously reported as an active period for razorback sucker in Imperial Ponds (Kesner et al. 2010b).

To analyze changes in habitat association for diel periods over time, seasons were assigned based on the month sampling was conducted; summer (May – September), autumn (October – November), winter (December – February), and spring (March – April). The long summer season was defined as months in which water temperatures in the ponds generally exceeded the limit for summer conditions as established by the Imperial Ponds work group (greater than 27.0° C).

General habitat distributions among seasons were analyzed using a two-way contingency table chi-squared (χ^2) analysis for each day and night period. The total number of contacts was summed across sampling trips within seasons and habitats to fill-in each contingency table and χ^2 statistics were calculated using R (http://www.r-project.org/). Contingency tables were graphically represented as stacked bar graphs for each pond representing the proportion of total contacts from each habitat within each season in day and night periods (see Results).

Additional remote scanner deployments were made on boat ramps, spawning beds, and other "hot spots" when scanners were available during routine monitoring trips and interim periods. The data were divided into diel replicates the same way as habitat association data, using the sunrise and sunset times of the first date of deployment. "Hot spot" data are often collected over a period of multiple days. Average contacts per day/night were calculated for the duration of the scanning period. Average contacts for "hot spot" data were mapped with total contacts from habitat association data in ArcGIS®. Each point on the map (circles for habitat association, squares for hot spots) represented the site of deployment. The contact data for each scanning type were divided into quintiles (each quintile represents 20% of the data). Each quintile was graphically represented in a size and color gradient corresponding to the range of possible contacts within the quintile. Quintiles were chosen over more traditional quartiles (often used to describe distribution of data in a box and whisker plot) because quintiles distinguished between deployments with zero contacts and deployments with one or a few contacts.

Habitat association for data collected from Pond 1 in 2011 was not assessed. Any comparison of habitat associations in Pond 1 would be inaccurate because fish were being transferred into Pond 1 between November 2010 and March 2011. Translocated fish may also exhibit different behaviors immediately after their introduction, and a full season of data based on the new deployment schedule had not been acquired.

Acoustic and Radio Telemetry

A radio telemetry study was conducted in 2010 to track razorback sucker during the summer in ponds 2 and 4, and an acoustic telemetry study was conducted during the summer of 2011 for bonytail and razorback sucker in Pond 1. Bonytail were included in 2011 to determine if that species used the rip-rap shore during the summer as was noted for the species in Cibola High Levee Pond (Mueller et al. 2003).

Radio telemetry was chosen in 2010 because tags and radio equipment were readily available and had previously been used on razorback sucker extensively in the lower Colorado River by Marsh & Associates (M&A) staff. Short duration trammel net sets were conducted in ponds 2 and 4 on April 12, 2010 to capture razorback sucker for radio tagging. Four razorback sucker from Pond 2 and three razorback sucker from Pond 4 were radio tagged (Advanced Telemetry Systems [ATS], Inc. Isanti, MN, model F-2020) and released into the pond of capture. Prior to tag mounting, each fish were anesthetized by immersion in a solution of MS-222. Two small (less than 2 mm) holes were drilled into the medio-dorsal musculature, and mounting wires were passed through these holes and secured by crimping metal keepers on the opposite side of the fish from the tag. Nylon backing disks were placed between the fish and each keeper to prohibit the keeper from working its way through the musculature. The wound site was swabbed with Betadine® prior to placing the fish in a recovery tank, and fish were released within 30 minutes of tagging. Four razorback sucker in Pond 2 and three razorback sucker in Pond 4 were captured and radio tagged on April 12, 2010 (Table 1). Razorback sucker were tracked on subsequent sampling trips from mid-April to mid-July, 2010, using an omni-directional whip antenna and an octagonal bi-directional antenna simultaneously. Tracking was generally conducted around the perimeter of the pond followed by transects across the middle. Tracking was conducted at least once during the daytime and nighttime hours each trip in each pond.

A second study using acoustic tags was conducted in the summer of 2011. Four bonytail and ten razorback sucker were implanted with acoustic telemetry tags (Sonotronics, Inc., Tucson, Arizona, model IBT 96-6-I) with a battery life of six months in March 10, 2011 and released into Pond 1 (Table 2). Surgical implantation procedures were similar for both species, following previous procedures described in Karam et al. (2008), and summarized here:

> Fish were anesthetized by immersion in a solution of MS-222, and anesthetic water was continually flushed over each fish's gills to maintain a proper level of anesthesia for the duration of the surgery. A small mediolateral incision was made slightly anterior and dorsal to the left pelvic fin and an acoustic transmitter sanitized in isopropanol was inserted into the abdominal cavity. The incision was sutured with 2-3 knots using USSC 3-0 Monosof black monofilament and a C-14 cutting needle. The closed wound was swabbed with Betadine, and the broad spectrum antibiotic Baytril® (Enrofloxacin; 23 mg/ml solution) was injected into dorsal-lateral musculature of each fish as a preventative measure for post-surgery infection (Martinsen and Horsberg, 1995). Individual injections ranged from 0.2-0.9 ml and were based on a categorical chart that identified appropriate dosage based on each fish's weight.

Tagged fish were tracked once during daylight hours and once during nighttime hours each trip. Fish were tracked using an Underwater Dive Receiver (UDR) purchased from Sonotronics Inc. Frequencies were preloaded to the UDR. Spot checks began at any location in the pond and were conducted by submerging the UDR from the boat and listening for any frequency in the vicinity. The closest signal was tracked until the signal could be heard loud and clear directly beneath the boat at the lowest gain setting. Gain is a measure of the signal amplification and it regulates the strength of the echo being received (the lower the gain the stronger the signal must be to receive it on the UDR). This differs from volume which just increases the loudness of the sound passed to the headphones. From experience with the UDR elsewhere, a strong signal when the UDR is set to the lowest gain setting indicates that the fish is within about five meters of the UDR. Two to three implanted tags shared the same frequency but had a unique code (signal pattern); for these tags the correct code was verified before the position was recorded. Location (UTM, NAD83), date, and time the signal was acquired were recorded on a data sheet for the corresponding fish (listed by frequency and code). Notes were taken on whether the fish was believed to be moving or stationary. Then the area was checked for additional tagged fish in the vicinity. The gain was kept at the lowest setting during spot checks until there were only a few fish left to contact. Frequencies (or specific codes) that had not been heard in a sampling period were targeted afterwards by increasing the gain and listening from different positions in the pond until the signal was acquired. Once a signal was acquired, the same procedure as above was used to determine and record the fish location.

To illustrate the telemetry contact location data, the utilization distribution was mapped by grouping the location data for each species in Pond 1 (Seaman and Powell 1996). A fixed kernel density estimation analysis was conducted using Hawth's Tools within ArcView (ESRI, Redlands, California) after contact data were imported. The program Animal Space Use (Horne and Garton 2009) was used to estimate the appropriate smoothing parameter calculated for each specific data set (Horne and Garton 2006). The likelihood cross-validation function was used (as opposed to using Least Squares cross-validation), because it produces less variability and is recommend for small sample sizes (Horne and Garton 2006).

Annual Autumn Sampling

Annual autumn sampling was conducted each year. Hoop nets were the primary sampling gear used to capture stocked native fish. Two types of hoop nets were used: a single throat 12.7 mm mesh net and a double-throat net with a single central lead (a 3.0 m piece of 0.9 m tall 12.7 mm mesh). Two box traps (1.8 m x 1.8 m x 1.8 m with 2, 3.7 m long wings and one 7.6 m long central lead) and three Oneida-type traps (1.2 m x 1.2 m x 1.2 m with three 3.7 m wings) were deployed in autumn 2009. Minnow traps (Gee standard, 6.4 mm mesh or exotic, 3.2 mm mesh) also were deployed to detect juvenile native and non-native fish. Hoop nets and minnow traps fished continuously but were checked at least once daily and cleared of all fish. Trammel (22.9 m long, 1.8 m deep, 38.1 mm mesh, 22.9 m long, 1.8 m tall, 76.2 mm mesh, 45.2 m long, 1.8 m tall, 12.7 mm mesh, 22.9 m long, 1.8 m tall, 38.1 mm mesh) and gill (45.2 m long, 1.8 m tall, 38.1 mm and 45.2 m long, 1.8 m tall, experimental mesh) nets were used when target numbers of native fish species could not be caught using other gears or when a pond contained only non-native fishes. Soak time was typically kept to less than three hours to minimize stress on native fish encountered. Electrofishing was used in autumn 2010 to aid in the capture and transfer of native fishes to Pond 1.

All native fish captured were held in onboard live wells for two hours or less before being placed in floating live cars. Bonytail and razorback sucker were scanned for PIT tags, measured (total length, TL, in mm), sexed (juvenile, male, female, or unknown), assessed for condition, and checked for external parasites and wounds before being returned to their pond of capture (except from November 2010 to March 2011 when native fish were transferred to Pond 1). All data were recorded on "Rite in the Rain"® datasheets and later transferred into the Microsoft Access® database. Non-native fish captured were identified to species (except juvenile sunfish that could not be reliably identified), enumerated and sacrificed.

Individual Growth

Individual growth for razorback sucker released into Imperial Ponds was analyzed for fish released into ponds 2, 4, and 6. Due to a lack of recaptures, growth was not calculated for bonytail stocked into ponds 2 and 3 and razorback sucker stocked into Pond 1. Growth was calculated as the difference between TL measured prior to stocking and TL measured during consolidation efforts. Growth data from Lake Mohave razorback sucker were used for comparison. A standard growth curve based on size at release and size at capture could not be used because release sizes of Imperial Ponds razorback sucker were significantly larger than razorback sucker released into Lake Mohave (means = 462 and 331 mm TL for Imperial Ponds and Lake Mohave respectively). Instead, the linear relationship between release size and growth was plotted and visually interpreted. Fish stocked into ponds 2 and 6 were at large between 650 and 800 days and so data plotted from Lake Mohave were filtered for a similar time period between stocking and capture. For Pond 4, fish were at large between 1000 and 1100 days and these data were plotted separately from ponds 2 and 6 along with Lake Mohave growth data with release and capture records 1000 and 1100 days apart. A best-fit linear regression line based on the Lake Mohave growth data was plotted for comparison because most of the Imperial Ponds fish were larger than Lake Mohave fish at stocking (i.e., projection of the regression line was used for comparison). Males and females were plotted separately for each comparison.

Reproduction and Recruitment

Spawning

Interim scanning provided additional contacts for spawning activity monitoring beginning in 2009. Deployments were concentrated on boat ramps in ponds 2, 4, and 6 and an artificial spawning bed in Pond 6 during the spawning season (December 2009 to May 2010).

Interim scanning data were analyzed using pairwise comparisons of FID contacts among interim periods for ponds 2, 4, and 6 (cross-trips comparisons). Unique FIDs contacted during one interim period were compared to each of the other interim periods within each pond (Kesner et al 2010b). These comparisons of unique contacts among interim periods on the boat ramps in all three ponds were used to describe the proportion of fish visiting these sites per sampling trip and the proportion of revisits over time. A similar comparison for interim period scanning between the boat ramp and spawning bed in Pond 6 also was conducted using a table comparing the number of FIDs in common between the boat ramp and spawning bed for the same interim period.

From November 2010 to May 2011, available scanners were deployed on the boat ramp and four out of six spawning bed locations on Pond 1 (Figure 3) during trips and interim periods. Due to scanner problems, updating remote sensing equipment, or delegating units to other locations, data for every potential spawning location on every deployment date were not available. Scanning schedules varied between a continuous or 48 hour cycle (24 hours scanning, 24 hours recharging). The number of FIDs for each deployment date was calculated throughout the spawning season from the combined effort of each scanned spawning location for that date. In addition, total contacts, scanning hours, catch per unit effort (CPE), unique FIDs and the number of fish contacted more than once (FIDs above threshold) were calculated for every deployment. Data are separated by species. Less data were available for bonytail because antenna tuning was occasionally lost rendering the units incapable of reading the FDX tags carried by this species.

Additional analysis was conducted for razorback sucker because data were available for this species on every deployment date. Unique FIDs of razorback sucker contacted on each spawning bed were compared to each of the other spawning beds scanned within interim periods. Often more scanners were available to scan during interim periods because they did not need to be allocated for habitat association scanning. The number of FIDs in common between the available pairs of spawning beds was entered into a table in which each cell was color-coded to represent a spawning bed. In addition, FIDs were compared between the boat ramp and spawning beds. When both spawning beds and the boat ramp were scanned simultaneously, comparisons of unique contacts among interim periods on the boat ramp and spawning beds were used to describe the proportion of fish visiting these sites.

Larval and Juvenile Sampling

Fishing lights rated to 250,000 candle power were deployed in the evening after dark and aquarium dip nets were used to capture positively phototactic razorback sucker larvae. Capture of bonytail larvae was also possible (presence of adult bonytail) in Pond 1 in 2011 and in ponds 2 and 3 during 2009 and 2010. In 2009, larval collections were conducted from February through April in ponds with adult razorback sucker (ponds 2, 4, and 6) during routine monitoring trips. Larval sampling in 2010 was extended January through May to increase the number of larval razorback sucker captures and increase the probability of encountering bonytail. Razorback sucker are known to spawn as early as November in Lake Mohave and in water temperatures from 10 – 21° C (Minckley and Marsh 2009), and bonytail spawning peaks in April to May (Jonez and Sumner 1954; Mueller et al. 2003) when water temperatures are approximately 18° C. In 2011, larval collections were conducted in Pond 1 from January through mid-May. In addition, three larval traps constructed identically to those used by Mueller et al. (1993) were deployed in Pond 1 during the second trip of April in an attempt to maximize the larval sampling effort. A Glo Lite Stix™ low light source (green, yellow, or orange) was placed inside each trap in an attempt to attract larvae. Traps were set overnight for three consecutive nights. All captured larvae were preserved in 95% ethanol, and larvae identified as bonytail or razorback sucker using the interactive key provided in Snyder et al. (2005) were sent to Arizona State University (ASU), Tempe, Arizona for genetic analysis.

In Pond 2, minnow trapping and hoop netting were conducted throughout winter 2008-2009 to estimate abundance of juvenile bonytail after recruitment was verified in the pond during autumn sampling (October 2008). Additional hoop netting was conducted late in the spawning season (April 2009) to assess spawning condition of captured adult bonytail and razorback sucker. In addition, standardized minnow traps were deployed throughout summer 2009 (May through July) to assess 2009 spawning success and post-larval recruitment. After 2009, attempts to quantitatively assess spawning condition and spawning success were discontinued, and documentation of spawning condition and success was determined qualitatively through observation during other monitoring activities such as annual sampling and collecting fish for radio and acoustic telemetry studies.

Snorkeling surveys were conducted when water clarity permitted to observe spawning adults or juvenile native fish. In 2008, random snorkeling transects were conducted to evaluate this technique for observing and assessing populations of native fish, but no native fish were observed (Kesner et al. 2008b). Therefore snorkeling in 2009, 2010, and 2011 was opportunistic (non-random), targeting areas of potential fish concentration (based on PIT scanning and boat observations) and was used for qualitative, not quantitative fish observations.

Invasive species

Specific sampling for non-native species was not routinely conducted because autumn sampling for native species captured non-natives as well. Additional small scale netting was conducted in winter and spring for a variety of reasons during the three year project in which catch of non-natives was recorded as follows: netting and minnow trapping for juvenile bonytail from December 2008 through January 2009 and May through August 2009 in Pond 2, netting and trapping for non-native removal before the native fish spawning season in Pond 6 conducted in winter of 2009-10, netting for adult bonytail observed in Pond 2 in March 2010, netting conducted in April 2010 to obtain razorback sucker in Pond 2 and in Pond 4 for a radio telemetry study, netting conducted during winter 2011 and netting and electrofishing in Ponds 2, 4, and 6 in an attempt to translocate all native fish from those ponds to Pond 1.

Data from gill and hoop netting in Pond 6 targeted to remove non-native species prior to spawning supplemented non-native captures from annual monitoring and recruitment assessment. Four, 36.6 m x 1 m x 12.7 mm gill nets and one, 45.7m x 1 m x 6.4 mm gill net were use to target non-natives. Hoop nets were of the same design as used in annual sampling. Incidental native fish captured were processed (scanned for PIT tags, measured, weighed, and assessed for health and condition) and released; non-native fish were sacrificed.

There was a paucity of sampling effort in ponds 1, 3, and 5 for a variety of different reasons. No netting effort was conducted in Pond 1 during autumn sampling of 2009 during a period of time that it was dewatered for renovation. Pond 3 was not sampled in autumn 2010 due to a total fish kill after treatment renovation. Pond 5 was only sampled twice during routine trips in November 2008 and June 2009. Because native fish were not stocked in Pond 5 there was no additional sampling effort in this pond. Ponds 2, 4, and 6 were sampled throughout the contract period because they had surviving native fish populations.

Attempts by Imperial Ponds Fisheries Work Group to eradicate non-native fish populations in ponds 1 and 3 began in the spring of 2009 and continued into 2010. Pond 1 was dewatered and treated with rotenone in April 2009 and July 2009. A second attempt to renovate Pond 1 occurred in April 2010 with a third application of rotenone near full pool at an elevation of 184 ft. Mosquitofish continued to be present in Pond 1 after the treatments. Samples of mosquitofish were taken in 2011 while razorback sucker larvae were present (February to April) to detect mosquitofish consumption of larval razorback sucker. Pond 3 was renovated at full pool (elevation of 186 ft) with two applications, one in March 2010 and a second in April 2010. No non-natives were observed or reported in Pond 3 since the second application (through September 2011).

Water Physico-chemistry

Water physico-chemistry at Imperial Ponds was monitored at least once a month from October 2007 through August 2011, and twice a month during summer (defined as when the mean water temperature exceeded 27° C). Reported data begins in October 2007 to encompass more information about yearly cycles although the first year of data precedes the current contract period. Vertical profiles of the water column were measured and recorded using a Hanna Instruments® (Woonsocket, RI) HI9828 multi-parameter probe at three locations in each pond: inflow, mid-pond, and near the outlet pipe. Vertical profiles were taken at 0.5 m increments from October 2007 to February 2010, when it was determined that the variability of water physico-chemical parameters in the water column could be measured effectively with three readings: at the bottom, mid-depth, and surface. Nominal parameters measured included temperature, specific conductivity, total dissolved solids (TDS), dissolved oxygen (DO), and pH. Measurements were taken near sunrise and sunset in order to capture the extremes of each variable being measured. Secchi depth and pond elevation (staff gauge level) also were recorded. Beginning July 2010, measurements of the Martinez Lake Inlet Channel (south channel) and well were taken at the same periods as pond water quality and from the Colorado River beginning in February 2011.

Photopoints

Photographs were taken to observe and document changes in growth, diversity, and abundance in emergent and shoreline vegetation, and to track bank erosion. Photopoints were taken triennially from the same GPS location and compass bearing (data form and reference photos in Appendix A and time series photopoints in Appendix B) each time starting in October 2008 and continuing every January, April, and August through 2011.

Results

Routine sampling trips to Imperial Ponds were conducted by a minimum of two biologists twice a month except in December 2008, 2009, 2010, and November 2009, which had one trip each, resulting in a total of 62 routine sampling trips during the study period. This included the annual autumn sampling conducted in October 2008, October 2009, and November 2010. Fish monitoring was focused on ponds 2, 4, and 6 for most of 2010 due to lack of a detectable native fish population in Pond 3, renovation efforts in Pond 1, and an absence of native fish stocking in Pond 5. Appendix C provides more detailed information on stocking and initial survival, incidence of non-native fish, and other relevant information for each pond from 2007 - 2011. Fish sampling from October 2010 to April 2011 was focused on moving native species out of ponds 2, 4, and 6 and into Pond 1 and monitoring Pond 1 with remote PIT scanners. Physico-chemical, shoreline vegetation, and other data were acquired monthly or seasonally in all six ponds.

Population and Habitat Association Monitoring

PIT Scanning

In the period between October 2008 and November 2010 (prior to fish consolidation into Pond 1), a total of 878 successful scanner deployments were made for a total of 50,332.74 scanning hours (for ponds 2, 4, and 6). This effort resulted in 126 bonytail and 49,000 razorback sucker PIT tag contacts. Interim (i.e., between routine trips) PIT scanning accounted for 28,784 contacts, while trip scanning accounted for 20,342 contacts. Pond 2 had the highest number of contacts with 27,550 contacts including all of the bonytail contacts. Ponds 4 and 6 had 3,000 and 18,537 razorback sucker contacts, respectively, and Pond 1 had 39 razorback sucker contacts between October and November of 2008 before salvage and renovation efforts began there.

Consolidation efforts into Pond 1 began in November 2010 and since then 227 successful scanner deployments and 18,940.93 scanning hours were conducted resulting in 1,547 bonytail and 49,829 razorback sucker contacts. There were 96 interim deployments totaling 15,043.5 scanning hours with 35,936 total contacts (1,310 bonytail and 34,626 razorback sucker). A total of 3,875.5 hours were spent scanning during trips for a total of 15,440 contacts (237 bonytail and 15,203 razorback sucker) before trip sampling protocol was changed. Contacts from deployments after modification of the sampling protocol were used solely for monthly population estimates.

Razorback sucker population estimates based on PIT scanning data remained fairly stable from August 2009 to April 2010 in Pond 4 and from August 2009 to November 2010 for ponds 2 and 6 (Figure 4). A lack of contacts or recaptures in Pond 4 produced gaps in the population estimates especially during the summer months (May through September). The last razorback sucker population estimates for these ponds, 47, 30, and 52 for ponds 2, 4, and 6 respectively are similar to the total razorback sucker removed from each pond during consolidation efforts, 49, 26, and 49 from ponds 2, 4, and 6 respectively. Two razorback sucker from each pond were captured without PIT tags, and therefore could not have been included in the final estimates.

Monthly survival based on the best fit CJS model, time varying recapture rate and fixed survival (model ϕ, p_t, Table 3), for Pond 2 was 98.5%. Based on this monthly value, an estimated 73% of the razorback sucker stocked (43 out of 59 fish) survived the entire at large period of 20 months (Table 4). This number is similar to the last population estimate (47) and the actual number of PIT tagged fish translocated (47).

The best fit CJS model for Pond 4 had a separate survival parameter for the month of October 2009 (model ϕ_{oct}, p_t), placing all mortality from the die-off into one sampling interval of nearly two months (August to October, 2009) with an estimated 26.0% of the population surviving that period (Tables 3 and 5). Survival for all other months based on this model was 96.6%, and an estimated 8.8% of the stocked razorback sucker (24 of 272) survived the at large period of approximately 32 months. This matches the number of PIT tagged fish transferred to Pond 1 and is similar to the last estimate of 30 fish. Two other models tested with additional die-off months had some support based on AIC likelihood values (Table 3). Encounter rates in Pond 4 during this period were fairly low, and the exact month or months the die-off occurred may never be known, but it likely occurred between July and October 2009.

The best fit CJS model for Pond 6 was with a die-off occurring between January and March 2009 (Table 3, model $\phi_{Jan\text{-}Mar}$, p_t). A model with three survival parameters (separate die-off parameters for January and March 2009, model $\phi_{Jan + Mar}$, p_t) had a model likelihood of 73%. This indicates that given the encounter histories, there is less support for the model with die-offs occurring in January and March exclusively (excluding February), but this model cannot be rejected outright. The survival parameter estimates from the best fit CJS model (die-off between January and March 2009) were 97.4% for monthly survival outside the die-off period and 60.6% for die-off months (Table 6). An estimated 21.7% (43 out of 198 fish stocked) survived a period of approximately 22 months. This number is similar to the last population estimate (52) and the actual number of PIT tagged fish translocated (47).

Habitat association scanning was conducted in ponds 2, 4, and 6 at least once each month from August 2009 until November 2010. This resulted in a total of 565 successful scanner deployments among the three ponds; 36 deployments had either a logger-scanner communication error or a scanner malfunction that resulted in loss of data for those relatively brief time periods. Total habitat scanning was 12,635 hours for a mean deployment length of 22.36 hours. These standardized deployments resulted in 9,878 contacts.

Habitat association based on standardized sampling for razorback sucker stocked into ponds 2, 4, and 6 was not consistent among seasons or ponds (Figure 5). Two-way Pearson χ^2 analyses of habitat association for each pond across seasons indicated significant differences (p <0.0001) in both day and night habitat association deployments for each pond. Statistical significance for Pond 4 was unreliable due to lack of successful scanner deployments in the open water and hummock in the spring. For all ponds there were consistently more contacts at night than during the day in every season (Figure 5).

The greatest contrast between numbers of day and night contacts was in summer (Figure 6). The greatest proportion of contacts during summer days was in open water. Hot spot scanning placements near inlet pipes in ponds 2 and 4 contacted an average of one individual per scanning period, even during the day when a majority of open water placements had no contacts. At night, habitat association switched from open water to hummock, rip-rap, and mud shore.

Autumn had the lowest number of contacts of all the seasons (Figures 5 and 7). Nighttime contacts during autumn were associated with shallow areas; shoreline habitat (mud or rip-rap) and hummocks, and daytime contacts were too few to interpret.

In winter there was an increase in the abundance of contacts in ponds 2 and 6 (Figure 8). The greatest proportion of those contacts occurred on the hummocks, often in the top 40% of the data range for both habitat association and hot spot scanning (Figures 5 and 8). Hot spot scanning placements on boat ramps and on the spawning bed of Pond 6 also consistently had contacts in the upper 40% of the data range during winter. In Pond 4, the greatest proportion of contacts occurred on rip-rap (Figure 5), primarily in the northwest corner where most random deployments were set. Hot spot scanning in two other locations along the rip-rap shore had contacts in the upper 20% of the data range (Figure 8). Hotspot or habitat association deployments on the hummocks or boat ramp had contacts in the upper 40% but not the upper 20% of the data range. The razorback sucker in Pond 4 all were tagged with a FDX tag, which have a lower contact rate; thus, some of the difference between ponds in habitat association patterns may be attributable to lower tag readability.

In spring, the number of contacts on the boat ramp continued to be in the upper 40% of the data range even as the total number of contacts begins to decline (Figure 9). There are no other major visible seasonal or diel patterns in habitat association.

After trip sampling protocol was changed, antenna orientation was also varied to determine its effect on contacts. Data were pared down to include only those deployments where both antennas were tuned to FDX and HDX tags and scanned for the entire sampling period. Both bonytail and razorback sucker FID contacts were included. After data were pared down, 12 pairs of side-by-side deployments of antennas in a bottom flat and bottom long orientation were analyzed. Data were separated by fish implanted with FDX tags and fish implanted with both FDX and HDX tags. Only three fish were implanted with HDX tags only, these fish would have a different detection probability then fish with only FDX and fish with HDX and FDX and were therefore excluded from analysis (there was not enough contact data from these three fish alone to make independent comparisons). There was no significant difference ($\alpha = 0.05$, $p > 0.05$) between the total contacts in bottom flat and bottom long orientations using the Wilcoxon matched-pairs signed-ranks test (Sokal and Rohlf 1995). However, antennas with a bottom flat orientation noticeably contacted more fish with FDX tags than antennas with a bottom long orientation (Table 7).

Acoustic and Radio Telemetry

In the 2010 telemetry study, a total of 339 and 450 minutes were spent tracking radio tagged razorback sucker resulting in 22 and 8 total contacts in ponds 2 and 4, respectively. All seven tagged fish were contacted at least once during the study. Seventy-two percent of radio contacts in Pond 2 were during the crepuscular period or hours of complete darkness. Of these, 94% were active (the fish was moving at the time of contact). Eighty-six percent of fish contacts were in open water in Pond 2. Sixty-six percent of fish contacted during the daytime hours were inactive in Pond 2 and all fish were contacted in open water approximately 3 meters in depth. Fifty-five percent of fish contacts in Pond 4 were during the crepuscular period or during hours of complete darkness, and 80% of these were active contacts. All daytime contacts were inactive. All contacts in Pond 4 were in open water on the south side of the pond. Radio signals were often difficult to acquire when tracking, presumably because the signal was degraded below detectability at depth. It is unknown exactly at what depth this degradation occurred, but maximum pond depth exceeds three meters at full pool.

In the 2011 acoustic telemetry study, totals of 71 and 155 positions were obtained for bonytail and razorback sucker respectively. All tagged fish, four bonytail and ten razorback sucker, were contacted at least once. Only positions acquired during the summer months of May through August were used to map the spatial utilization distribution of bonytail and razorback sucker using a fixed kernel density estimate. There were totals of 24 daytime and 16 nighttime positions acquired for bonytail and there were totals of 48 day and 31 nighttime positions for razorback sucker. Tagged bonytail during the day targeted deep areas near the northeast corner and areas along the north and south shorelines converging in a deep area west of the hummock (Figure 10a). Tagged razorback sucker avoided the shorelines during the day and were concentrated in the deep areas around and along the northeast shorelines (Figure 10a). The distribution extended from a bulrush marsh located centrally in the northeast corner to the southeast corner of the pond near the boat ramp. The razorback sucker distribution also included the deep area west of the hummock, but it did not generally overlap with bonytail density distributions in the area. Bonytail were distributed during nighttime hours in the open water across the length of the pond from east to west and south near the boat ramp, but they avoided the shallow area to the west of the hummock (Figure 10b), while razorback sucker were concentrated on the boat ramp and in areas near or at the spawning beds.

Annual Autumn Sampling

A total effort of 10,892.27 hours of netting and trapping (Table 8) resulted in 305 bonytail and 168 razorback sucker captures and a total catch of 6,529 non-native fish (Table 9). Almost half of the netting and trapping hours were conducted in Pond 2 (4,667.93 hours). All except one bonytail were captured in Pond 2, and of these only three were stocked fish. The rest of the bonytail were wild born recruits, which were PIT tagged and processed. Pond 2 also had the most recaptures of razorback sucker; 63 were handled and processed during autumn sampling in 2009 and in 2010. There were only seven razorback sucker captures in Pond 1 and one bonytail capture in Pond 3, despite extensive sampling (5,640.92 and 5,572.57 hours, respectively). Fifty-four razorback sucker were handled and processed in Pond 4 in 1,473.00 hours of sampling, and 44 razorback sucker were handled and processed in Pond 6 in 805.30 hours of sampling.

Individual growth

As in other populations, females grew faster than males in all ponds, and the longer time at large for fish stocked into Pond 4 resulted in greater growth on average (Figures 11 and 12). Although generally the growth of razorback sucker in Imperial Ponds is within the scatter of growth measurements from Lake Mohave, nearly every individual point for Imperial Ponds fish growth is below the regression line based on Lake Mohave fish. This indicates that the fish on average grew slower in Imperial Ponds than in Lake Mohave.

Reproduction and Recruitment

Spawning

The number of razorback sucker contacts on boat ramp locations in ponds 2, 4, and 6, and on the spawning bed in Pond 6, indicate that razorback sucker actively used these locations during the spawning season from December 2009 to May 2010. The greatest number of fish was contacted between January and March and the proportion of fish that were contacted multiple times was highest between December and the beginning of April (Kesner et al. 2010b). Between 25 and 93% of fish contacted in Pond 2 were contacted more than five times in that time period. In Pond 4, 41 to 92% of fish were contacted more than once between January and April. From January to April in Pond 6, 66 to 86% of fish were contacted more than once. Fish appeared to have high activity throughout the spawning season on the spawning bed of Pond 6, with between 53 and 87% of fish contacted more than once from December through May. Cross-trip comparisons for the boat ramp and spawning bed locations in Pond 6 indicate that between 10 and 29 razorback sucker visited both locations during any interim period throughout the spawning season (Kesner et al. 2010b).

Sixty-six deployments were made on boat ramp and spawning bed locations in Pond 1 from November 2010 to May 2011 for a total of 7,110.65 scanning hours, 37,551 contacts, and 205 unique FIDs (82 bonytail and 123 razorback sucker). A peak in unique FID contacts occurred in March, 38 bonytail were contacted during both interims, and 102 and 103 razorback sucker were contacted on first and second interims respectively (Table 10). The peak in part may be due to the addition of bonytail and razorback sucker into Pond 1 as fish continued to be moved from ponds 2, 4, and 6 from November 2010 until March 2011.

Few bonytail were contacted on boat ramp and spawning bed locations, only one deployment had a CPE above one (Table 11). Eight bonytail on average were contacted in a deployment and 31% of bonytail were contacted more than once. The number of bonytail contacted varied between 0 and 38 over the course of the spawning season (Table 10).

Between 0 and 96% of razorback sucker were contacted more than once for each deployment over the spawning season (Table 12). On average, 51 razorback sucker were contacted in a deployment and 69% were contacted more than once in a deployment. The proportion of unique fish contacted more than once varied by location. For example, on the boat ramp between 61 and 94% of razorback sucker were contacted more than once, whereas on Spawning Bed 6 between 0 and 70% were contacted more than once. The number of contacts, CPE, and total unique varied by location as well. On spawning beds 2 and 3 there was a peak in total contacts and CPE in January, whereas on the boat ramp and spawning beds 1 and 6 the peak in total contacts and CPE occurred in March.

Although the number of visits and revisits vary by location, comparisons of unique contacts among spawning beds and between the boat ramp and collective spawning bed locations indicate that razorback sucker visited multiple spawning locations multiple times throughout the spawning season (Tables 13 and 14). In deployment periods when all five spawning locations were scanned, some proportion of razorback sucker visited all locations (Table 13). The number of unique fish detected at all spawning locations was limited by the minimum number of contacts at a single location. For example, in the case where only four fish were contacted at every location (February 25, 2011), the number of possible detections was limited to the four contacts at Spawning Bed 6 (Table 14). The highest incidence of contacts between all five locations was 29, and occurred during the second March interim period, coinciding with the peak in unique FID contacts.

Larval and Juvenile Sampling

In the peak of the 2009 spawning season (February - April), no native fish larvae were collected in total efforts of 272, 162, and 234 minutes for ponds 2, 4, and 6, respectively. Mark and recapture efforts to estimate juvenile bonytail abundance in Pond 2 were conducted in December 2008 and January 2009. A total effort of 4,203 net hours resulted in the capture of 87 bonytail (Kesner et al. 2010a). There were no recaptures and therefore no juvenile bonytail population estimates were possible. Netting was initiated again in April in another attempt to obtain an estimate. Twenty-two juvenile bonytail were captured, but again, no recaptures were sampled. Standardized minnow trap sets in Pond 2 were deployed from April through July 2009 for a total effort of 1,789 trap hours, and one juvenile bonytail was captured.

In 2010, total larval sampling efforts of 255 minutes and 285 minutes were exerted in ponds 4 and 6 respectively. One razorback sucker larva was collected in Pond 4 in February and none were collected in Pond 6. In Pond 2, 461 minutes of larval sampling was conducted in February and 11 razorback sucker larvae were collected; mean water temperature of the ponds was 15 °C. One bonytail larva was collected in March when mean water temperature was 17 °C. This specimen was the only collection of bonytail larvae from Imperial Ponds since their completion. During larval sampling in 2010, a school of 30-40 bonytail was observed in Pond 2 around the boat ramp area. Based on their apparent size of 300 to 350 mm, these bonytail were likely surviving 2008 recruits.

In 2011, a total larval sampling effort of 917 minutes was conducted in Pond 1, which resulted in the capture of 0 bonytail and 60 razorback sucker larvae. Fifty-three of the larvae were collected in March when mean water temperature was 17° C, and the seven remaining were collected in April when mean water temperature was 22° C. No larvae were collected in larval traps, total effort 83.10 trap hours.

The first confirmed razorback sucker recruit was captured at Imperial Ponds during autumn sampling in 2010. The juvenile razorback sucker was captured in Pond 2, measured at 315 mm TL, was PIT tagged with an FDX tag and released. On August 24, 2011, a dead juvenile razorback sucker was found floating on the surface of Pond 1. Total length was approximately 219 mm and the fish was presumed to be a recruit from spawning in early 2011.

Invasive Species

There was a total of 40,773.63 hours of effort in combined netting and trapping including autumn sampling over the three year study period (Table 15), which resulted in a total catch of 12,408 non-native fishes (Table 16). Warmouth predominated the catch in ponds 2, 3, and 4 (excluding juvenile sunfishes), and bluegill dominated the catch in ponds 1 and 6. Mosquitofish was the most abundant fish captured in Pond 5. However, hundreds to thousands of mosquitofish captured in minnow traps and seines in post-renovated Pond 1 were not recorded and the species was generally underrepresented in recorded samples because most individuals of the species were able to pass through all nets and traps except 3.2 mm mesh minnow traps ("exotic" Gee minnow traps) which were used less frequently than standard 6.4 mm mesh Gee minnow traps.

Except for ponds where renovation efforts have been attempted, the number of non-native fish species inhabiting each pond has increased since sampling began in 2007 (Table 17). Initially, only carp and mosquitofish were observed or captured in any pond. Threadfin shad, bluegill sunfish, redear sunfish, and warmouth were first captured at Imperial Ponds post reconstruction during autumn sampling 2008. Black crappie was identified in ponds 3, 4, and 6 in 2009. A single adult striped bass was captured in Pond 2 in April 2010; it is believed this fish was introduced by an individual of the fishing public because of its large size at the time of capture (430 mm). There has been no other evidence of this species in the ponds. Red swamp crayfish (*Procambarus clarkii*) and American bullfrog (*Lithobates catesbeiana*) also were noted to be present in the system throughout the study period.

Water Physico-chemistry

Means of most physico-chemical variables: DO, temperature, conductivity, and TDS for Imperial Ponds have remained within acceptable limits where established by the Imperial Ponds Fisheries Work Group (Figures 13 - 22); pH < 9.0, DO > 4 mg/l, and temperature < 33.3° C. Minimum and maximum values of pH, DO, and temperature have, however, exceeded established limits multiple times within sampling years, most notably during summer.

Mean DO fluctuates within and among years, but values have generally remained between 5 and 15 mg/l. Within the water column, DO is generally lowest at the bottom of the pond and highest near the

surface. In summer, the difference between the bottom and top of the water column is most pronounced, with readings often near 0 mg/l at the bottom, and above 10 mg/l at the surface.
DO also is highest on average in early summer, peaking between May and August, followed by a large decline in either August or September. In 2008 and 2009, the peak DO was between 8 and 13 mg/l, but after summer 2009, DO dropped by about 5 mg/l on average. Mean DO peaked between 7 and 16 mg/l in summer 2010, followed by an average decline of 6 mg/l for ponds 2, 4, and 6, but 10 mg/l for ponds 1, 3, and 5 (Figures 13 and 14). Mean DO was below the established limit in ponds 1, 3, and 5 with the lowest mean values of 2.0 (August 2010), 3.0 (September 2010), and 3.7 mg/l (September 2010) respectively. In 2011, the peak in mean DO occurred between the end of May and mid-June with values between 13 and 16 mg/l for ponds 2, 3, 4, 5, and 6. This was followed by an average decline of 10 mg/l to the first August trip, with mean readings below the limit for ponds 2 and 3 at 3.9 and 3.8 mg/l, respectively. The mean DO in Pond 1 reached its peak in late July at a value of 10.9 mg/l and declined to 5.2 mg/l during the last trip in August. DO maxima and minima fluctuate with growth of submergent vegetation. Between June and August, submergent vegetation was visible underneath and sometimes even on the water surface throughout the ponds. Photorespiration of these plants contributes to high DO in summer. When submergent vegetation dies-off at the end of the summer, DO declines.

Mean temperature of Imperial ponds is cyclical and ranges from a minimum of approximately 12 °C in January to about 32 °C in July or August (Figures 15 and 16). Maximum temperatures have exceeded the limit in summer: August 2009, 33.4 °C in Pond 2 and 34.0 °C in Pond 3; August 2010, 33.7 °C in Pond 5 and 34.5 °C in Pond 1; August 2011, 33.8 °C in Pond 1, 34.2 °C in Pond 2, 34.5° C in Pond 5, 33.5 °C in Pond 5, and 34.0 °C in Pond 6.

Mean pH for the ponds generally fluctuated between 7.5 and 9.5 (Figures 17 and 18). Fluctuations in pH were highly variable between ponds and years. For example, with the exception of December 2007 and January 2011, the pH in Pond 1 has remained below the limit and does not experience major fluctuations. Pond 2, however, has consistently peaked above the limit in June followed by a sharp decline and a smaller peak in September or October. There was a markedly high spike in pH above 9.5 for every pond except Pond 5 (9.1) in June 2011. As of the end of August 2011, ponds 2, 4, and 6 remain above the limit with mean pH at 9.1, 9.1, and 9.2, respectively.

Mean conductivity of ponds 2, 3, 4, and 6 remained fairly consistent until March 2011 when it started to fluctuate with pronounced spikes and declines through August in a similar pattern. Pond 5 had a general increase in conductivity over time, beginning at about 2,000 and fluctuating around 5,500 µS/cm in the past year with a peak as high as 7,396 µS/cm. Conductivity in Pond 1 has also increased to about 5,000 µS/cm; its increase in conductivity is correlated with the first renovation which ended in July 2009 (Figures 19 and 20).

Trends in TDS are the same as specific conductivity because its value is converted from the measurement of conductivity. In order to avoid being redundant, trends in TDS will not be discussed, but TDS figures are provided (Figures 21 and 22).

Water physico-chemistry readings of the well were consistent from month to month when they could be taken from July 2010 through February 2011 (Table 18). Average temperature was 21.9 °C, pH was 7.9, DO was 8.8 mg/l, and specific conductivity was 1,223 µS/cm. Parameter values were almost the same between the Colorado River and the south channel. Most of the parameters change throughout the year, but pH remains about 8.3 (pond average: 8.5). In the south channel, specific conductivity ranged between 746 and 1664 µS/cm from July 2010 to June 2011. Temperature was lowest in January at 9.9 °C and highest in August at 30.8 °C, the same as the pond average for August 2010. DO was as low as 4.8 and as high as 11.1 mg/l.

Water clarity fluctuated in all ponds by a meter or more each year (Figures 23 and 24). Water clarity in Pond 5 was generally lower than other ponds on most trips. Water elevation in all ponds fluctuated two feet or less (0.61 meters) since April 2010; remaining around an elevation 185.6 throughout 2010 (Figures 25 and 26). However, as of March 2011, water level began to decline steadily in ponds 2, 3, 4, 5, and 6 because supplemental water was no longer being supplied, reaching a minimum of 183.2 ft on average, in August 2011.

Photopoints

Shoreline vegetation followed the same trend across all six ponds since the construction was completed in 2007. Documentation began in October 2008 and continued through August 2011 (Appendix B); photographs from Pond 1 for August 2009, and for all ponds in August 2010 were not saved because of a failure to transfer data. In October 2008, large verdant stands of cattail and phragmites grew on the mud shorelines. These vegetation stands continued to look healthy through January 2009. Shoreline vegetation showed signs of decline during August 2009, and was mowed down by refuge personnel using a boom mower in the first quarter of 2011.

Photo-documentation showed shoreline erosion that occurred in areas not colonized by vegetation. Below is a summary of field and photopoint observations for each pond. See Appendix B for photopoint slides.

Pond 1

Shoreline vegetation on the south side of Pond 1 (Picture series D) was sparse October 2008 - April 2009. After Pond 1 was drained and refilled, stands of cattail started growing on this shoreline (January 2010) and covered the entire south shoreline except where the spawning beds were located. North (Picture series B) and southeast (Picture series A) shorelines remained largely dominated by phragmites. East shoreline (Picture series C) has not been invaded by any vegetation, and the cattail stand that lined the boat ramp from October 2008 to January 2009 died-off.

Pond 2

North shoreline of Pond 2 (Picture series E) near the boat ramp had a large stand of phragmites growing from October 2008 – August 2009. In this series of pictures, the staff gauge could be clearly seen in the water next to the boat ramp but in the August 2009 photograph, the staff gauge is completely covered. From January 2010 – April 2010, vegetation that encroached on the boat ramp was trampled by boat launch activities. Vegetation was mowed January 2011. Sparse vegetation, mainly sages and individual plants that rooted in between boulders, grew on the western rip-rap shore (Picture series F). The southern shoreline gradually eroded and never had dense stands of vegetation (Picture series G).

Pond 3

A mix of cattail and phragmites dominated the north (Picture series I), south (foreground Picture series J), and east shorelines (Picture series J) since October 2008. The rip-rap shoreline (west) had few plants (Picture series H), which usually died down after the growing season or were submerged during high water levels.

Pond 4

Shoreline vegetation was abundant on all shorelines of Pond 4 since reconstruction. The mud shorelines (north, south, and east) had thick stands of phragmites (series K and series M). Although the phragmites stands died down during decline observed in August 2009, the stand on the northeast corner of the pond was still thick enough that it obstructed the view across the eastern shoreline from photopoint M. The rip-rap shore (Picture series L) also had a thick stands of phragmites rooted on soil next to the top boulders and in between the boulders closer to the water line.

Pond 5

A mix of cattail and phragmites was abundant on the east and south shorelines from October of 2008 - April 2009, with a declining trend starting in August 2009. The north shoreline had sparse vegetation growing on it since monitoring began, but was characterized by thin phragmites clumps that never created dense, wall-like stands (Picture series N). The rip-rap shoreline (west) had moderate vegetation growth (Picture series O). A cattail stand started to grow in the shallow water on the southwest corner of the pond on the rip-rap shore, but was unable to spread effectively (N and O). The marsh gradually receded from the middle of the pond (Picture series P and Q). Although it is hard to tell from the over grown phragmites stand in the foreground of the preceding photographs (Q), the eastern portion of the marsh died off by April 2009.

Pond 6

Cattail spread from the mud shore to rip-rap shore in the shallow areas in the southwest corner of this pond (Picture series R). In addition, phragmites spread from the soil above the rip-rap shore and extended into the water line. The mud shoreline on the northeast shore and south shore was a mix of cattail and phragmites stands (Picture series T) since October 2008. The corner of the southeast shoreline remained largely barren until spring 2009 (Picture S and U) when phragmites began to establish. The southeast and east shoreline experienced heavy erosion. The north/northwest corner of the pond was invaded by salt cedar from January 2009 – April 2010 (Picture series R and S). The salt cedar was manually removed by workers and the shoreline was weathered smooth, which extended the shoreline and created a shallow shelf. The marsh that grew in the middle of the pond from October 2008 - August 2009 (Picture series R) was almost completely dead by January 2010.

Discussion

It has been nearly four years since the first native fish stocking into Imperial Ponds, and from a native species conservation perspective the project as a whole has been a limited success. Bonytail and razorback sucker both were able to survive, reproduce, and recruit in Imperial Ponds when proper water physico-chemistry was maintained, but recruitment was curtailed by the presence of non-native fish species. Except for apparent summer die-offs in ponds 1 (2007) and 4 (2009), and a post-stocking die-off in Pond 6, survival of stocked razorback sucker was comparable to the population in Lake Mohave where annual survival is approximately 70% (Kesner et al. 2008a; Marsh et al. 2003). Most stocked bonytail were lost within six months post-release, possibly due to avian predation (Kesner et al. 2008b), yet recruitment from remaining individuals far outpaced that of razorback sucker. Non-native fishes appear to have not only persisted through the Imperial Ponds construction process, but also were introduced via the water supply (McDonald and Karchesky 2010), and human interference. Remedial pumping of cooler, oxygenated water is recommended to maintain fish health during the hot summer months, and a secure water source for all six ponds should be developed and made available.

Most features of the ponds that were specifically designed for bonytail and razorback sucker were readily utilized by both species. Razorback sucker in Pond 1 were highly associated with the gravel boat ramp and spawning beds during the suspected spawning period (December – April). These results were similar to those reported in Kesner et al. (2010b) for Pond 6. Cross-trip comparisons showed that fish visited the spawning bed and boat ramp in Pond 6 multiple times throughout the spawning season. In general, hummocks, boat ramps, and spawning beds were utilized heavily throughout the year. The gravel/cobble substrate of these areas may provide quality foraging areas for these species, especially in summer when nighttime activity in these areas was greatest.

Habitat association data along with radio and acoustic telemetry results indicated that in summer, native fishes utilized the deep, open water refuges, especially during the day. Mean water temperatures in summer months range from approximately 27 to 33 °C. This is perhaps a behavioral response to avoid high summer temperatures and exposure to the sun, and is again an indication of native fishes utilizing specific features designed in the pond as expected, at least for razorback sucker. For bonytail, the utilization of deep water during the summer daylight hours was not expected. In Cibola High Levee Pond, bonytail sought refuge within the spaces between boulders along the rip-rap shore during the daylight hours of summer, coming out to forage after dark (Marsh 2004). The lack of bonytail contacts in the rip-rap of Pond 1, either by PIT or acoustic tag (day or night) indicates that the bonytail were not utilizing the rip-rap at Imperial Ponds in the same way. There are multiple differences between the two locations, and there are too few examples of these backwater habitats to draw conclusions from this one pond, however, the rip-rap shore at Imperial Ponds is tightly packed with little interstitial space compared to the rock size and thickness at Cibola High Levee Pond. Therefore the rip-rap in Imperial Ponds may not provide adequate space for bonytail occupation. In Pond 1, the rip-rap shore is also the shortest among all ponds, and is in a shallow area of the pond partially blocked by the hummock (Figure 1).

All native fish larvae were collected between February and April. Mean water temperature was between 15 and 22 °C, within the known spawning temperatures for bonytail and razorback sucker. Only one bonytail larva was captured out of four spawning seasons, but bonytail recruitment was substantial based on the capture of unmarked bonytail in multiple years. In late 2008, 109 juvenile bonytail were caught, one unmarked adult bonytail was caught in 2009 and 124 unmarked juvenile and adult bonytail were captured during consolidation efforts from November 2010 through April 2011. Since consolidation, bonytail have utilized the spawning beds and boat ramp in Pond 1. It is unknown if they are using these sites for spawning, but bonytail have been observed to broadcast spawn on gravelly shelves in Lake Mohave (Jonez and Sumner 1954) and Cibola High Levee pond (Mueller et al. 2003). Only future sampling can determine if recruitment continues in Pond 1 as it had in Pond 2. No bonytail larvae were captured in 2011, but as previous years have shown, the lack of larvae is a poor indicator of bonytail spawning success. Bonytail larvae are at least nominally phototatic (Snyder and Meismer 1997), and have been collected in light traps (Mueller et al. 2003), so the reason for their absence in collections is unknown. More information about the behavior and characteristics of early life stages of bonytail could help to explain the dearth in larval captures. Clearly, novel sampling techniques that successfully capture bonytail larval need to be identified or developed and implemented, and Imperial Ponds represents a potential site for appropriate investigations.

Razorback sucker larvae were collected during this study in 2010 and 2011. The sixty razorback sucker larvae collected from Pond 1 in 2011 was the highest catch per unit effort (60 larvae in 15.3 hours = 4 larvae per hour) since larval monitoring began at Imperial Ponds in 2008. In that year, 23 larvae were collected in 6.5 hours (3.5 larvae per hour) in Pond 1 (Kesner et al. 2008b). Larval collections in 2008 and 2011 were made when populations of non-native sunfishes were either reduced or eliminated from Pond 1. Razorback sucker spawning in 2008 occurred before any population of sunfish in the ponds was detected, even though extensive sampling was conducted in the previous autumn. The larvae collected in 2011 were from Pond 1, which since renovation is not known to contain any sunfish species. Mosquitofish on the other hand have been abundant since 2007 in all ponds except Pond 3 since renovation in 2010. The impact of this species on recruitment is currently being investigated.

The first confirmed razorback sucker recruit was captured during autumn sampling in 2009 in Pond 2. The following year, a dead juvenile razorback sucker with two puncture wounds was found floating on the surface of Pond 1. However, capture of six untagged razorback sucker during autumn sampling in 2010 may indicate that there was limited recruitment of razorback sucker in each pond with a resident adult population. Larger recruitment events are probable without the presence of sunfish species, but can only be determined through future sampling in Pond 1.

Water physico-chemistry in general has been adequate to support fish in all ponds, but pH continues to be near or above the established limit for many of the summer months (June – August). Supplemental well water pumping was effective in mitigating stressful conditions for fish. Pumping lowered pH when established limits were exceeded in June 2010, and maintained DO levels above the limit for ponds 2, 4, and 6. Well water pumping also was effective in keeping mean water temperature under the limit of 33.3° C.

Consolidation of native fishes into Pond 1 was necessary due to water supply issues. Initially, well water was only to be used as a temperature mitigation measure during hot summer months when the main supply water from the south channel could not keep pond temperatures below the limit of 33.3 °C. However, the well became the primary source of water for ponds with native fish after the wedge-wire screen on the south channel pump apparently failed to keep additional non-native fish species from contaminating the ponds (McDonald and Karchesky 2010). Unfortunately, the single well has been inadequate to maintain water physico-chemistry for the three ponds with native fish, and so all fish were moved into a single pond with a direct connection to the well. The other ponds have been left available to study water supply options and to determine what water physico-chemical conditions arise without pumping, to examine dynamics of biological components including persistent non-native fishes, and to support other investigations. The declines in water level, extreme fluctuations in specific conductivity, peak in pH, and drop in DO for ponds 2 through 6 in spring-summer 2011 are all coincident with the cessation of water pumping.

Imperial Ponds continues as a work in progress. The two key ingredients for a native fish refugia, the primary purpose for Imperial Ponds (LCR MSCP 2008) have yet to be met; an adequate and safe water supply and a pond free of non-native fishes (Minckley et al. 2003). These ingredients in practice have been more difficult to achieve than anticipated. A low level of native fish recruitment and subsequent lack of population growth within the ponds is therefore not surprising. However, the limited recruitment of bonytail in Pond 2 among a plethora of non-native species is surprising and unexplained, although not unprecedented (e.g. Lake Mead on a larger scale [Albrecht et al. 2007]). Although there have been setbacks, there have also been opportunities. In the long-term, learning how to supply adequate and safe water and determining the non-native species that are a serious threat to bonytail and razorback sucker recruitment informs the program as a whole, and informing the backwater program through research is an important role that Imperial Ponds has continued to fulfill.

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Table 1. Capture and tagging data for seven razorback sucker captured, affixed with an external mount radio tag (Advanced Telemetry Systems [ATS], Inc. Isanti, MN, model F-2020), released, and tracked in their pond of capture from April to July, 2010, at Imperial Ponds, INWR, Arizona.

Pond	Capture TL (mm)	Stocked TL (mm)	Gender	Frequency (MHz)
2	610	540	Female	40.600
2	435	NA	Male	40.140
2	550	488	Female	40.061
2	525	470	Male	40.041
4	503	NA	Male	40.641
4	505	NA	Female	40.020
4	555	441	Female	40.080

Table 2. Capture and tagging data for four bonytail and ten razorback sucker implanted with an acoustic telemetry tag (Sonotronics, Tucson, Arizona), released, and tracked in Pond 1 from March 2011 through August 2011. Total length (TL) is in millimeters, and weight is in grams; dashes (--) indicate that the fish was not weighed.

Tag number	Frequency	Code	TL	Gender	Weight
Bonytail					
246	74	3-5-5-5	370	unknown	379
245	73	4-5-4-8	370	unknown	--
272	70	5-7-6-6	375	unknown	--
244	72	3-4-6-7	360	unknown	--
Razorback sucker					
228	71	4-4-4-8	540	Male	1847
242	70	3-4-3-5	485	Male	1236
234	77	5-5-5-6	590	Female	2450
231	74	4-5-5-5	592	Female	2514
227	70	3-7-4-7	570	Female	1860
229	72	4-4-5-5	585	Female	2185
276	74	3-3-8	562	Female	2030
232	75	4-6-5-8	565	Female	2372
262	75	5-7-7-8	550	Female	1752
233	76	4-6-6-6	560	Female	1646

Table 3. Model structure and selection criteria output from MARK for different mark-recapture models used to assess monthly survival for razorback sucker at Imperial Ponds, INWR. Model structure is indicated by subscripts following survival and recapture designations of ϕ and p respectively. A "t" indicates a time-varying parameter, and month or months in subscripts represent sampling intervals in which a separate survival parameter was modeled. No subscript denotes a fixed parameter.

Model	Parameters	AIC	Likelihood	Deviance
Pond 2				
ϕ, p_t	28	1247.08	1.000	720.14
ϕ_t p_t	53	1280.04	0.000	697.99
Pond 4				
$\phi_{Oct\ 2009}$, p_t	29	2855.73	1.000	945.22
$\phi_{Aug\text{-}Oct\ 2009}$, p_t	29	2856.22	0.733	945.71
$\phi_{Jul\text{-}Aug\ 2009}$, p_t	29	2558.48	0.253	947.97
ϕ_t, p_t	53	2886.62	0.000	923.63
$\phi_{Jun\text{-}Aug\ 2009}$, p_t	29	2898.58	0.000	988.07
Pond 6				
$\phi_{Jan\text{-}Mar\ 2009}$, p_t	20	1556.30	1.000	600.77
$\phi_{Jan\ +\ Mar\ 2009}$, p_t	21	1556.92	0.733	599.59
ϕ_t, p_t	35	1567.24	0.002	579.58
$\phi_{Jan\ 2009}$, p_t	20	1639.67	0.000	684.14

Table 4. Pond 2 razorback sucker survival and population estimates for all sampling periods. Interval survival is adjusted from the monthly estimate according to the length of sampling interval (in months). Cumulative survival is the product of all preceding values of interval survival. The population estimate is the inferred decline in population size according to cumulative survival estimates and the original number of stocked fish, 59.

Interval		Survival			Population
		Monthly	Interval	Cumulative	Estimate
Dec 2008 - Jan 2009	1.2	0.985	0.982	0.982	58
Jan 2009 - Feb 2009	1.4	0.985	0.980	0.980	57
Feb 2009 - Apr 2009	1.6	0.985	0.976	0.976	55
Apr 2009 - Apr 2009	0.5	0.985	0.993	0.993	55
Apr 2009 - May 2009	0.9	0.985	0.986	0.986	54
May 2009 - Jul 2009	1.5	0.985	0.978	0.978	53
Jul 2009 - Aug 2009	1.1	0.985	0.983	0.983	52
Aug 2009 - Aug 2009	0.5	0.985	0.993	0.993	52
Aug 2009 - Sep 2010	0.9	0.985	0.986	0.986	51
Sep 2009 - Oct 2009	0.9	0.985	0.986	0.986	50
Oct 2009 - Nov 2009	0.7	0.985	0.989	0.989	50
Nov 2009 - Dec 2009	1.2	0.985	0.983	0.983	49
Dec 2009 - Jan 2010	0.7	0.985	0.990	0.990	49
Jan 2010 - Jan 2010	0.5	0.985	0.993	0.993	48
Jan 2010 - Feb 2010	0.5	0.985	0.993	0.993	48
Feb 2010 - Feb 2010	0.5	0.985	0.993	0.993	47
Feb 2010 - Mar 2010	0.5	0.985	0.993	0.993	47
Mar 2010 - Apr 2010	0.9	0.985	0.986	0.986	47
Apr 2010 - Apr 2010	0.5	0.985	0.993	0.993	46
Apr 2010 - Apr 2010	0.5	0.985	0.993	0.993	46
Apr 2010 - May 2010	0.5	0.985	0.993	0.993	46
May 2010 - May 2010	0.5	0.985	0.993	0.993	45
May 2010 - Jun 2010	0.5	0.985	0.993	0.993	45
Jun 2010 - Jun 2010	0.4	0.985	0.994	0.994	45
Jun 2010 - Jul 2010	0.5	0.985	0.993	0.993	44
Jul 2010 - Jul 2010	0.5	0.985	0.993	0.993	44
Jul 2010 - Aug 2010	1.0	0.985	0.986	0.986	43

Table 5. Pond 4 razorback sucker survival and population estimates for all sampling periods. Two parameters of survival are calculated for this model (Aug - Oct 2009 and all others fixed). Interval survival is adjusted from the monthly estimate according to the length of sampling interval (in months). Cumulative survival is the product of all preceding values of interval survival. The population estimate is the inferred decline in population size according to cumulative survival estimates and the original number of stocked fish, 272.

Interval		Survival Monthly	Interval	Cumulative	Population Estimate
Dec 2007 - Apr 2008	5.4	0.966	0.832	0.832	226
Apr 2008 - Aug 2008	4.3	0.966	0.864	0.864	196
Aug 2008 - Oct 2008	2.1	0.966	0.930	0.930	182
Oct 2009 - Jan 2009	3.3	0.966	0.894	0.894	163
Jan 2009 - Feb 2009	0.5	0.966	0.984	0.984	160
Feb 2009 - Apr 2009	1.7	0.966	0.944	0.944	151
Apr 2009 - May 2009	1.4	0.966	0.955	0.955	144
May 2009 - Jun 2009	1.4	0.966	0.953	0.953	138
Jun 2009 - Jul 2009	0.9	0.966	0.970	0.970	133
Jul 2009 - Aug 2009	1.2	0.966	0.960	0.960	128
Aug 2009 - Oct 2009	1.9	0.486	0.260	0.260	33
Oct 2009 - Nov 2009	0.7	0.966	0.976	0.976	32
Nov 2009 - Dec 2009	1.2	0.966	0.961	0.961	31
Dec 2010 - Jan 2010	0.7	0.966	0.976	0.976	30
Jan 2010 - Jan 2010	0.5	0.966	0.984	0.984	30
Jan 2010 - Feb 2010	0.5	0.966	0.985	0.985	30
Feb 2010 - Feb 2010	0.5	0.966	0.984	0.984	29
Feb 2010 - Mar 2010	0.5	0.966	0.985	0.985	29
Mar 2010 - Apr 2010	0.9	0.966	0.969	0.969	28
Apr 2010 - Apr 2010	0.5	0.966	0.984	0.984	27
Apr 2010 - Apr 2010	0.5	0.966	0.984	0.984	27
Apr 2010 - May 2010	0.9	0.966	0.969	0.969	26
May 2010 - Jun 2010	0.5	0.966	0.984	0.984	26
Jun 2010 - Jun 2010	0.4	0.966	0.986	0.986	25
Jun 2010 - Jul 2010	0.5	0.966	0.983	0.983	25
Jul 2010 - Jul 2010	0.5	0.966	0.984	0.984	24
Jul 2010 - Aug 2010	1.0	0.966	0.968	0.968	24

Table 6. Pond 6 razorback sucker survival and population estimates for all sampling periods. Two parameters of survival are calculated for this model (Jan-Mar 2009 and all others constant). Interval survival is adjusted from the monthly estimate according to the length of sampling interval (in months). Cumulative survival is the product of all preceding values of interval survival. The population estimate is the inferred decline in population size according to cumulative survival estimates and the original number of stocked fish, 198.

		Survival			Population
Interval		Monthly	Interval	Cumulative	Estimate
Jan 2009 - Jan 2009	0.3	0.606	0.853	0.853	169
Jan 2009 - Mar 2009	1.9	0.606	0.393	0.335	66
Mar 2009 - Apr 2009	1.6	0.974	0.959	0.322	64
Apr 2009 - Jun 2009	1.4	0.974	0.964	0.310	61
Jun 2009 - Jul 2009	1.4	0.974	0.965	0.299	59
Jul 2009 - Aug 2009	0.7	0.974	0.981	0.293	58
Aug 2009 - Sept 2009	1.0	0.974	0.975	0.286	57
Sept 2009 - Oct 2009	0.9	0.974	0.976	0.279	55
Oct 2009 - Nov 2009	1.2	0.974	0.970	0.271	54
Nov 2009 - Dec 2009	1.2	0.974	0.970	0.263	52
Dec 2010 - Jan 2010	0.7	0.974	0.982	0.258	51
Jan 2010 - Feb 2010	0.9	0.974	0.976	0.252	50
Feb 2010 - Mar 2010	0.9	0.974	0.976	0.246	49
Mar 2010 - Apr 2010	1.4	0.974	0.964	0.237	47
Apr 2010 - May 2010	0.9	0.974	0.976	0.231	46
May 2010 - Jun 2010	1.0	0.974	0.976	0.226	45
Jun 2010 - Jul 2010	0.9	0.974	0.976	0.220	44
Jul 2010 - Aug 2010	0.9	0.974	0.976	0.215	43

Table 7. Displays the number of unique FID (fish identification number) contacts recorded from side-by-side antenna deployments in bottom long and bottom flat orientations. Table is divided by contacts made with fish that were implanted with FDX tags only, and fish with both FDX and HDX tags. The difference between the number of contacts from each antenna is included as well as the absolute difference and the signed rank used to compute the Wilcoxon matched-pairs signed-ranks test. Neither test was significant ($p > 0.05$).

Bottom flat	Bottom long	Difference (D)	Absolute D	Signed rank
FDX				
119	0	119	119	4
174	0	174	174	2.5
0	13	-13	13	-9
0	8	-8	8	-10.5
174	0	174	174	2.5
255	0	255	255	1
8	0	8	8	10.5
22	0	22	22	7
21	1	20	20	8
29	1	28	28	6
7	0	7	7	12
39	0	39	39	5
FDX and HDX				
69	49	20	20	7
69	53	16	16	8
134	81	53	53	3
333	150	183	183	1
160	113	47	47	4
231	157	74	74	2
9	10	-1	1	-12
2	4	-2	2	-11
2	12	-10	10	-9
2	8	-6	6	-10
4	31	-27	27	-6
10	38	-28	28	-5

Table 8. Total autumn sampling effort by gear type for the study period (October 2008 through September 2011) in Imperial Ponds, INWR. Effort for nets and traps is reported in net-hours and electrofishing is reported in real-time electrofishing seconds. Gill nets were only deployed in 2009, and box traps only in 2009. Electrofishing (E-fishing) reported in shocking seconds was only conducted in 2010 and is not included in total effort calculations.

Pond	Box	E-fishing	Gill	Hoop	Minnow	Trammel	Total
1	0	0	62.50	1,182.20	593.97	60.35	1,899.02
2	66.10	450	10.08	2,621.82	1,809.33	160.60	4,667.93
3	31.80	0	3.83	978.17	1,022.85	10.37	2,047.02
4	74.80	450	5.28	1,029.50	147.20	216.22	1,473.00
6	28.70	0	0.00	253.80	149.30	373.50	805.30
Total	201.4	900	81.69	6,065.49	3,722.65	821.04	10,892.27

Table 9. Total catch for autumn sampling 2008 – 2011 in Imperial Ponds, INWR. Electrofishing was only conducted in ponds 2 and 4 in 2010. NA indicates a lack of sampling for a given gear type and pond.

Species	Box	Electrofishing	Gill	Hoop	Minnow	Trammel	Total	Proportion
Pond 1								
Threadfin shad	NA	NA	NA	147	0	65	212	0.20
Common carp	NA	NA	NA	51	0	64	115	0.11
Razorback sucker	NA	NA	1	2	0	4	7	0.01
Mosquitofish	NA	NA	NA	0	120	0	120	0.11
Bluegill sunfish	NA	NA	NA	522	73	7	602	0.57
Juvenile sunfish	NA	NA	NA	0	0	0	0	>0.01
Warmouth	NA	NA	NA	0	0	8	8	0.01
Total							1064	1
Pond 2								
Threadfin shad	0	NA	3	3	0	0	6	>0.01
Bonytail	0	11	81	82	2	128	304	0.10
Razorback sucker	0	0	0	5	0	58	63	0.02
Mosquitofish	0	NA	0	0	45	0	45	0.02
Bluegill sunfish	2	NA	2	837	123	69	1033	0.35
Juvenile sunfish	0	NA	0	56	732	0	788	0.27
Redear sunfish	9	NA	0	126	17	3	155	0.05
Warmouth	4	NA	0	499	245	139	887	0.30
Total							3281	1
Pond 3								
Threadfin shad	3	NA	3	2	0	0	8	0.01
Bonytail	0	NA	0	1	0	0	1	>0.01
Common carp	9	NA	0	16	11	1	37	0.05
Mosquitofish	0	NA	0	0	7	0	7	0.01
Black crappie	0	NA	9	6	0	1	16	0.02
Bluegill sunfish	14	NA	2	19	9	0	44	0.05
Juvenile sunfish	0	NA	0	0	71	0	71	0.09
Redear sunfish	3	NA	0	16	39	0	58	0.07
Warmouth	12	NA	0	421	143	0	576	0.70
Total							818	1
Pond 4								
Threadfin shad	2	4	16	0	0	98	120	0.09
Common carp	0	1	0	16	0	0	17	0.01
Razorback sucker	1	2	0	5	0	46	54	0.04
Mosquitofish	0	0	0	0	6	0	6	>0.01
Black crappie	0	1	0	0	0	1	2	>0.01
Bluegill sunfish	177	19	0	181	0	9	386	0.27
Juvenile sunfish	0	0	0	58	9	0	67	0.05
Redear sunfish	21	0	0	130	39	3	193	0.14
Warmouth	57	6	0	395	64	44	566	0.40
Total							1411	1
Pond 6								
Razorback sucker	0	NA	0	2	0	42	44	0.10
Black crappie	1	NA	0	0	0	0	1	>0.01
Bluegill sunfish	18	NA	0	129	8	1	156	0.36
Juvenile sunfish	0	NA	0	0	125	0	125	0.29
Redear sunfish	7	NA	0	14	0	36	57	0.13
Warmouth	0	NA	0	41	0	8	49	0.11
Total							432	1

Table 10. Summary of unique FIDs (fish identification numbers) by species scanned in combined boat ramp and spawning bed deployments in Pond 1 starting on the corresponding date. Deployments with no bonytail contacts were the result of either an absence of bonytail in the area or an out of tune (with respect to FDX tags) antenna.

Date	Scan period	Razorback sucker	Bonytail	Total
02-Nov-10	trip	30	4	34
05-Nov-10	interim	71	2	73
23-Nov-10	interim	65	0	65
24-Nov-10	interim	38	0	38
14-Dec-10	interim	64	0	64
18-Jan-11	trip	76	0	76
21-Jan-11	interim	80	5	85
31-Jan-11	trip	80	2	82
01-Feb-11	trip	22	4	26
03-Feb-11	interim	83	9	92
04-Feb-11	interim	74	12	86
08-Feb-11	interim	48	0	48
15-Feb-11	trip	64	1	65
18-Feb-11	interim	80	15	95
22-Feb-11	trip	57	0	57
23-Feb-11	trip	26	13	39
25-Feb-11	interim	77	12	89
08-Mar-11	trip	40	11	51
09-Mar-11	trip	68	1	69
11-Mar-11	interim	102	38	140
22-Mar-11	trip	70	0	70
25-Mar-11	interim	103	38	141
04-Apr-11	trip	78	0	78
05-Apr-11	trip	11	0	11
07-Apr-11	interim	93	5	98
18-Apr-11	trip	67	0	67
21-Apr-11	interim	88	2	90

Table 11. Summary of bonytail contacts from remote scanning on boat ramp and spawning bed locations in Pond 1. Contacts per effort (CE) represents the number of contacts per hour. The number of unique fish contacts above threshold (Above threshold) is defined as the number of unique fish (Unique) that were contacted more than once in Pond 1.

Date	Scanning type	Total contacts	Effort hours	CE	Unique	Above threshold	Proportion
Boat ramp							
21-Jan-11	interim	8	90.35	0.09	5	2	0.40
31-Jan-11	trip	2	39.57	0.05	2	0	0.00
04-Feb-11	interim	36	96.02	0.37	12	6	0.50
07-Apr-11	interim	5	43.23	0.12	5	0	0.00
21-Apr-11	interim	1	434.43	0.00	1	0	0.00
Spawning bed 1							
02-Nov-10	trip	7	72.10	0.10	4	2	0.50
05-Nov-10	interim	2	216.08	0.01	2	0	0.00
15-Feb-11	trip	1	64.67	0.02	1	0	0.00
23-Feb-11	trip	16	42.12	0.38	13	3	0.23
11-Mar-11	interim	14	136.93	0.10	4	1	0.25
21-Apr-11	interim	2	435.70	0.00	1	1	1.00
Spawning bed 2							
03-Feb-11	interim	2	93.83	0.02	1	1	1.00
18-Feb-11	interim	21	48.02	0.44	15	4	0.27
22-Feb-11	trip	0	65.35	0.00	0	0	NA
25-Feb-11	interim	14	96.02	0.15	12	2	0.17
08-Mar-11	trip	36	23.28	1.55	11	7	0.64
09-Mar-11	trip	1	44.80	0.02	1	0	0.00
11-Mar-11	interim	60	137.05	0.44	35	9	0.26
22-Mar-11	trip	0	68.00	0.00	0	0	NA
Spawning bed 3							
25-Mar-11	interim	54	120.03	0.45	38	11	0.29
Spawning bed 6							
01-Feb-11	trip	13	53.83	0.24	4	1	0.25
03-Feb-11	interim	28	96.03	0.29	9	4	0.44

Table 12. Summary of razorback sucker contacts from remote PIT scanning on boat ramp and spawning bed locations in Pond 1. Contacts per effort (CE) represents the number of contacts per hour. The number of unique fish contacts above threshold (Above threshold) is defined as the number of unique fish (Unique) that were contacted more than once in Pond 1.

Date	Scan period	Total contacts	Effort hours	CE	Unique	Above threshold	Proportion
Boat ramp							
21-Jan-11	interim	486	90.35	5.38	73	60	0.82
31-Jan-11	trip	455	39.57	11.50	72	57	0.79
04-Feb-11	interim	658	96.02	6.85	74	68	0.92
18-Feb-11	interim	495	47.83	10.35	67	60	0.90
25-Feb-11	interim	641	96.03	6.67	61	53	0.87
08-Mar-11	trip	103	23.22	4.44	23	14	0.61
09-Mar-11	interim	425	45.08	9.43	60	49	0.82
11-Mar-11	interim	861	135.85	6.34	65	54	0.83
22-Mar-11	trip	2322	20.97	110.75	60	54	0.90
25-Mar-11	interim	960	120.05	8.00	80	70	0.88
07-Apr-11	interim	2052	43.23	47.46	52	41	0.79
21-Apr-11	interim	933	434.43	2.15	82	77	0.94
Spawning bed 1							
02-Nov-10	trip	68	72.10	0.94	30	17	0.57
05-Nov-10	interim	385	216.08	1.78	68	59	0.87
24-Nov-10	interim	159	240.03	0.66	38	25	0.66
14-Dec-10	interim	551	288.05	1.91	64	58	0.91
18-Jan-11	trip	598	63.48	9.42	62	56	0.90
08-Feb-11	interim	101	96.03	1.05	48	24	0.50
15-Feb-11	trip	233	64.67	3.60	59	46	0.78
18-Feb-11	interim	294	48.00	6.13	66	51	0.77
23-Feb-11	trip	51	42.12	1.21	26	12	0.46
25-Feb-11	interim	886	95.93	9.24	67	64	0.96
11-Mar-11	interim	997	136.93	7.28	79	63	0.80
25-Mar-11	interim	498	120.07	4.15	76	60	0.79
04-Apr-11	trip	346	67.88	5.10	74	60	0.81
07-Apr-11	trip	878	139.07	6.31	86	82	0.95
18-Apr-11	trip	148	64.23	2.30	56	39	0.70
21-Apr-11	interim	863	435.70	1.98	84	77	0.92
Spawning bed 2							
21-Jan-11	interim	3204	90.13	35.55	68	63	0.93
03-Feb-11	interim	106	93.83	1.13	51	25	0.49
18-Feb-11	interim	213	48.02	4.44	57	41	0.72
22-Feb-11	trip	0	65.35	0.00	0	0	NA
25-Feb-11	interim	186	96.02	1.94	44	35	0.80
08-Mar-11	trip	7	23.28	0.30	4	3	0.75
09-Mar-11	trip	157	44.80	3.50	44	27	0.61
11-Mar-11	interim	49	137.05	0.36	32	12	0.38
22-Mar-11	trip	0	68.00	0.00	0	0	NA
25-Mar-11	interim	120	137.25	0.87	41	25	0.61
05-Apr-11	trip	13	44.67	0.29	11	2	0.18
07-Apr-11	interim	22	96.03	0.23	18	3	0.17

Table 12. Continued.

Date	Scan period	Total contacts	Effort hours	CE	Unique	Above threshold	Proportion
Spawning bed 3							
05-Nov-10	interim	311	215.93	1.44	64	53	0.83
23-Nov-10	interim	203	255.73	0.79	65	43	0.66
18-Jan-11	trip	269	63.27	4.25	63	49	0.78
21-Jan-11	interim	3366	89.92	37.43	59	52	0.88
31-Jan-11	trip	3322	72.08	46.09	63	56	0.89
03-Feb-11	interim	1785	96.00	18.59	64	57	0.89
15-Feb-11	trip	170	65.38	2.60	54	41	0.76
18-Feb-11	interim	135	48.00	2.81	46	31	0.67
22-Feb-11	trip	289	65.32	4.42	57	46	0.81
25-Feb-11	interim	1582	96.02	16.48	70	62	0.89
11-Mar-11	interim	956	267.60	3.57	86	76	0.88
25-Mar-11	interim	762	120.03	6.35	81	64	0.79
07-Apr-11	interim	308	96.02	3.21	62	41	0.66
Spawning bed 6							
01-Feb-11	trip	48	53.83	0.89	22	12	0.55
03-Feb-11	interim	211	96.03	2.20	47	27	0.57
15-Feb-11	trip	3	66.12	0.05	3	0	0.00
18-Feb-11	interim	30	114.17	0.26	20	8	0.40
22-Feb-11	trip	14	65.72	0.21	10	4	0.40
25-Feb-11	interim	4	96.02	0.04	4	0	0.00
08-Mar-11	trip	77	67.87	1.13	27	8	0.30
11-Mar-11	interim	447	137.30	3.26	73	51	0.70
22-Mar-11	trip	179	67.00	2.67	43	27	0.63
25-Mar-11	interim	518	118.85	4.36	67	46	0.69
04-Apr-11	trip	435	68.07	6.39	49	27	0.55
18-Apr-11	trip	54	64.95	0.83	34	13	0.38
21-Apr-11	interim	226	215.98	1.05	49	24	0.49

Table 13. Summary of unique and common razorback sucker contacts between spawning bed and boat ramp locations for each interim deployment when both the boat ramp and one or more spawning beds were scanned. The number of razorback sucker contacted (Unique) on the boat ramp (BR), the number of unique FIDs for the combined spawning bed efforts (SB), the number of fish contacted on both the boat ramp and at least one spawning bed (BR + SB), and the number of fish contacted on the boat ramp and all spawning beds scanned (BR + all SB) is included. Dates on which all four spawning beds and the boat ramp were scanned are indicated by an asterisk (*).

Date	BR Unique	SB Unique	BR + SB	BR + all SB
21-Jan-11	73	72	65	51
03-Feb-11	74	86	72	16
18-Feb-11*	67	75	62	13
25-Feb-11*	61	74	58	4
11-Mar-11*	65	102	65	10
25-Mar-11*	80	96	75	29
07-Apr-11	52	88	47	9
21-Apr-11	82	86	80	44

Table 14. Comparison of razorback sucker contacts during interim trips of the spawning season. Cells are color coded according to spawning bed (SB) location as illustrated at the right hand side of the table (e.g., yellow cells represent spawning bed 1). The number in each cell represents the number of contacts in common between paired spawning bed locations according to cell color and column heading. The total number of FIDs (unique fish identification numbers) contacted among scanned spawning beds was entered into the last column of the table. Cells with a dash (--) indicate no scanner was deployed for the corresponding spawning bed location for that interim trip.

	Spawning Beds								
Date	SB1		SB2		SB3		SB6		Total in common
05-Nov-10	70	61	--	--	61	64	--	--	61
	--	--	--	--	--	--	--	--	
23-Nov-10	38	--	--	--	36	65	--	--	36
	36	--	--	--	--	--	--	--	
21-Jan-11	--	--	--	55	--	59	--	--	55
	--	--	68	--	55	--	--	--	
03-Feb-11	--	--	--	47	--	56	--	28	16
	--	--	52	20	47	28	20	64	
18-Feb-11	66	39	53	36	39	46	19	14	13
	53	19	72	20	36	14	20	20	
25-Feb-11	67	43	43	42	64	70	4	4	4
	43	4	44	4	42	4	4	4	
11-Mar-11	79	73	19	21	73	86	67	68	13
	19	67	32	16	21	68	16	73	
25-Mar-11	76	61	38	37	61	81	58	57	29
	38	58	41	34	37	57	34	67	
07-Apr-11	52	61	17	13	61	62	--	--	13
	17	--	18	--	13	--	--	--	
21-Apr-11	84	--	--	--	--	--	47	--	47
	--	47	--	--	--	--	--	49	

SB1	SB3
SB2	SB 6

Table 15. Total effort for netting and trapping in net hours (or trapping hours) for the study period (October 2008 through September 2011) in Imperial Ponds, INWR including autumn sampling. Rounding of individual cells resulted in some column sums not equaling the value in the "Total" row.

Pond	Box trap	Gill net	Hoop net	Minnow trap	Trammel net	Total
1	NA	537.7	813.3	4082.1	207.8	5640.9
2	165.2	6962.2	31.3	13901.2	417.1	21477.0
3	130.7	1326.0	7.7	4037.8	70.4	5572.6
4	261.3	362.5	5.3	3097.1	535.3	4261.4
5	NA	62.0	45.6	109.0	NA	216.6
6	43.8	387.7	527.4	1249.8	1396.6	3605.2
Total	601.0	9638.0	1430.5	26477.0	2627.3	40773.6

Table 16. Total catch by net or trap type for the study period (October 2008 through September 2011) in Imperial Ponds, INWR. NA indicates a lack of sampling for a given gear type and pond.

Species	Box	Gill	Hoop	Minnow	Trammel	Total	Proportion
Pond 1							
Threadfin shad	NA	74	3	0	65	142	0.08
Common carp	NA	54	143	0	78	275	0.16
Mosquitofish	NA	0	0	141	0	141	0.08
Bluegill sunfish	NA	0	796	73	7	876	0.50
Juvenile sunfish	NA	22	0	0	0	22	0.01
Warmouth	NA	5	272	0	8	285	0.16
Total						1741	1.00
Pond 2							
Threadfin shad	0	3	4	0	0	7	0.00
Mosquitofish	0	0	0	1151	0	1151	0.17
Striped bass	0	0	0	0	1	1	>0.01
Bluegill sunfish	2	7	1007	148	178	1342	0.20
Juvenile sunfish	0	0	56	2660	0	2716	0.40
Redear sunfish	9	0	135	20	13	177	0.03
Warmouth	4	0	605	288	461	1358	0.20
Total						6752	1.00
Pond 3							
Threadfin shad	3	3	2	0	0	8	0.01
Common carp	9	9	28	11	5	62	0.06
Mosquitofish	0	0	0	7	0	7	0.01
Black crappie	0	0	9	0	1	10	0.01
Bluegill sunfish	14	2	165	9	0	190	0.17
Juvenile sunfish	0	0	1	71	0	72	0.06
Redear sunfish	3	0	17	2	0	22	0.02
Warmouth	12	0	551	180	0	743	0.67
Total						1114	1.00
Pond 4							
Threadfin shad	2	16	6	0	94	118	0.08
Mosquitofish	0	0	0	100	0	100	0.07
Black Crappie	0	0	0	0	1	1	>0.01
Bluegill sunfish	177	0	232	0	8	417	0.27
Juvenile sunfish	0	0	58	0	3	70	0.05
Redear sunfish	21	0	128	39	10	198	0.13
Warmouth	57	0	433	64	62	616	0.41
Total						1520	1.00
Pond 5							
Threadfin shad	NA	28	0	0	NA	28	0.29
Common carp	NA	1	0	0	NA	1	0.01
Mosquitofish	NA	0	0	53	NA	53	0.55
Bluegill sunfish	NA	2	9	1	NA	12	0.12
Warmouth	NA	1	2	0	NA	3	0.03
Total						97	1.00
Pond 6							
Threadfin shad	0	1	6	0	409	416	0.35
Mosquitofish	0	0	0	12	0	12	0.01
Black Crappie	1	0	0	0	0	1	>0.01
Bluegill sunfish	18	9	250	17	45	339	0.29
Juvenile sunfish	0	0	0	125	0	125	0.11
Redear sunfish	0	6	21	0	58	85	0.07
Warmouth	7	9	118	12	60	206	0.17
Total						1184	1.00

Table 17. A timeline indicating presence of non-native fish species (shaded areas) in each pond based on occurrence in netting and trapping data. Pond 1 was renovated in April 2009, but mosquitofish persisted after that operation. Pond 3 was renovated in March 2010 and appeared fishless as of September 2011.

	2007	2008	2009		2010			2011	
Species	Sep	Oct	Apr	Oct	Mar	Apr	Nov	Mar	Aug
Pond 1									
Threadfin shad		■							
Common carp	■	■							
Mosquitofish	■	■	■	■	■	■	■	■	■
Bluegill sunfish		■							
Warmouth		■							
Pond 2									
Threadfin shad		■	■	■	■	■	■	■	■
Common carp	■	■	■	■	■	■	■	■	■
Mosquitofish	■	■	■	■	■	■	■	■	■
Striped bass						■			
Bluegill sunfish		■	■	■	■	■	■	■	■
Redear sunfish				■	■	■	■	■	■
Warmouth		■	■	■	■	■	■	■	■
Pond 3									
Threadfin shad		■	■	■					
Common carp	■	■	■	■					
Mosquitofish	■	■	■	■					
Black crappie				■					
Bluegill sunfish		■	■	■					
Redear sunfish		■	■	■					
Warmouth		■	■	■					
Pond 4									
Threadfin shad		■	■	■	■	■	■	■	■
Common carp							■	■	■
Mosquitofish	■	■	■	■	■	■	■	■	■
Black crappie				■	■	■	■	■	■
Bluegill sunfish		■	■	■	■	■	■	■	■
Redear sunfish		■	■	■	■	■	■	■	■
Warmouth		■	■	■	■	■	■	■	■
Pond 5									
Threadfin shad		■	■	■	■	■	■	■	■
Common carp		■	■	■	■	■	■	■	■
Mosquitofish	■	■	■	■	■	■	■	■	■
Bluegill sunfish		■	■	■	■	■	■	■	■
Warmouth		■	■	■	■	■	■	■	■
Pond 6									
Threadfin shad		■	■	■	■	■	■	■	■
Mosquitofish	■	■	■	■	■	■	■	■	■
Black crappie				■	■	■	■	■	■
Bluegill sunfish		■	■	■	■	■	■	■	■
Redear sunfish		■	■	■	■	■	■	■	■
Warmouth		■	■	■	■	■	■	■	■

Table 18. Mean values for water physico-chemistry data from the Colorado River, well, and south channel at Imperial National Wildlife Refuge. There are no DO data for November and December 2010 due to a probe malfunction. No data were recorded for the well if the pump was shut off during monitoring (July 2010 – March 2011). As of April 2011, there was no longer access to well water from the valve due to the diversion of well water to supply Pond 1 only.

Date	Temp (° C)	pH	DO (mg/l)	Specific cond. (µS/cm)	TDS (mg/l)
River					
February	13.9	8.4	7.3	1099	549
March	15.8	8.4	12.1	1641	832
April	20.9	8.3	8.6	1028	515
May	19.8	8.3	5.7	1359	680
June T1	24.3	8.7	7.3	1527	764
June T2	27.4	8.1	5.1	947	473
Well					
July	22.2	7.6	8.8	1200	601
August T1	22.6	7.9	10.1	1040	520
September T2	22	8.1	7.1	1238	619
November	21.7	8.1	--	1274	637
December	21.4	8.3	--	1369	684
February	21.5	7.6	9.3	1217	608
South channel					
July	29.8	7.6	5.7	1034	517
August T1	29.5	8.2	8.8	906	453
August T2	30.8	7.8	6	746	373
September T1	26.5	8.1	6.1	1104	552
September T2	27.5	8.3	4.8	1068	534
October	23.4	8.5	8.2	817	409
November	20.4	8.5	--	1086	543
December	14.3	8.3	--	1223	612
January	9.9	9.4	9.4	1164	583
February	13.5	8.4	9.5	1331	665
March	15.9	8.4	11.1	1664	821
April	20.9	7.9	7.8	1047	523
May	20.2	8.2	6.8	1333	666
June T1	24.3	8.4	7.4	1604	802
June T2	27.4	8.2	5.4	946	473

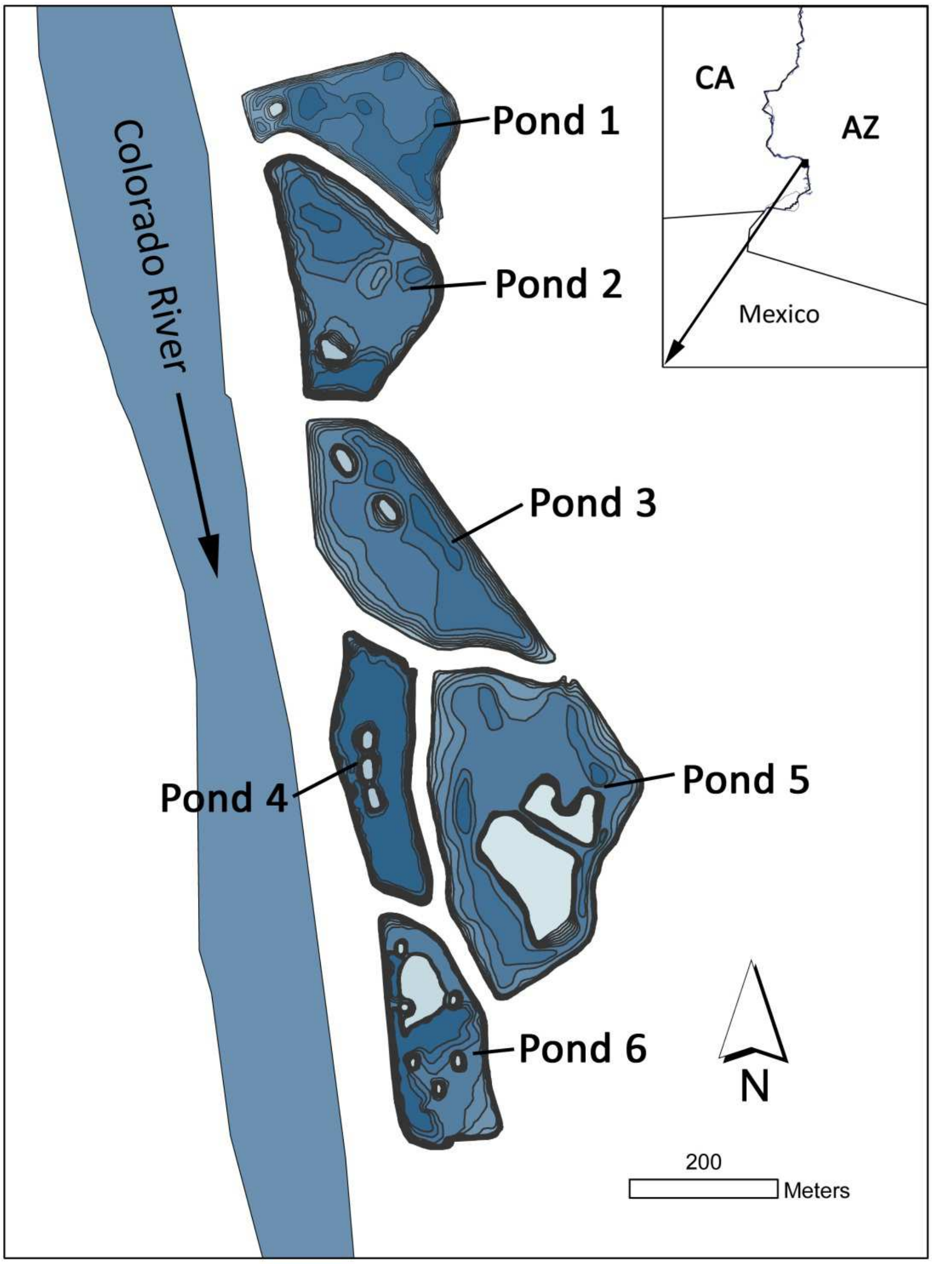


Figure 1. Bathymetric map of the six Imperial Ponds located at INWR, Arizona, and area map (inset). Contour lines represent a change in elevation (pond depth) of one foot.

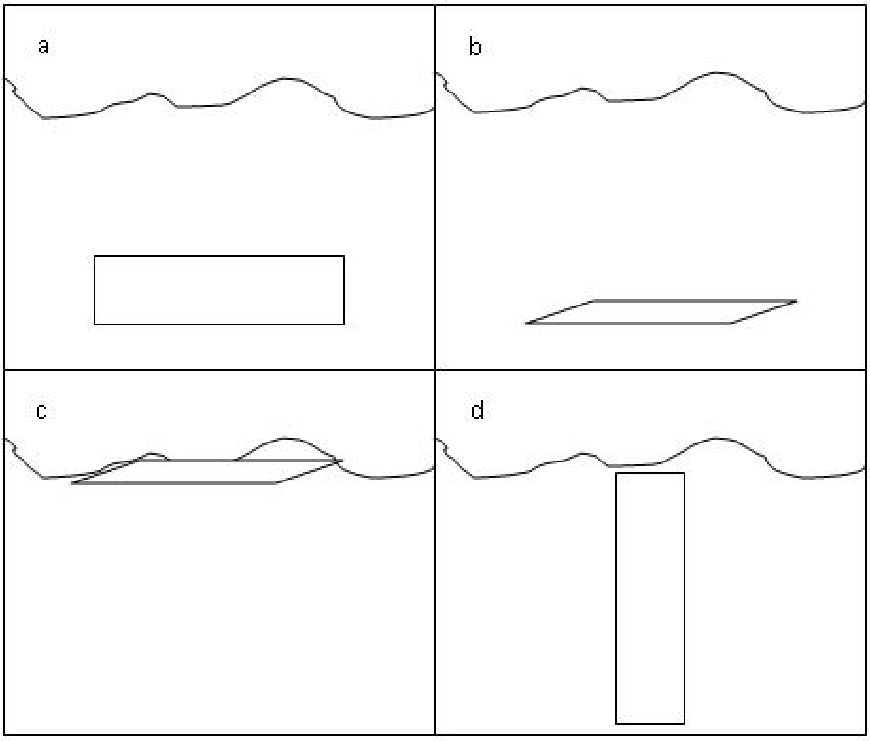


Figure 2. Antenna orientations tested in Pond 1: bottom long (a), bottom flat (b), surface flat (c) and bottom tall (d).

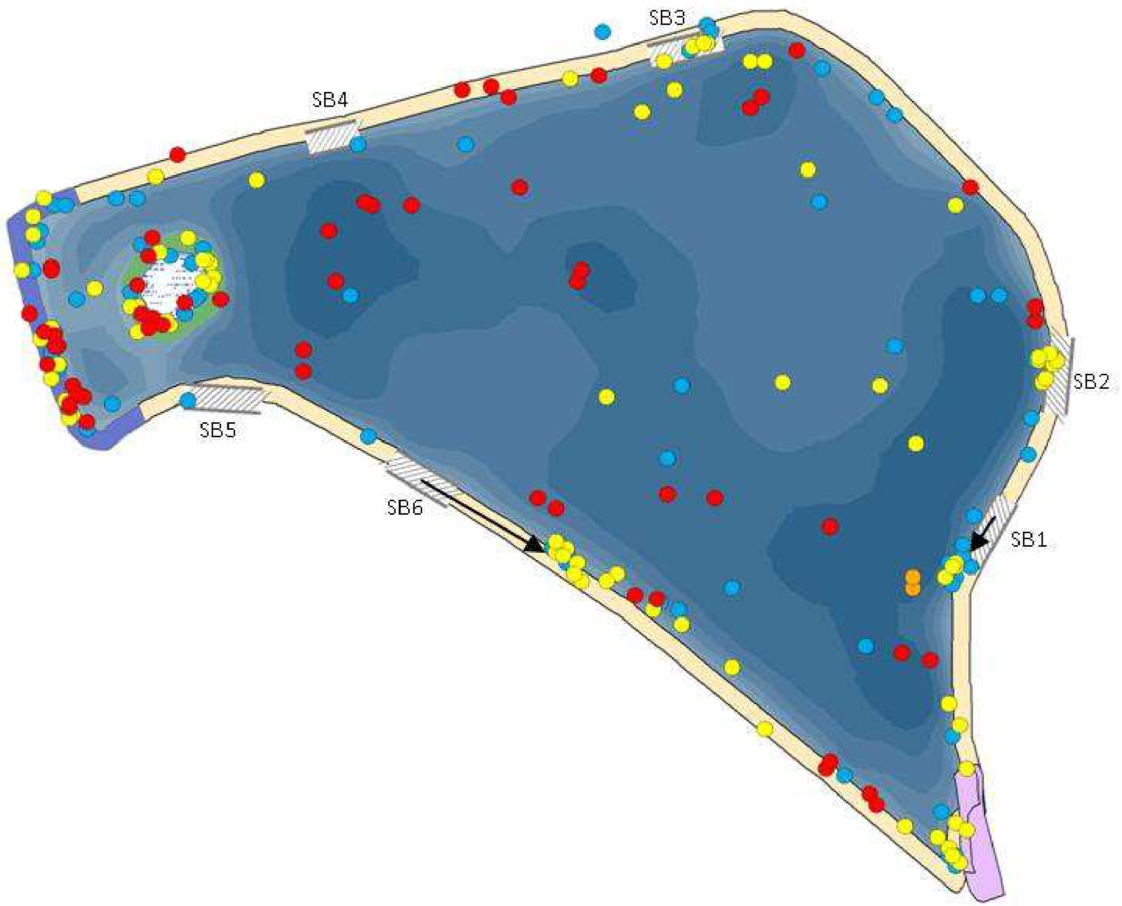


Figure 3. Remote PIT scanner deployment locations in Pond 1 used to track bonytail and razorback sucker from November 2010 to August 2011. Mapped habitats are delineated by colors: rip-rap shore (purple), mud shore (tan), hummock (green) and open water (blue). Boat ramps (light purple) and spawning bed locations (grey-lined, labeled SB) were scanned as well. Spawning bed locations were mapped at their intended location but arrows were used to point to the actual location. The season of scanning was indicated by color; summer (red), autumn (orange), winter (blue) and spring (yellow).

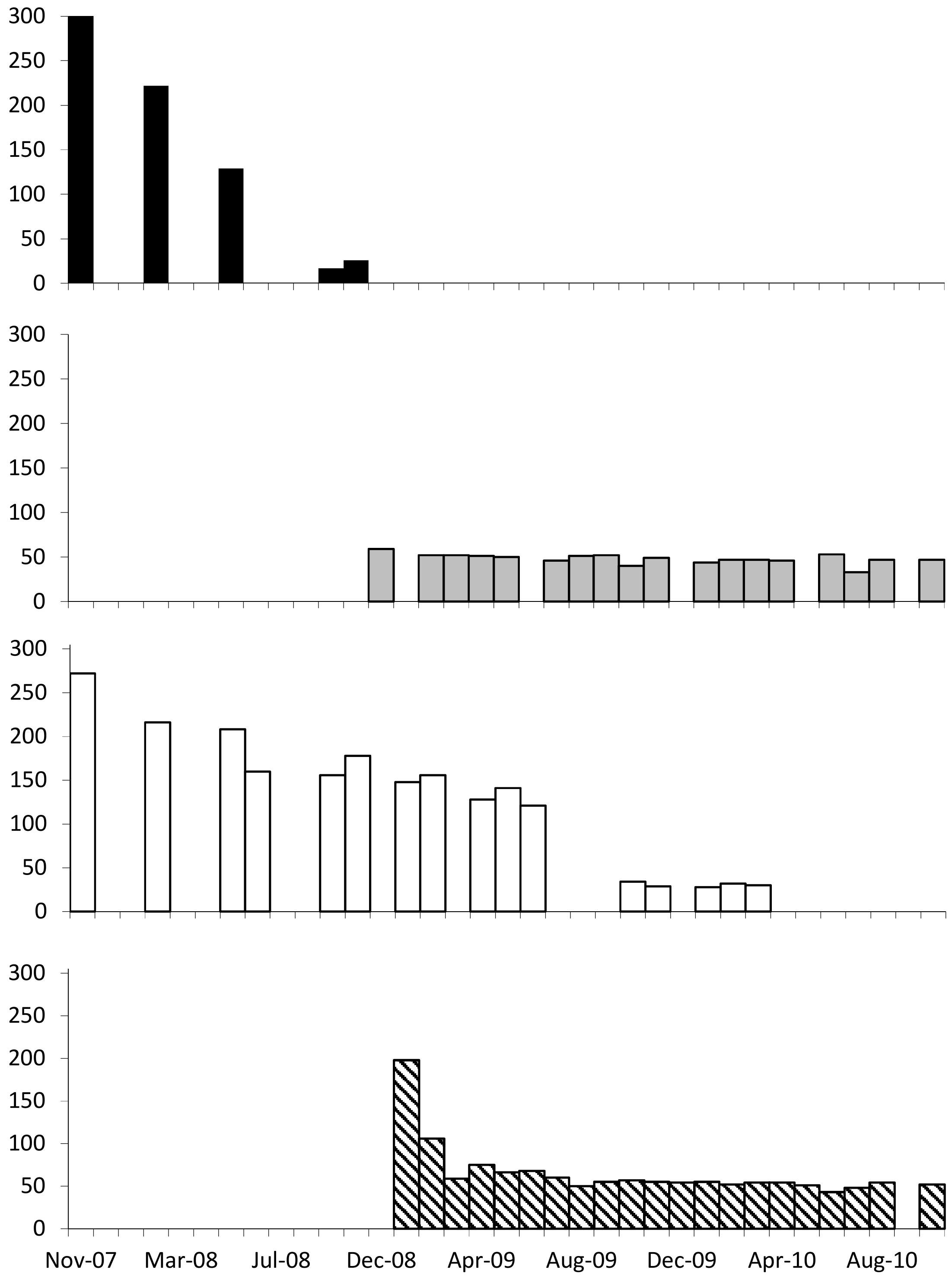


Figure 4. Population estimates for all razorback sucker stocked at Imperial Ponds. Pond 1 (black bars) and 4 (white bars) were stocked in November 2007. Pond 2 (grey bars) and 6 (striped bars) were stocked in December 2008 and January 2009 respectively. Missing values are due to a lack of contacts.

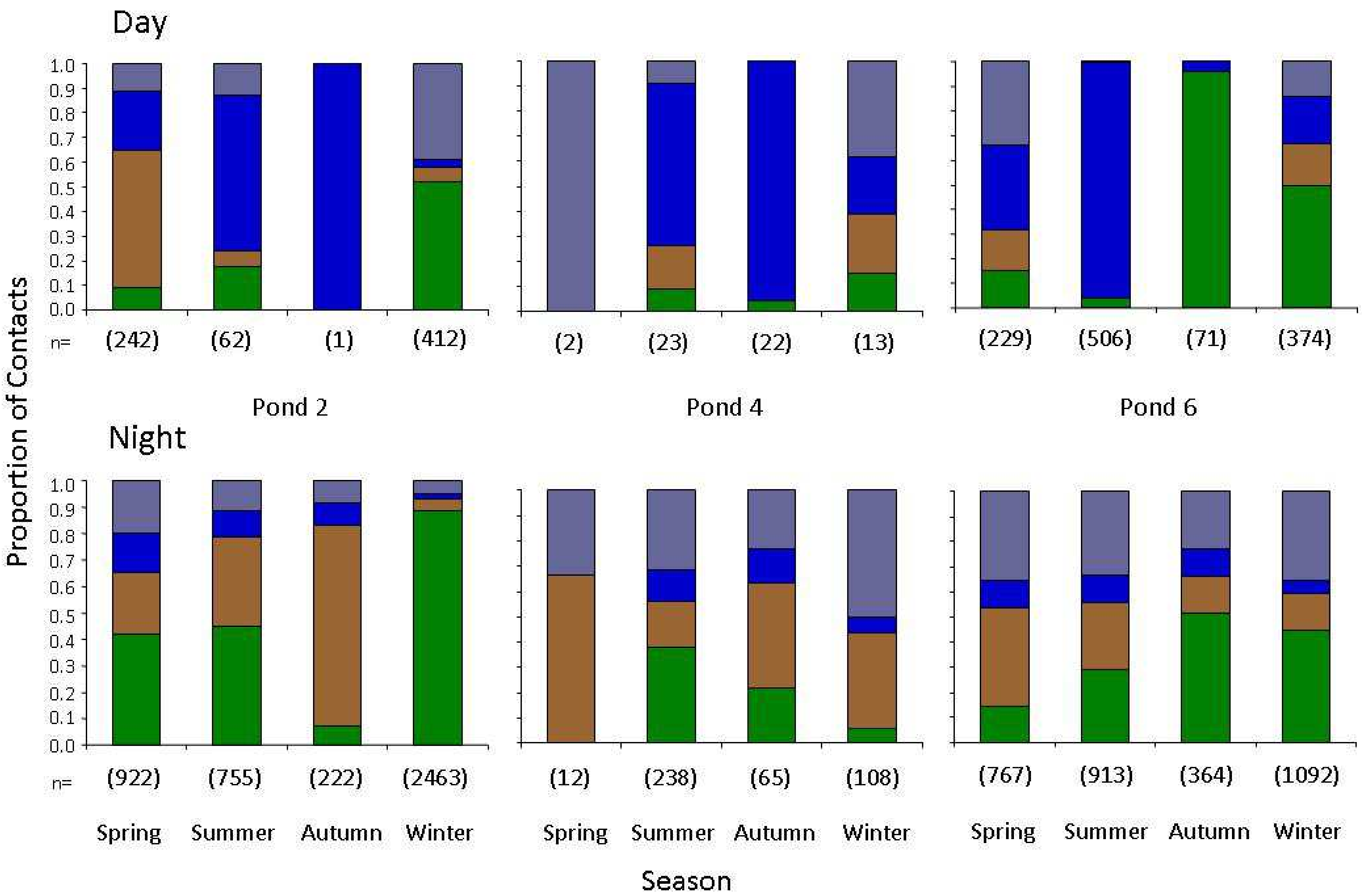


Figure 5. Seasonal proportion of razorback sucker PIT scanner contacts divided by day and night contacts from standardized habitat association sampling in ponds 2, 4, and 6 from August 2009 to November 2010. Two-way Pearson chi-square tests indicated significant differences ($p < 0.0001$) in seasonal habitat usage among four habitat types; hummock (green), mud shore (brown), open water (blue), and rip-rap shore (purple).

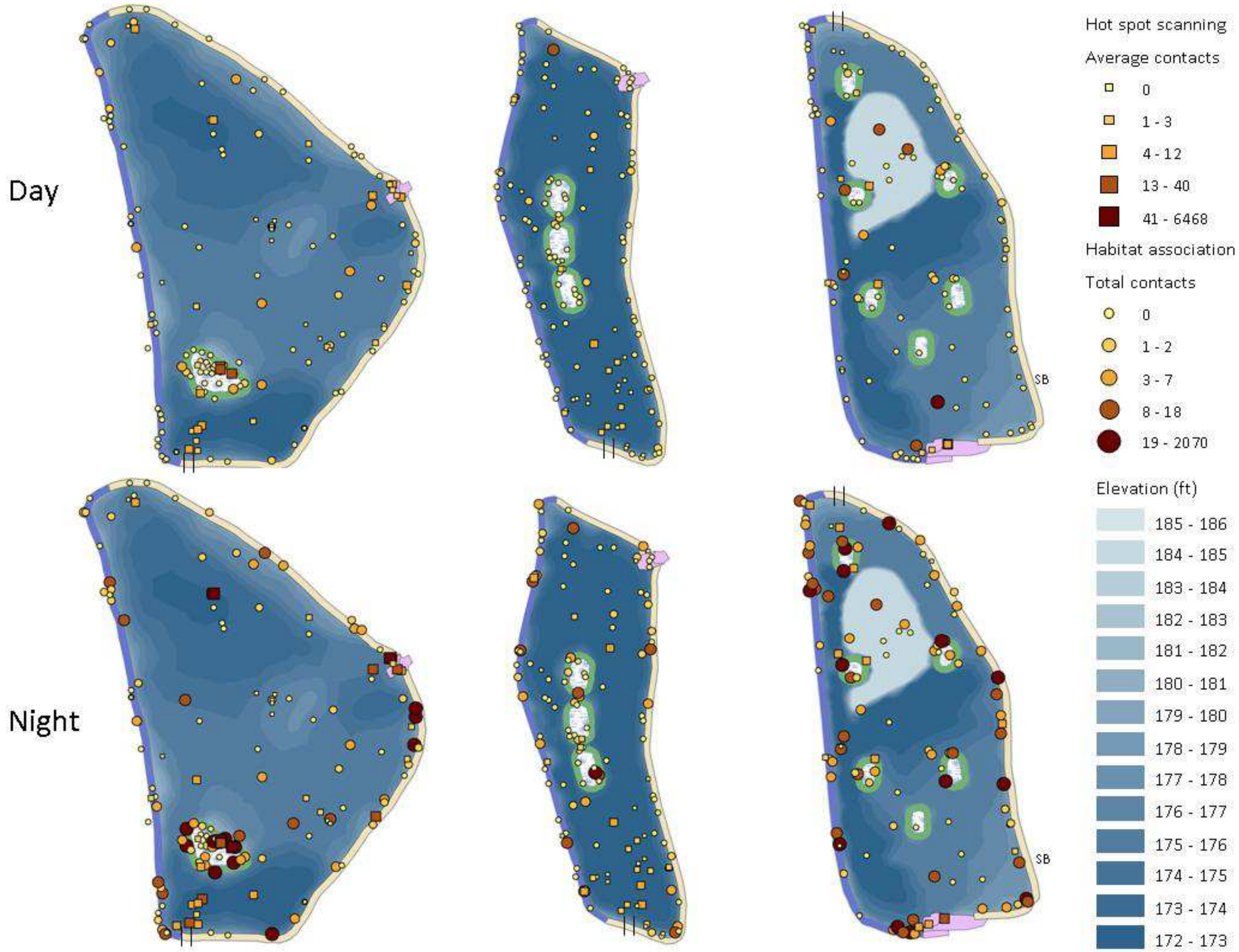


Figure 6. Summer habitat association (circles) and hot spot scanning (squares) contacts for razorback sucker in ponds 2, 4, and 6 for day and night-time periods. Symbols are located at the corresponding geographic deployment location on the rip-rap shore (purple), mud shore (tan), hummock (green), open water (blue), and the boat ramp (light purple). The approximate location of inlet pipes are indicated with parallel lines and the location of the spawning bed in Pond 6 is labeled 'SB'. The number of contacts at each deployment corresponds to the range of contacts possible for the quintile, as delineated in the key. The elevation of the open water in each pond was provided by Reclamation bathymetry data.

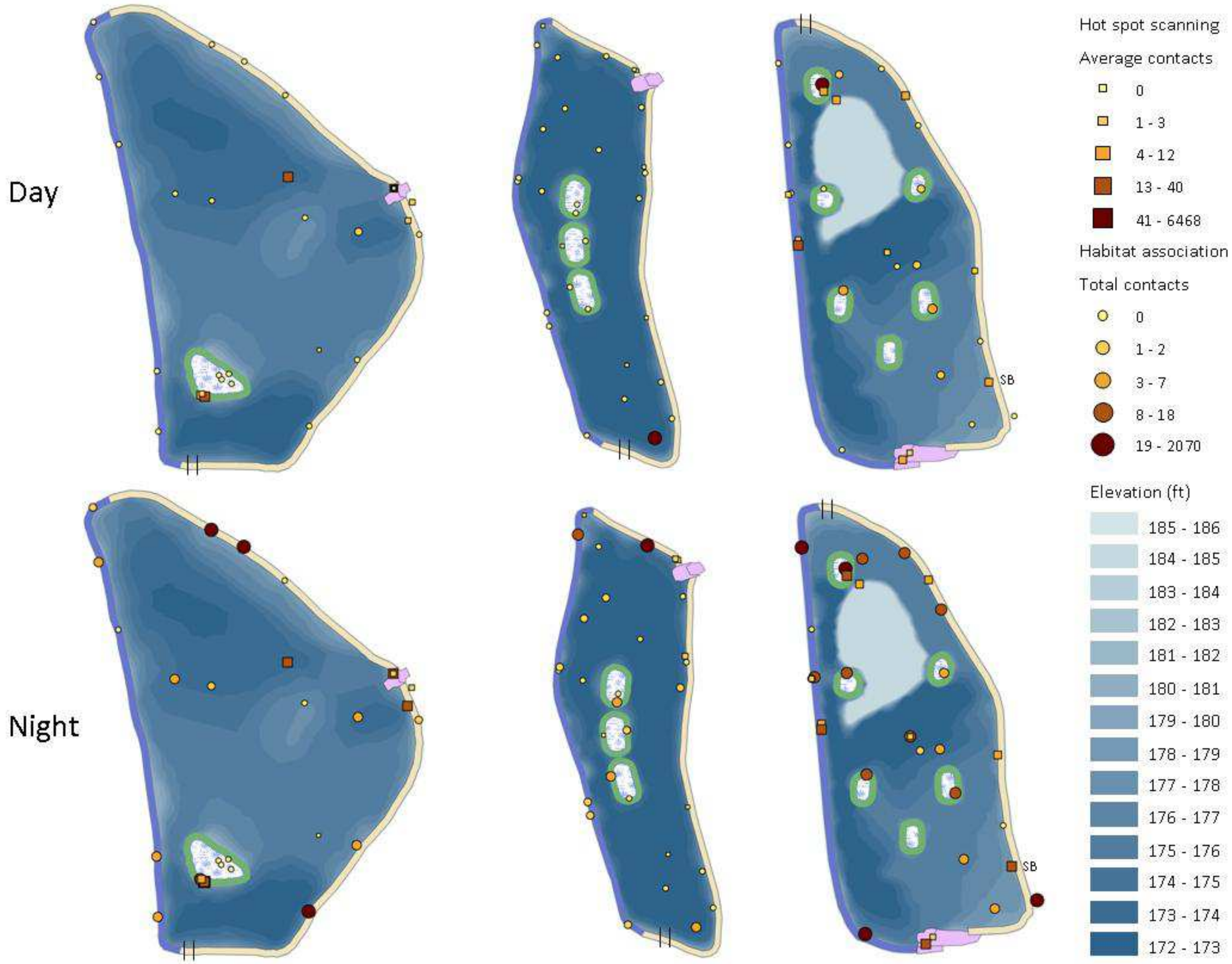


Figure 7. Autumn habitat association (circles) and hot spot scanning (squares) contacts for razorback sucker in ponds 2, 4, and 6 for day and night-time periods. Symbols are located at the corresponding geographic deployment location on the rip-rap shore (purple), mud shore (tan), hummock (green), open water (blue), and the boat ramp (light purple). The approximate location of inlet pipes are indicated with parallel lines and the location of the spawning bed in Pond 6 is labeled 'SB'. The number of contacts at each deployment corresponds to the range of contacts possible for the quintile, as delineated in the key. The elevation of the open water in each pond was provided by Reclamation bathymetry data.

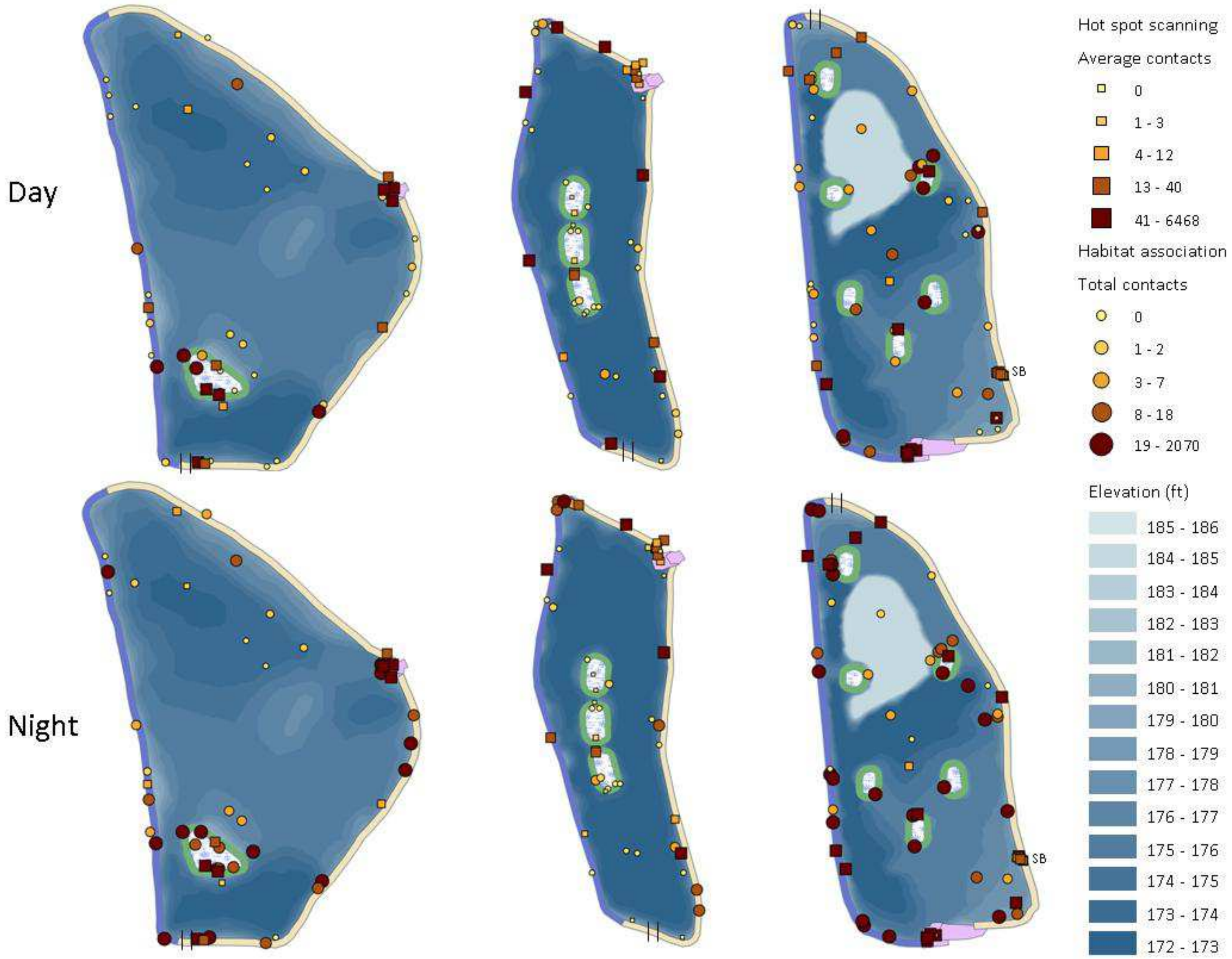


Figure 8. Winter habitat association (circles) and hot spot scanning (squares) contacts for razorback sucker in ponds 2, 4, and 6 for day and night-time periods. Symbols are located at the corresponding geographic deployment location on the rip-rap shore (purple), mud shore (tan), hummock (green), open water (blue), and the boat ramp (light purple). The approximate location of inlet pipes are indicated with parallel lines and the location of the spawning bed in Pond 6 is labeled 'SB'. The number of contacts at each deployment corresponds to the range of contacts possible for the quintile, as delineated in the key. The elevation of the open water in each pond was provided by Reclamation bathymetry data.

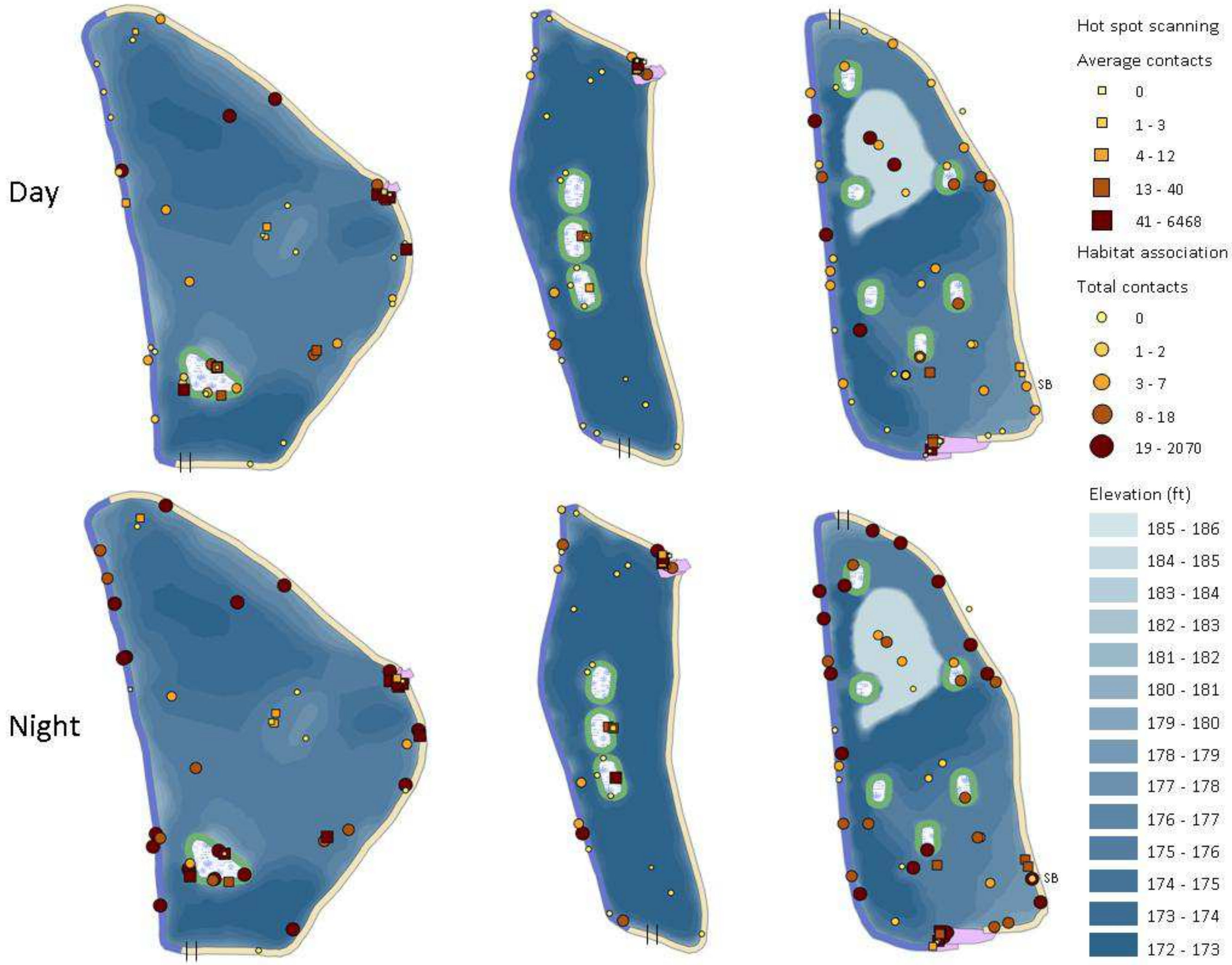


Figure 9. Spring habitat association (circles) and hot spot scanning (squares) contacts for razorback sucker in ponds 2, 4, and 6 for day and night-time periods. Symbols are located at the corresponding geographic deployment location on the rip-rap shore (purple), mud shore (tan), hummock (green), open water (blue), and the boat ramp (light purple). The approximate location of inlet pipes are indicated with parallel lines and the location of the spawning bed in Pond 6 is labeled 'SB'. The number of contacts at each deployment corresponds to the range of contacts possible for the quintile, as delineated in the key. The elevation of the open water in each pond was provided by Reclamation bathymetry data.

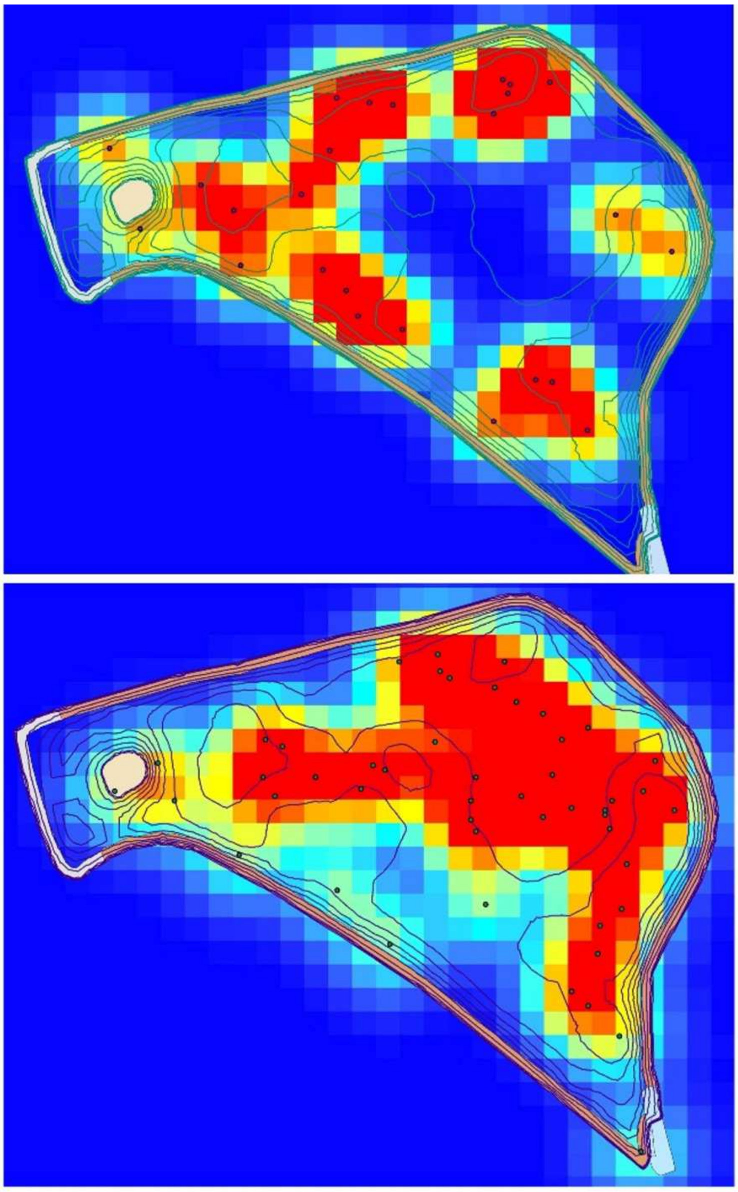


Figure 10a. Kernel density estimate displaying the utilization distribution of bonytail (top) and razorback sucker (bottom) during daytime hours (5:00 to 19:00) from May-August 2011. Red shade indicates the highest level of utilization and blue indicates the lowest level of utilization. Actual fish locations are marked as points.

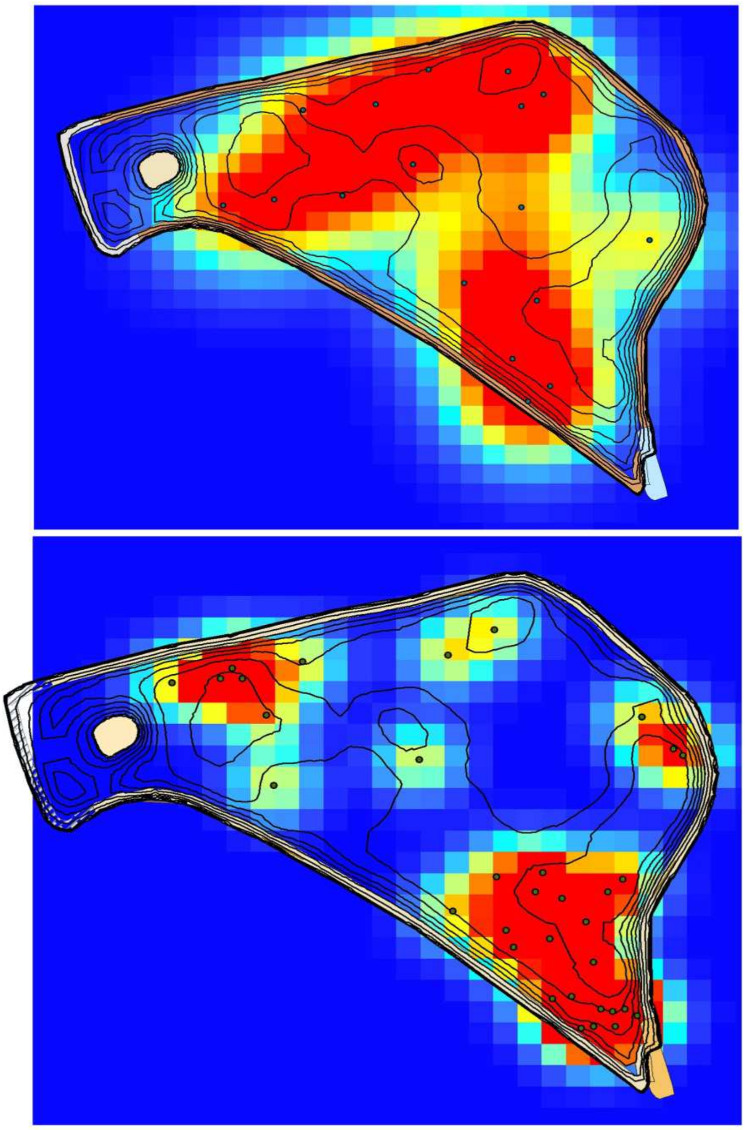


Figure 10b. Kernel density estimate displaying the utilization distribution of bonytail (top) and razorback sucker (bottom) during nighttime hours (19:01 to 4:59) from May-August 2011. Red shade indicates the highest level of utilization and blue indicates the lowest level of utilization. Actual fish locations are marked as points.

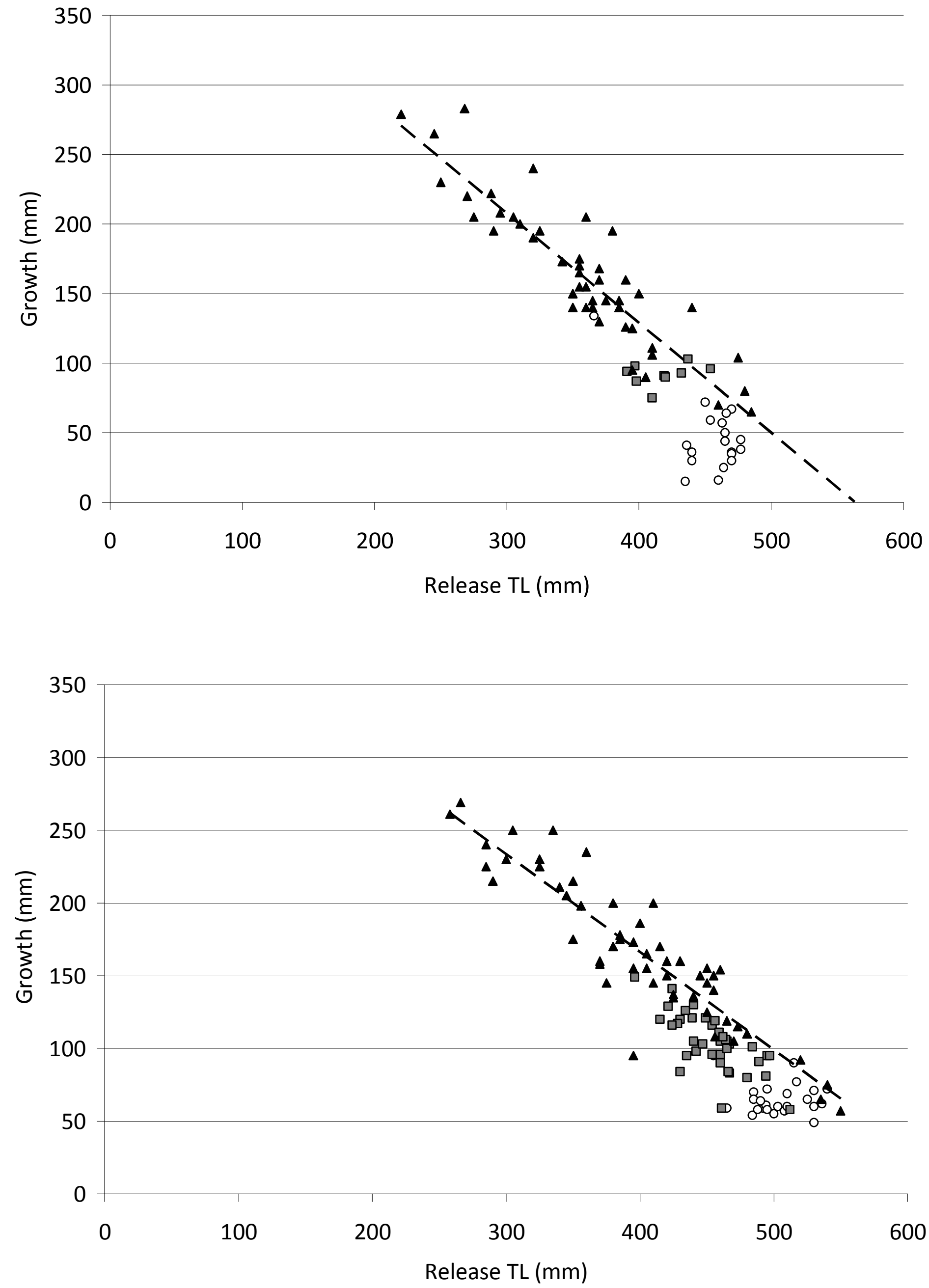


Figure 11. Growth for male (top) and female (bottom) razorback sucker released into Pond 2 (open circles) and Pond 6 (closed squares) at Imperial Ponds and razorback sucker stocked into Lake Mohave (closed triangles). Fish were captured and measured for growth between 650 and 800 days after release. The dashed regression line is based on Lake Mohave growth data (r^2 = 0.85 for males and females; Marsh & Associates unpublished data).

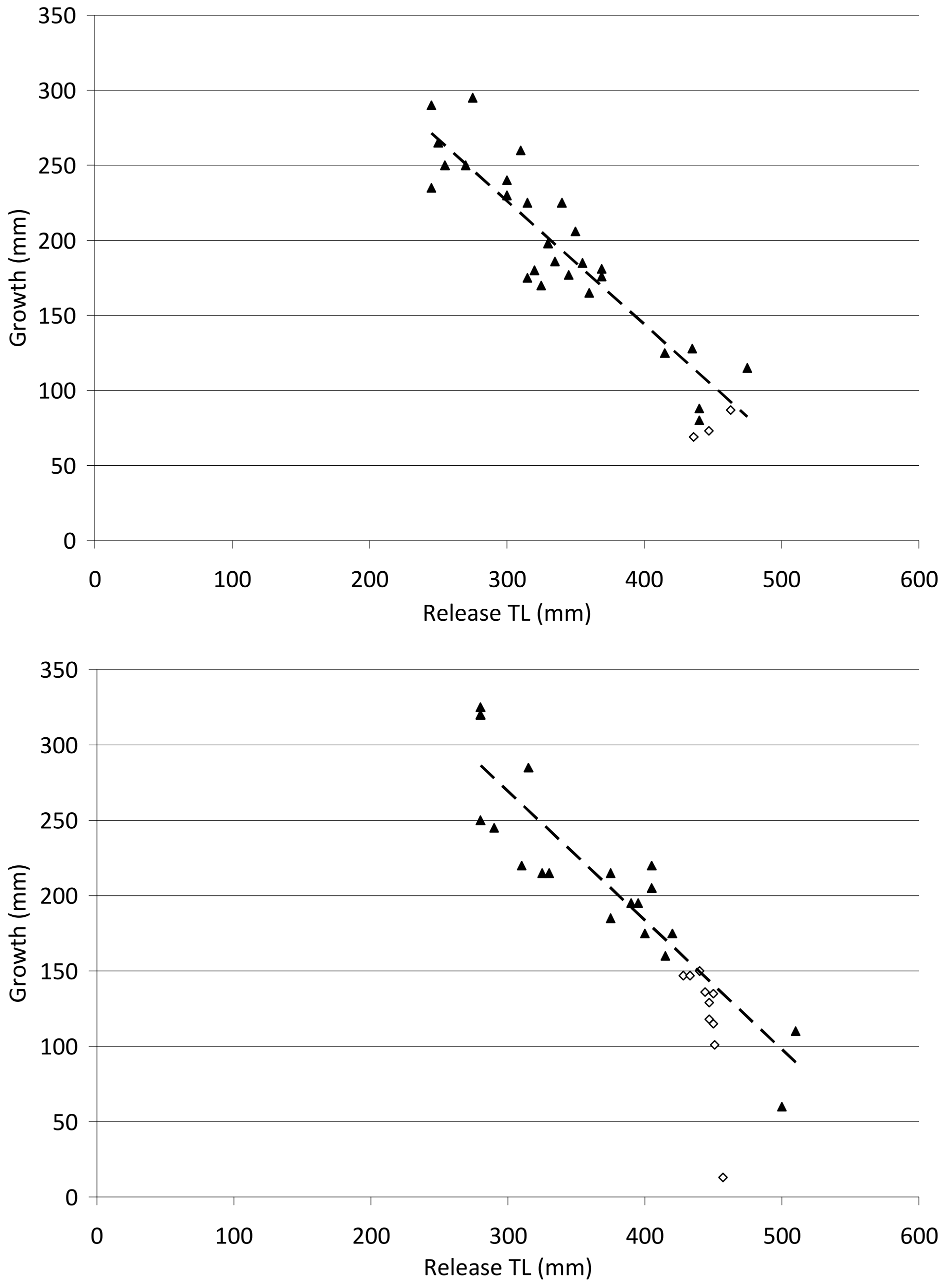


Figure 12. Growth for male (top) and female (bottom) razorback sucker released into Pond 4 (open diamonds) at Imperial Ponds and razorback sucker stocked into Lake Mohave (closed triangles). Fish were captured and measured for growth between 1,000 and 1,100 days after release. The dashed regression lines are based on Lake Mohave growth data (r^2 = 0.83 for males and 0.82 for females; Marsh & Associates unpublished data).

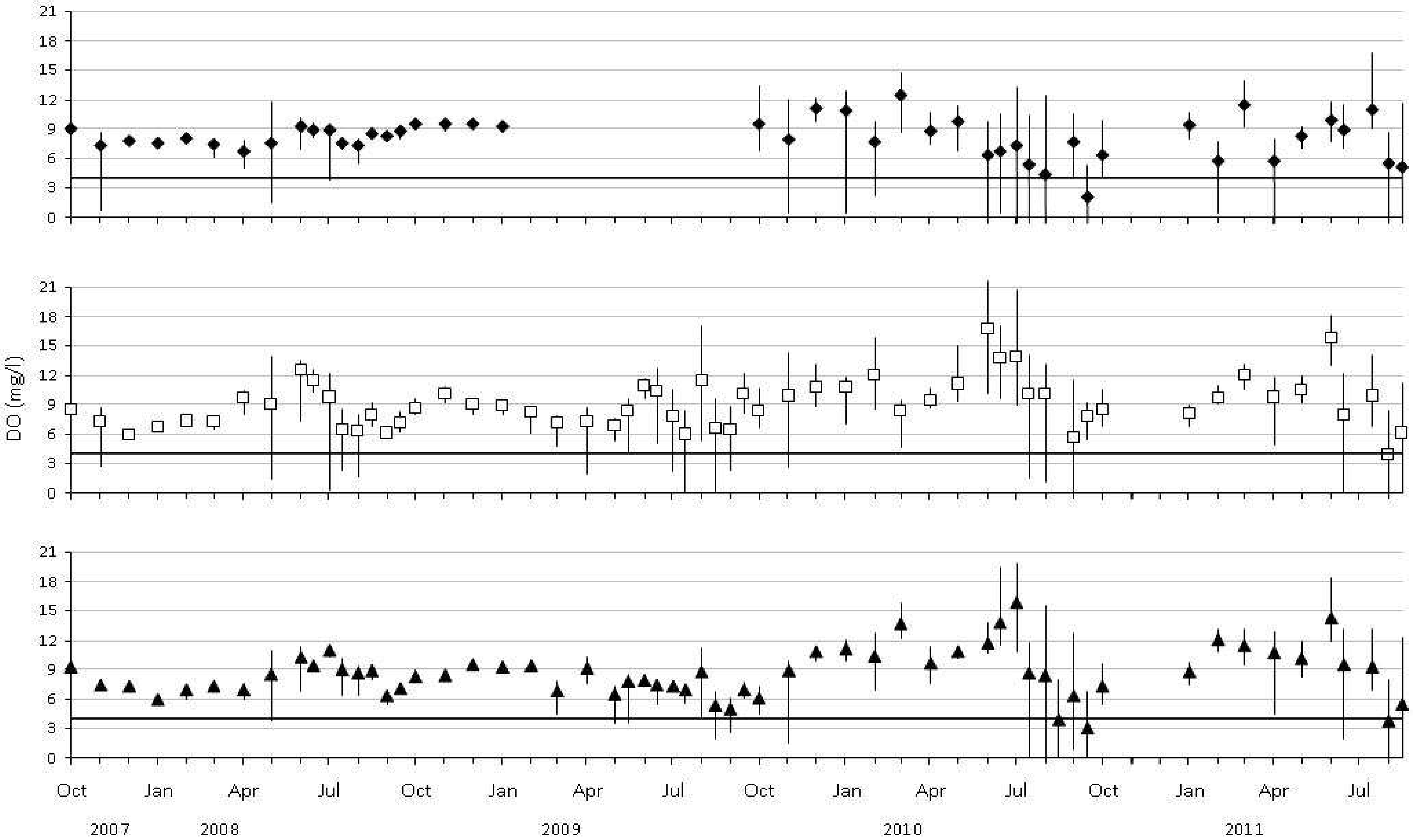


Figure 13. Mean dissolved oxygen (DO) for Pond 1 (closed diamonds), Pond 2 (open squares), and Pond 3 (closed triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. Horizontal line is at the DO limit of 4 mg/l. There are no data from Pond 1 from February to September 2009 due to renovation activities.

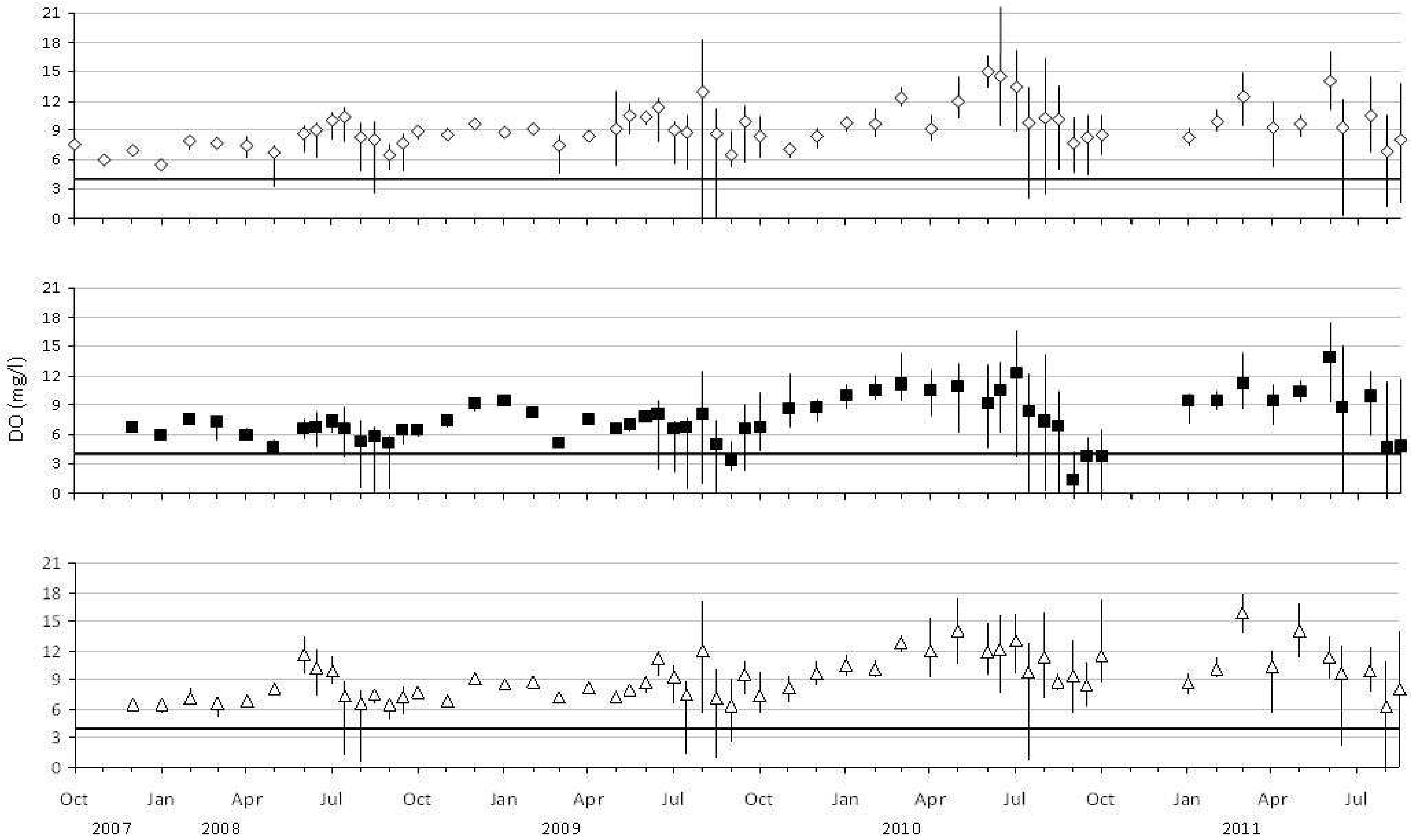


Figure 14. Mean dissolved oxygen (DO) for Pond 4 (open diamonds), Pond 5 (closed squares), and Pond 6 (open triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. Horizontal line is at the DO limit of 4 mg/l.

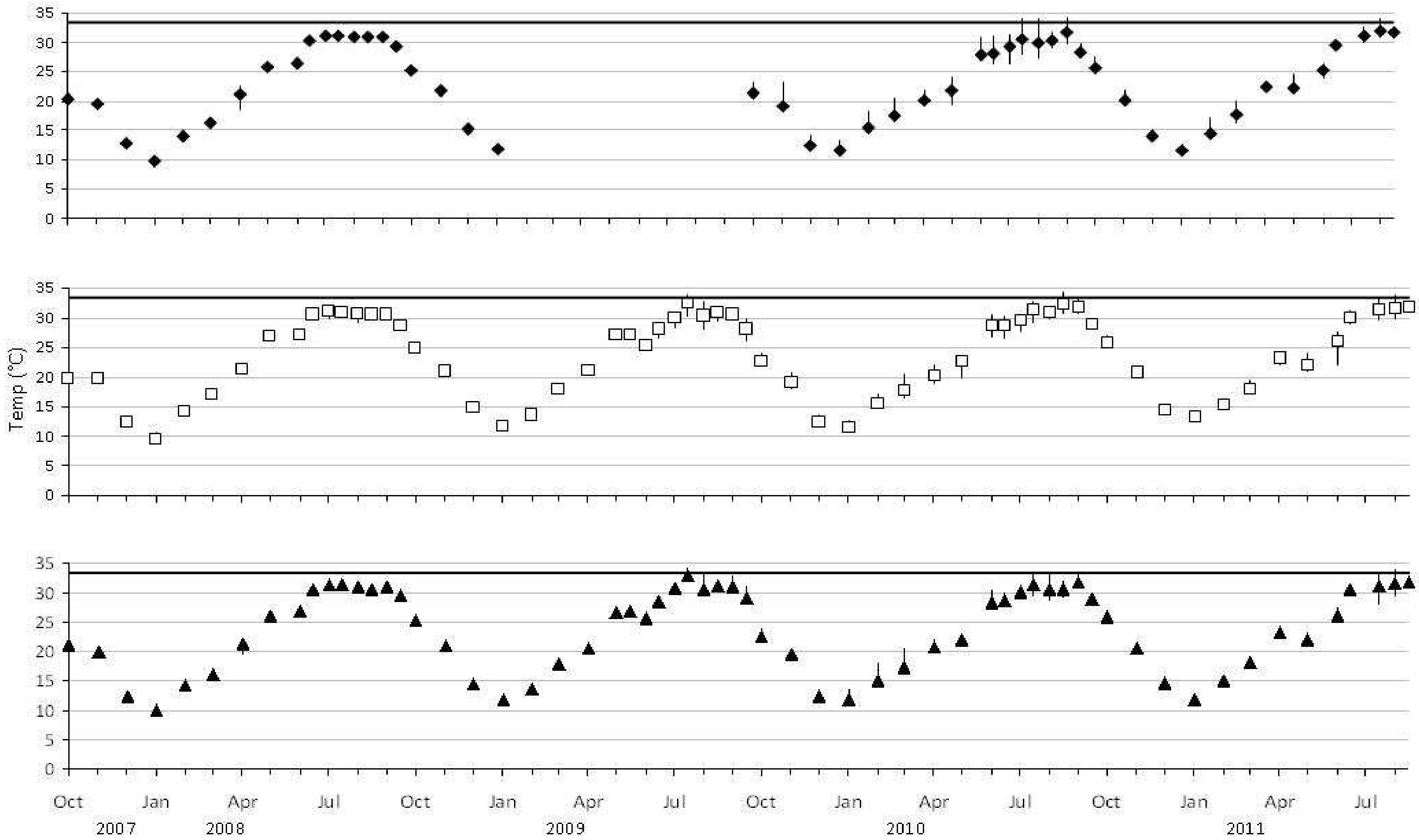


Figure 15. Mean temperature for Pond 1 (closed diamonds), Pond 2 (open squares), and Pond 3 (closed triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. Horizontal line is at the temperature limit of 33.3 C. There are no data from Pond 1 from February to September 2009 due to renovation activities.

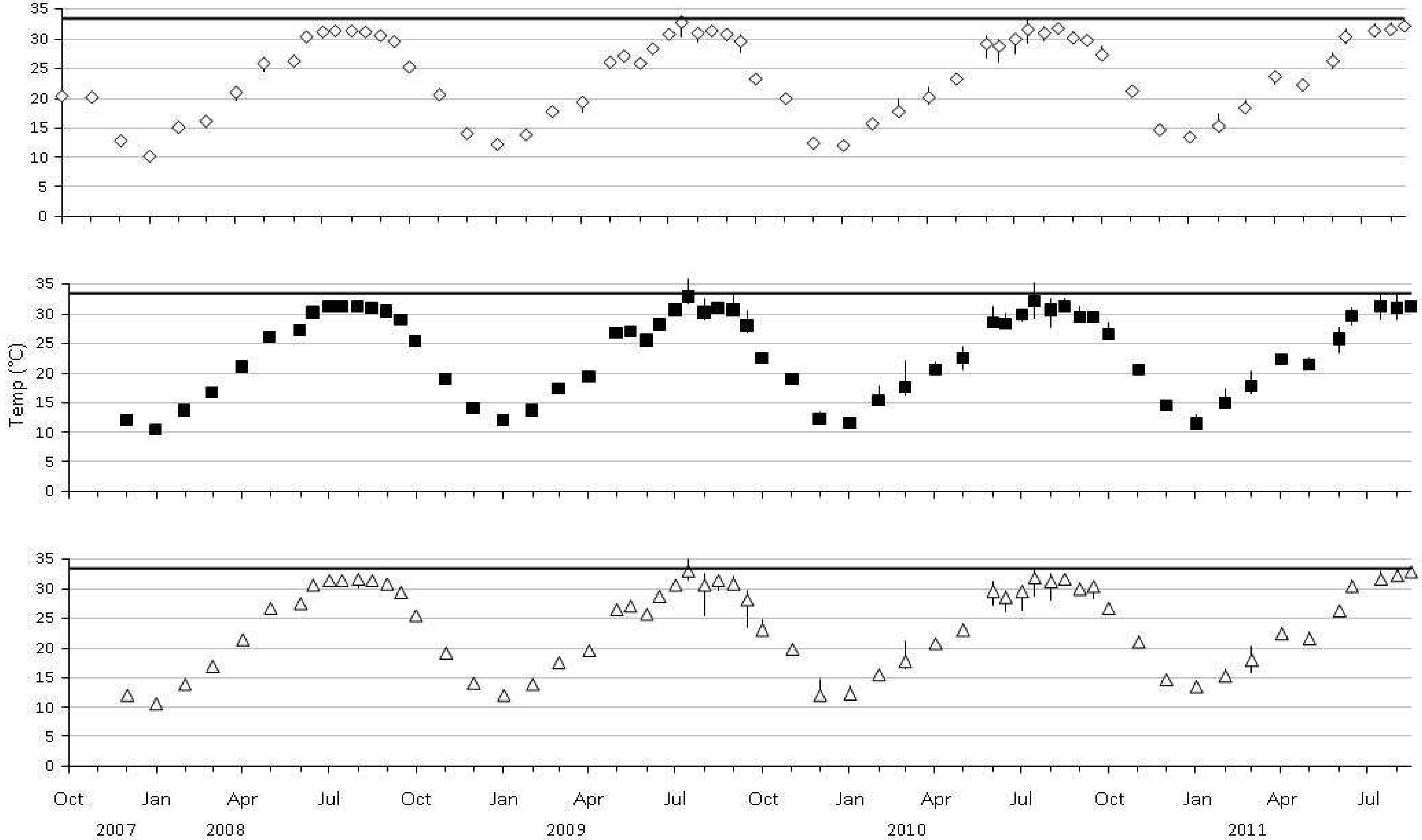


Figure 16. Mean temperature for Pond 4 (open diamonds), Pond 5 (closed squares), and Pond 6 (open triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. Horizontal line is at the temperature limit of 33.3 C. There are no data from Pond 1 from February to September 2009 due to renovation activities.

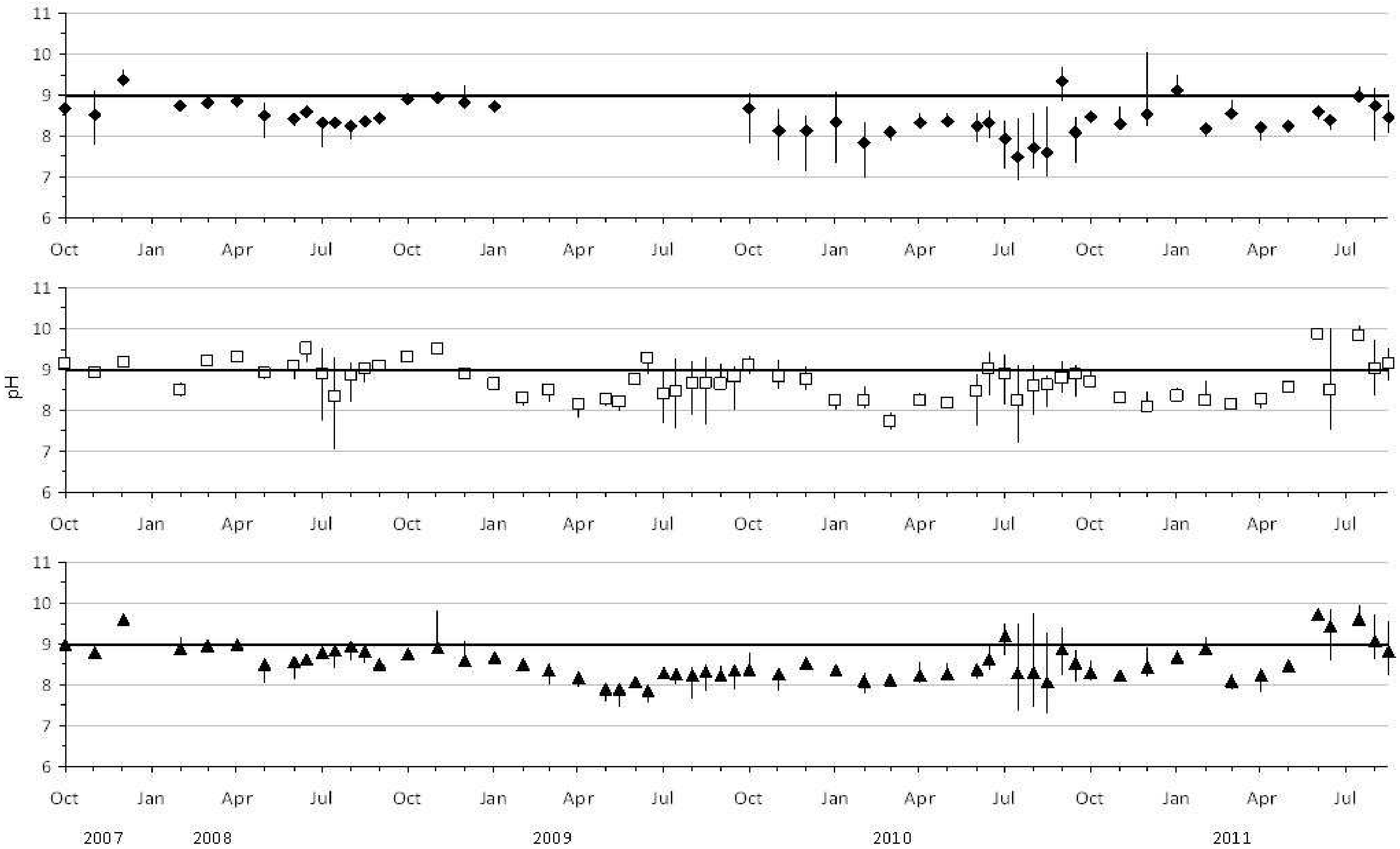


Figure 17. Mean pH for Pond 1 (closed diamonds), Pond 2 (open squares), and Pond 3 (closed triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. Horizontal line is at the pH limit of 9.0. There are no data from Pond 1 from February to September 2009 due to renovation activities.

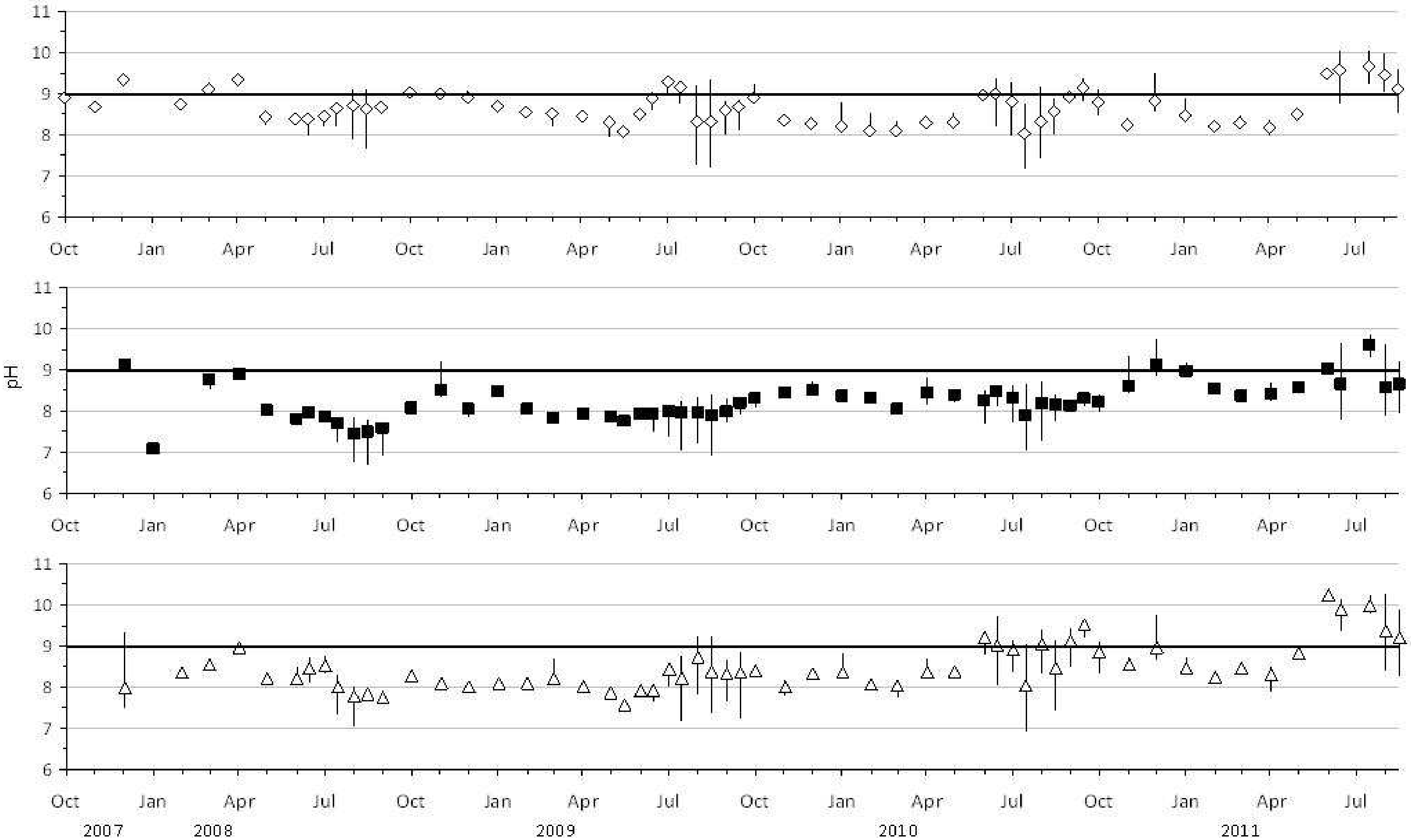


Figure 18. Mean pH for Pond 4 (open diamonds), Pond 5 (closed squares), and Pond 6 (open triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. Horizontal line is at the pH limit of 9.0.

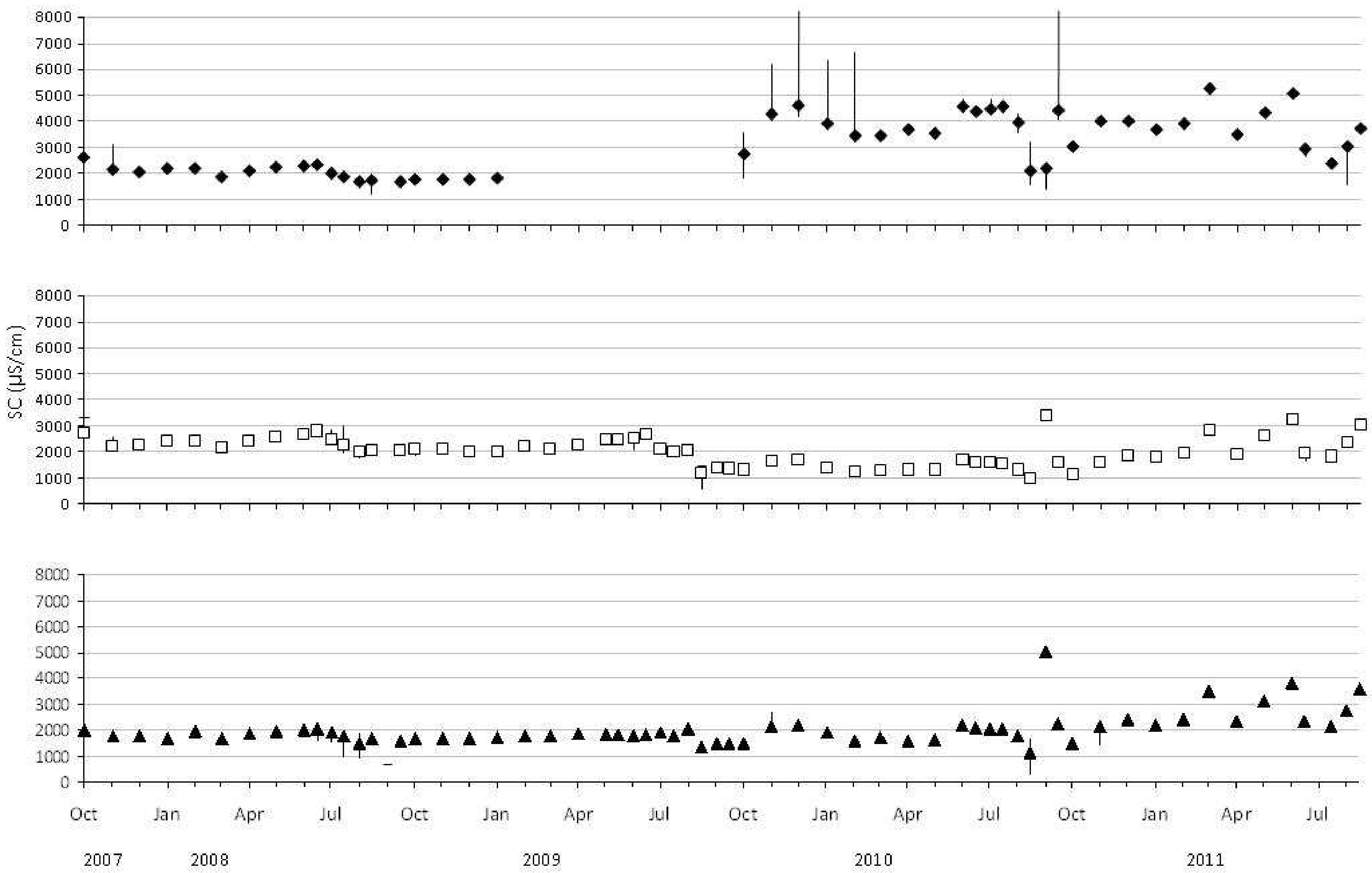


Figure 19. Mean specific conductivity for Pond 1 (closed diamonds), Pond 2 (open squares), and Pond 3 (closed triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. There are no data from Pond 1 from February to September 2009 due to renovation activities.

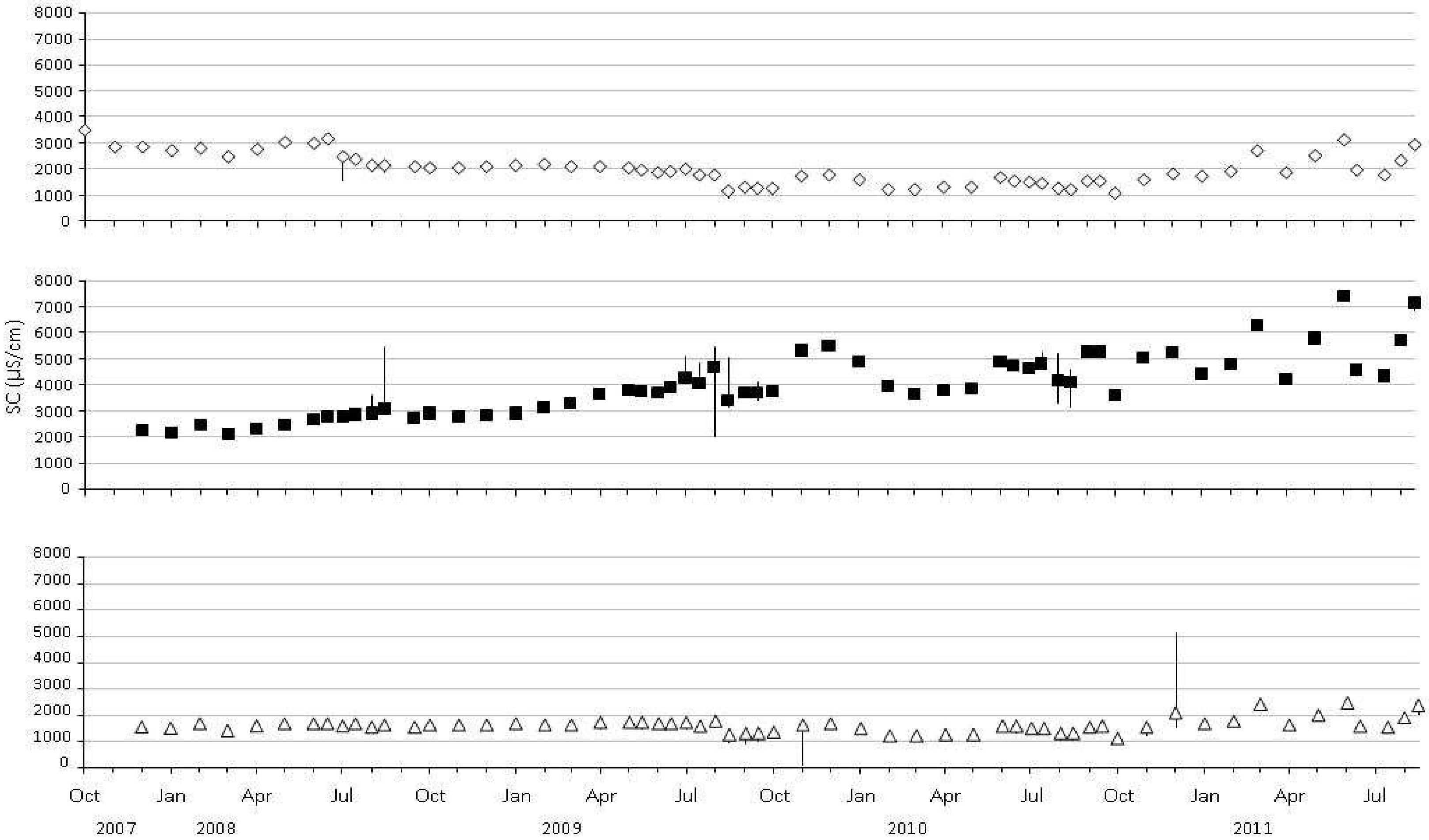


Figure 20. Mean specific conductivity for Pond 4 (open diamonds), Pond 5 (closed squares), and Pond 6 (open triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings.

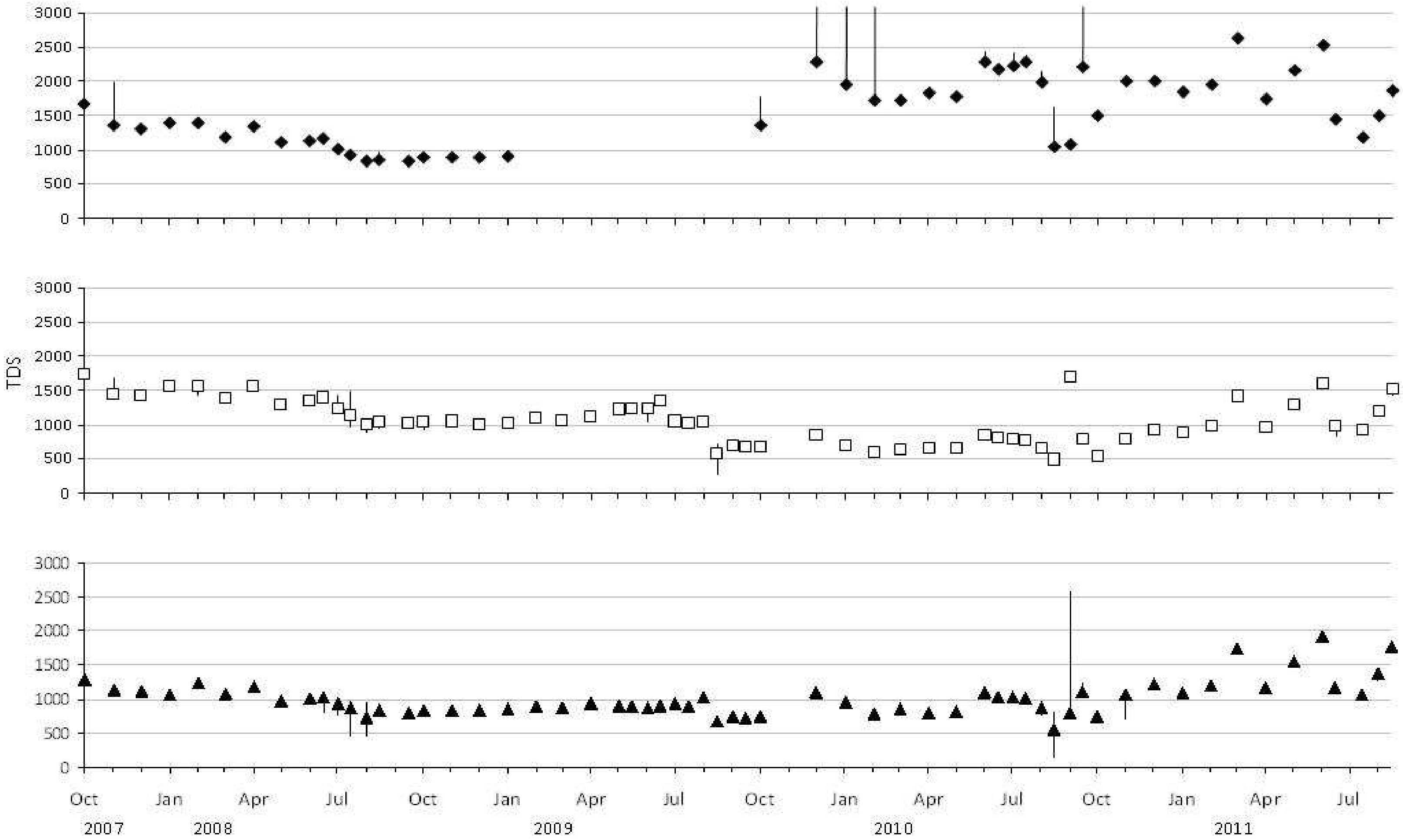


Figure 21. Mean total dissolved solids (TDS) for Pond 1 (closed diamonds), Pond 2 (open squares), and Pond 3 (closed triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings. There are no data from Pond 1 from February to September 2009 due to renovation activities.

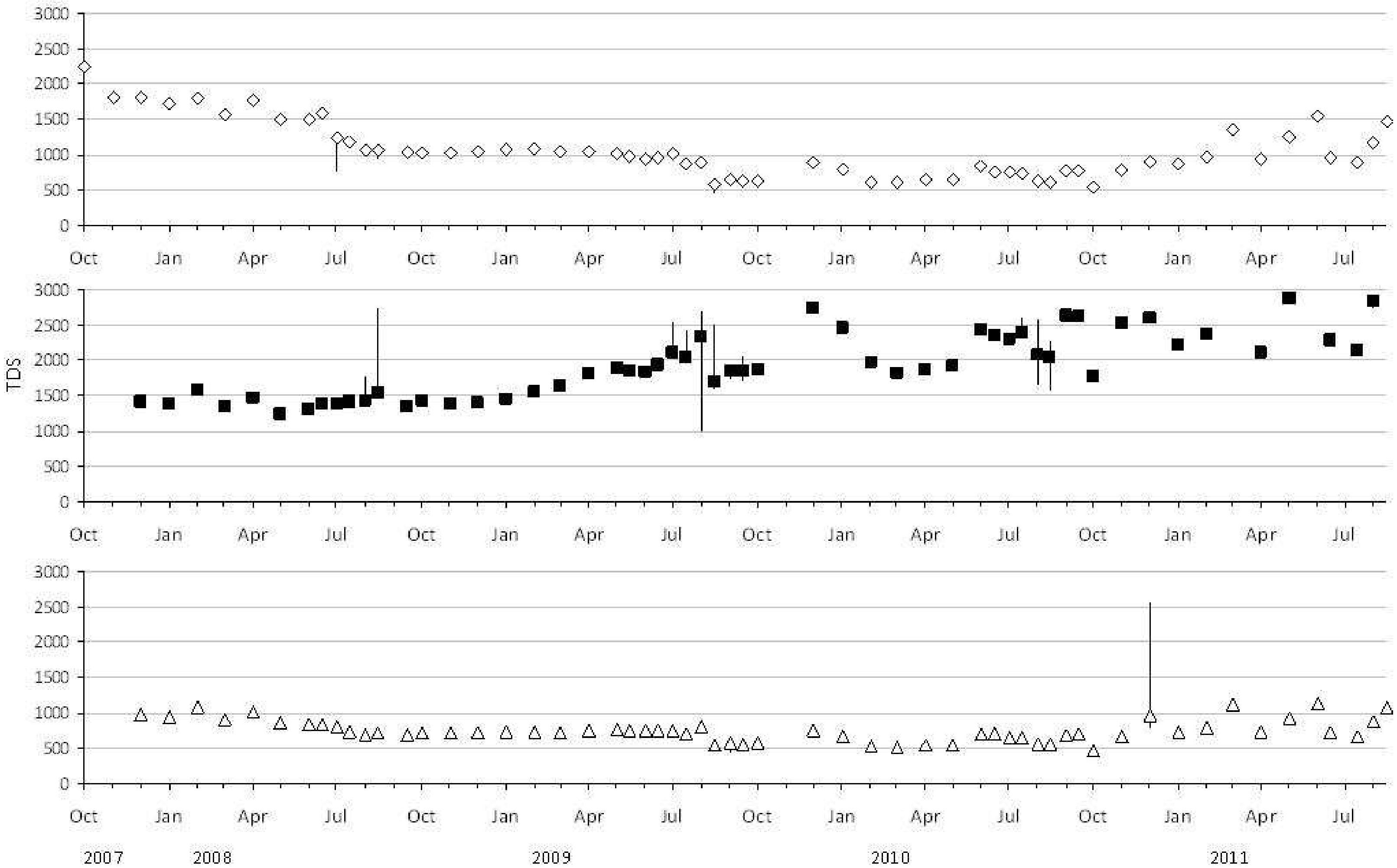


Figure 22. Mean total dissolved solids (TDS) for Pond 4 (open diamonds), Pond 5 (closed squares), and Pond 6 (open triangles) from October 2007 through August 2011. Vertical lines extend to the minimum and maximum readings.

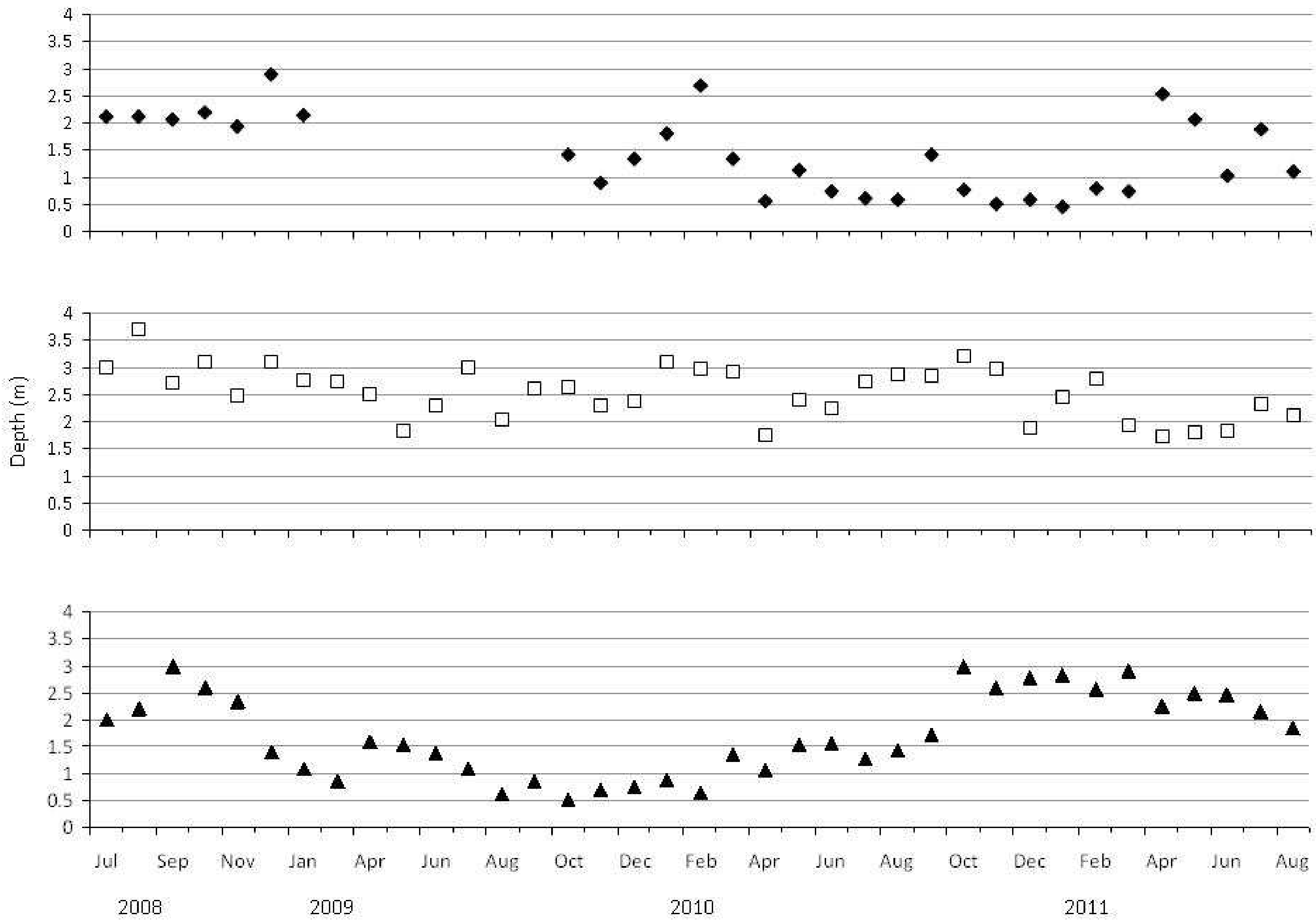


Figure 23. Secchi Depth in meters for Pond 1 (closed diamonds), Pond 2 (open squares), and Pond 3 (closed triangles) from July 2008 through August 2011. There are no data from Pond 1 from February to September 2009 due to renovation activities.

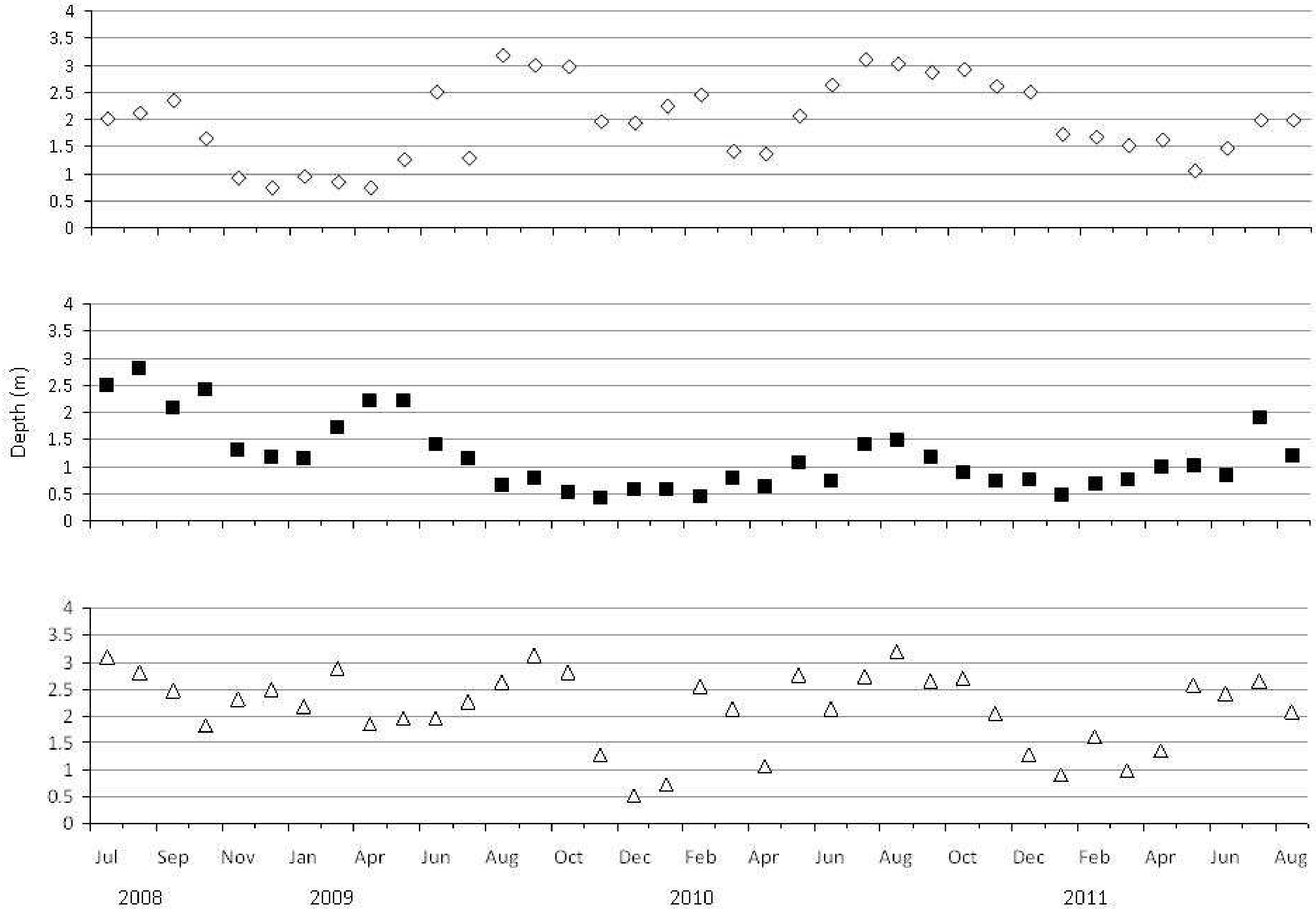


Figure 24. Secchi depth **in meters** for Pond 4 (open diamonds), Pond 5 (closed squares), and Pond 6 (open triangles) from July 2008 through August 2011.

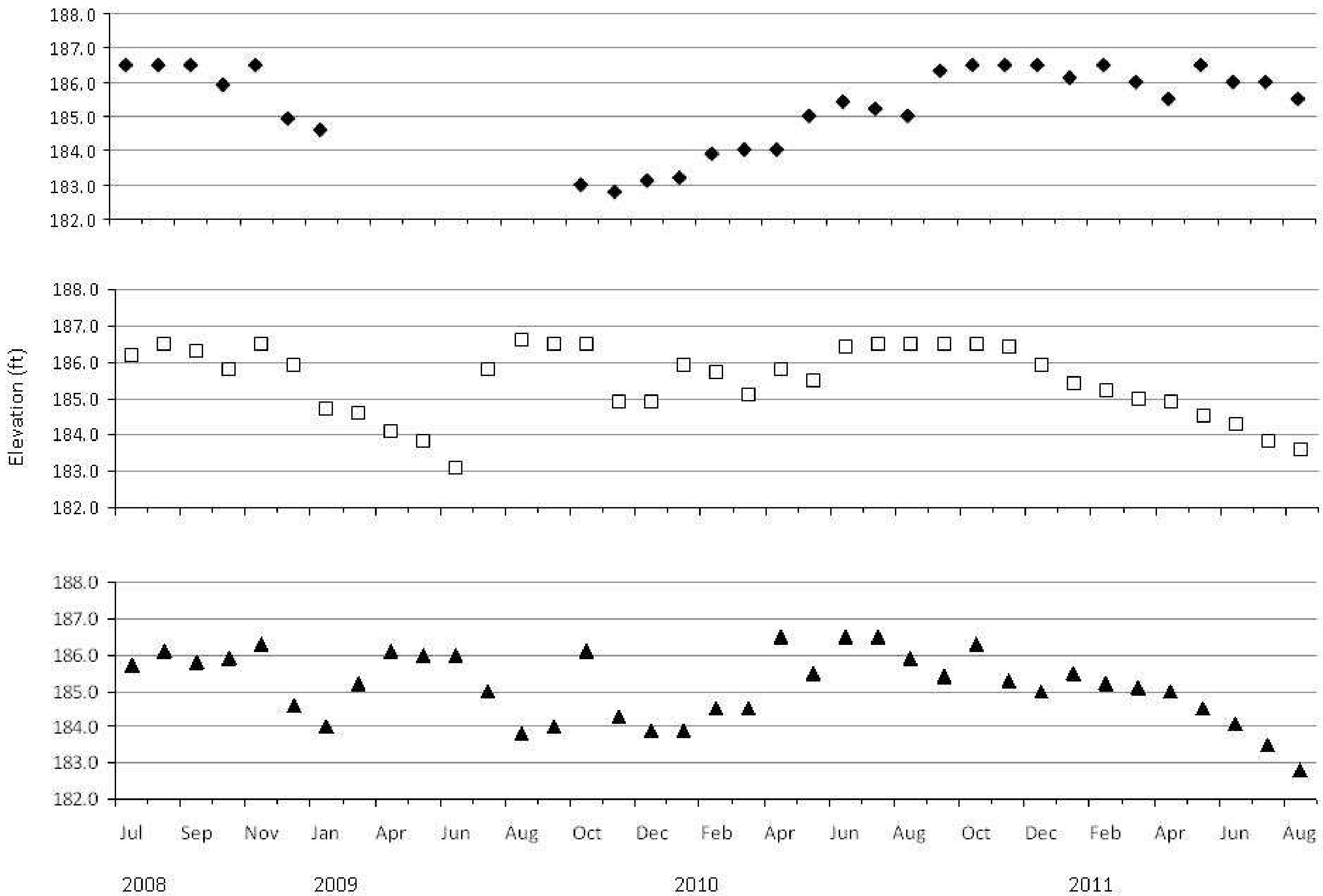


Figure 25. Pond elevations (ft) based on staff gauge readings for Pond 1 (closed diamonds), Pond 2 (open squares), and Pond 3 (closed triangles) from July 2008 through August 2011. Elevation readings are limited to the top of the staff gauge at 186.5 ft.

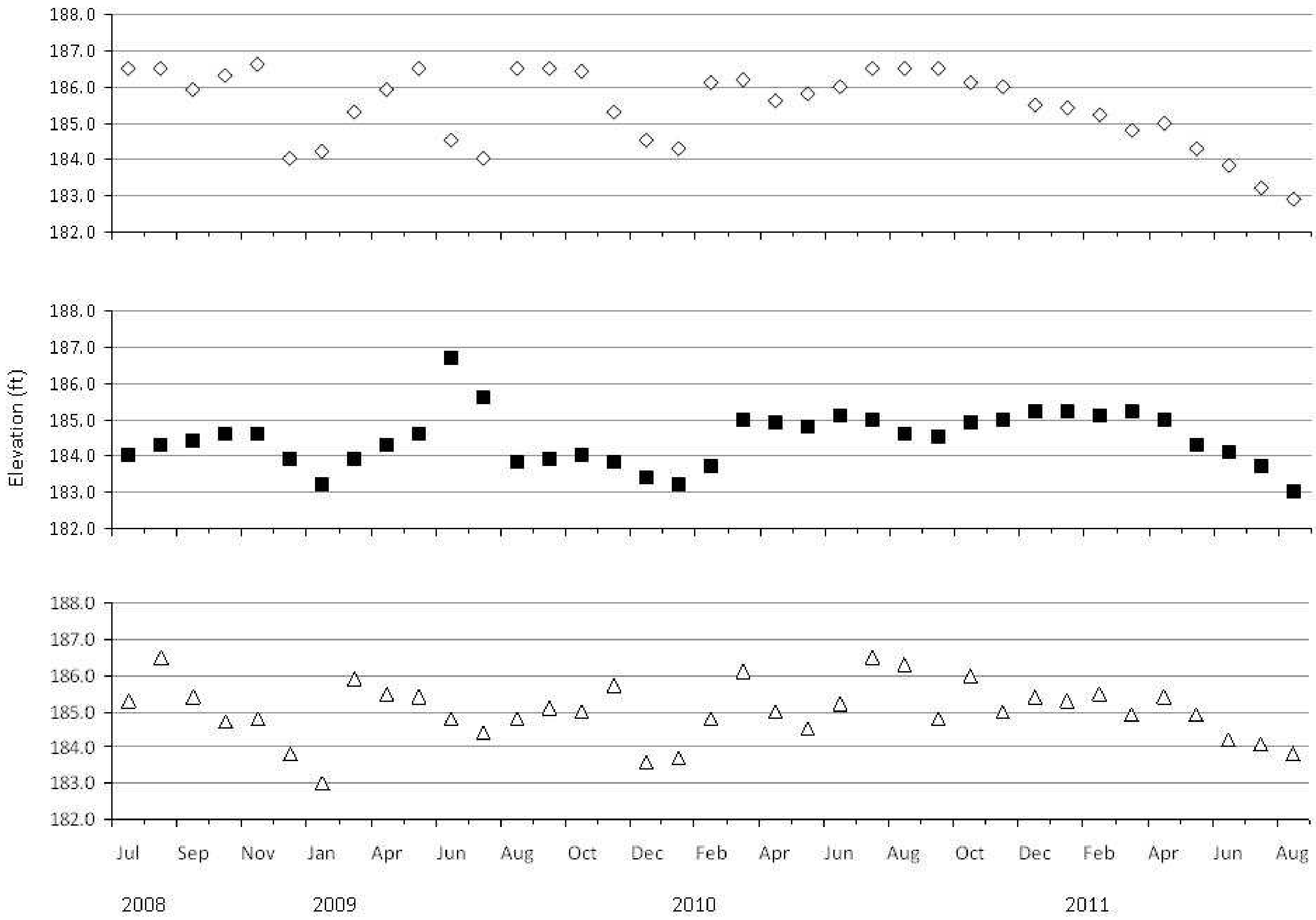


Figure 26. Pond elevations (ft) based on staff gauge readings for Pond 4 (open diamonds), Pond 5 (closed squares), and Pond 6 (open triangles) from July 2008 through August 2011. Elevation readings are limited to the top of the staff gauge at 186.5 ft.

Appendix A

Photopoint Reference Datasheet

Date:

Pond #1	**UTM 11S**	**Bearing**
Photo # 1 (A)	734127 E 3653798 N	223
Photo # 2 (B)	734127 E 3653798 N	247
Photo # 3 (C)	734152 E 3653558 N	349
Photo # 4 (D)	734152 E 3653558 N	298
Comments		


A


B


C


D

Date:

Pond #2	**UTM 11S**	**Bearing**
Photo #1 (E)	734156 E 3653527 N	291
Photo #2 (F)	733990 E 3653329 N	325
Photo #3 (G)	733963 E 3653337 N	60
Comments		


H

Date:

Pond #3	**UTM 11S**	**Bearing**
Photo #1 (H)	733973 E 3653314 N	160
Photo #2 (I)	733970 E 3653312 N	96
Photo #3 (J)	734303 E 3652980 N	319
Comments		


I


J

K

Date:

Pond #4	**UTM 11S**	**Bearing**
Photo #1 (K)	734048 E 3652685 N	95
Photo #2 (L)	734063 E 3652670 N	340
Photo #3 (M)	734121 3652993 N	181
Comments		

L

M

Date:

Pond #5	**UTM 11S**	**Bearing**
Photo #1 (N)	734134 E 3652966 N	84
Photo #2 (O)	734149 E 3652976 N	170
Photo #3 (P)	734224 E 3652523 N	37
Photo #4 (Q)	734339 E 3652588 N	348
Comments		

N

O

P

Q

Date:

Pond #6	**UTM 11S**	**Bearing**
Photo #1 (R)	734068 E 3652644 N	146
Photo #2 (S)	734240 E 3652348 N	254
Photo #3 (T)	734068 E 3652644 N	104
Photo #4 (U)	734233 E 3652341 N	329
Comments		

Appendix B
Pond Photopoints

Pond 1

	A	B	C	D

Oct 2008




Jan 2009




Apr 2009




Pond 1

A	B	C	D

Jan 2010

Apr 2010

Jan 2011

Pond 1

A	B	C	D

Apr 2011




Pond 2

	E	F	G
Oct 2008			
Jan 2009			
Apr 2009			

Pond 2

E F G

Aug 2009



Jan 2010



Apr 2010



Pond 2

	E	F	G

Jan 2011



Apr 2011



Pond 3

H I J

Oct 2008



Jan 2009



Apr 2009



Pond 3

H	I	J

Aug 2009



Jan 2010



Apr 2010



Pond 3

	H	I	J
Jan 2011			
Apr 2011			

Pond 4

K **L** **M**

Oct 2008



Jan 2009



Apr 2009



Pond 4

	K	L	M
Aug 2009			
Jan 2010			
Apr 2010			

Pond 4

	K	L	M
Jan 2011			
Apr 2011			

Pond 5

N	O	P	Q

Oct 2008




Jan 2009




Apr 2009




Pond 5

N O P Q

Aug 2009




Jan 2010




Apr 2010




Pond 5

	N	O	P	Q
Jan 2011				
Apr 2011				

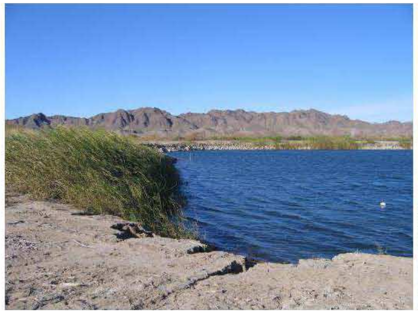
Pond 6

R | S | T | U

Oct 2008




Jan 2009

Apr 2009




Pond 6

R S T U

Aug 2009

Jan 2010

Apr 2010

Pond 6

R	S	T	U

Jan 2011




Apr 2011




Appendix C

Pond Summaries

Each pond since establishment (summer 2007), has had a different history of fish presence, stocking, and monitoring and will be summarized individually up through August 2011. All six ponds were sampled using trammel nets and electrofishing in September 2007 to detect fish and other species present in the ponds prior to stocking. Due to renovation and water delivery experiments being conducted by Reclamation, efforts to consolidate all native fish from ponds 2, 4 and 6 into Pond 1 began in November 2010 (autumn sampling). Consolidation efforts concluded in March 2011. Supplemental water pumping was discontinued in March 2011 to ponds 2, 3, 4, 5, and 6 to collect baseline water elevations and water-physico chemical parameters (e.g. natural conditions of the ponds without pumping).

Pond 1

During pre-stocking sampling in 2007, western mosquitofish (*Gambusia affinis*) were observed on the surface throughout the pond and one juvenile common carp (*Cyprinus carpio*) was captured. Red swamp crayfish (*Procambarus clarkii*) and American bullfrog (*Lithobates catesbeiana*) were also observed or captured prior to stocking Pond 1 with native fish. Pond 1 was stocked on November 5, 2007 with 305 razorback sucker, all of which were implanted with full-duplex (FDX) passive integrated transponder (PIT) tags. Post-stocking survival was relatively high (~70%) for the first six months, but estimates declined rapidly in summer 2008 and by October 2008, the population had crashed to approximately 20 fish (~6% survival). Water physico-chemistry did not appear to cause the crash because no measurement exceeded established thresholds. Two razorback sucker were found dead on July 25, 2008. Fourteen razorback sucker were salvaged from the pond and released into Pond 4 in February 2009.

Several species of non-native fish were captured during autumn sampling 2008. Threadfin shad (*Dorosoma petenense*), bluegill (*Lepomis macrochirus*), and warmouth (*Lepomis gulosus*) were captured in addition to the initially present carp and mosquitofish. The pond was dewatered and treated with rotenone in April 2009 with a follow up application in July 2009. Pond restoration was attempted for a second time April 20, 2010 to attempt to eliminate mosquitofish, the only remaining fish inhabiting the pond but the treatment was unsuccessful and mosquitofish continue to persist.

In May 2010, six spawning beds were installed via Reclamation. In November 2010, efforts to consolidate native fish from ponds 2, 4, and 6 began. As a result, 44 bonytail and 94 razorback sucker were released to Pond 1. Netting continued through March 2011 and an additional 68 bonytail and 30 razorback sucker were relocated to Pond 1 from ponds 2, 4, and 6. In March 2011, four bonytail and 10 razorback sucker were implanted with acoustic telemetry tags to study habitat preference during summer months. Due to an entrainment study at INWR, well water pumping was discontinued in March 2011. Pond 1 was connected to an independent line from the well in April 2011 and well water pumping was resumed in May 2011. Two brown pelicans (*Pelecanus occidentalis*) were observed by refuge staff feeding on fish (species unknown) the week of July 4, 2011 at Pond 1 (Joseph Barnett, INWR, personal communication). On August 12, 2011 an injured brown pelican was placed on Pond 1 by a third party and removed by refuge staff August 16, 2011. The pelican was observed eating fish and was to be scanned for PIT tags (Brenda Zaun, INWR, personal communication). On August 24, 2011, a dead juvenile razorback sucker was found floating on the surface of Pond 1. Total length was approximately 219 mm and the fish was presumed to be a recruit from spawning events in early 2011.

Pond 2

During pre-stocking sampling in sampling 2007, mosquitofish were observed throughout the pond and one adult carp was captured. At the time, submergent vegetation covered approximately 80% of the surface area, which was the most substantial build up among the six ponds. The pond was stocked with 800 PIT tagged (FDX) bonytail on December 12, 2007. Approximately 95% of the bonytail stocked perished within two months post-stocking, but no mortalities were directly observed by researchers or refuge staff. Few remote sensing contacts were made with bonytail in 2008. On October 9, 2008, several small (approximately 90 mm) bonytail were observed swimming near the boat ramp. During autumn 2008 sampling, 64 juvenile and one adult bonytail were captured along with non-native threadfin shad, bluegill, warmouth and mosquitofish.

Following autumn sampling 2008, an unsuccessful attempt was made to obtain data to calculate a mark-recapture estimate of the juvenile bonytail population. Twenty-eight juvenile bonytail were captured and marked (left pelvic fin clip) in December 2008 and recapture efforts in January 2009 resulted in the capture of 59 juveniles with no recaptures detected. Thirteen of the juvenile bonytail captured during these efforts were PIT tagged. In December 2008, 59 razorback sucker were stocked into Pond 2, each of which was implanted with a half duplex (HDX) PIT tag. An unknown number also contained an FDX PIT tag from a hatchery growth study. Three artificial habitats were deployed in Pond 2 in an attempt to provide cover for the remaining population of adult and juvenile bonytail. Each habitat was fitted with a PIT tag antenna and each habitat-antenna was deployed separately (January 29, March 31, and April 3, 2009). Post-stocking mortality of razorback sucker stocked into the pond was immeasurably low by July 2009. In autumn 2009, 17 adult razorback sucker were captured and redear sunfish (*Lepomis microlophus*) was added to the list of non-natives captured in Pond 2. A single striped bass (*Morone saxatilis*) was captured in spring 2010 and removed. The species has not been captured from the pond since. During autumn sampling in 2010, the first capture of a juvenile razorback sucker at Imperial Ponds occurred. The juvenile measured 315 mm TL and was captured in Pond 2. It was marked with a FDX PIT tag and released. During consolidation efforts in November, 2010, 112 bonytail and 49 razorback sucker were captured out of Pond 2. Two razorback sucker were untagged, it is unknown if they were natural recruits or stocked fish that shed their tags. All bonytail captured were untagged recruits.

Pond 3

During pre-stocking sampling in 2007, carp and mosquitofish were found throughout the pond. The pond was stocked with 800 PIT tagged (FDX) bonytail on December 12, 2007. Post-stocking survival was low, with an estimated 120 fish surviving through April 2008 (15% survival). No bonytail were captured during autumn 2008 sampling and no fish were contacted with remote sensing equipment since June 2008. Causes of initial mortality are unknown, but avian predation is a suspected to contribute to the decline. It is unknown if the 120 fish that survived through April 2008 were lost to unfavorable physico-chemistry conditions experienced in the summer months, to avian predation, or other unknown causes. Also during autumn 2008 sampling, non-native threadfin shad, carp, warmouth, bluegill, redear sunfish, and mosquitofish were captured. After extensive sampling for bonytail with no contacts or captures, this pond was believed to be devoid of native fish. In autumn 2009 sampling, black crappie (Pomoxis nigromaculatus) was added to the non-native species list captured in this pond. In February 2010 the pond was renovated. A complete kill was achieved at full pool. No bonytail were salvaged during the renovation. To date Pond 3 appears to be devoid of fish. Reclamation continues to sample the pond for possible non-native fish invasions. Besides being fishless, Pond 3 is unique among Imperial Ponds in that it is dominated by deep open water. The shoreline has not eroded and the banks are steep and covered with vegetation.

Pond 4

During pre-stocking sampling in 2007, mosquitofish were found throughout the pond. The pond was stocked with 272 PIT tagged (FDX) razorback sucker on November 5, 2007. Initial survival was high in Pond 4, estimated at 75% in the first year post-stocking (Kesner et al. 2008b), seven of the stocked razorback sucker were captured during autumn 2008 sampling. Non-native threadfin shad, bluegill, redear sunfish, warmouth, and mosquitofish were also captured during autumn 2008 sampling. Survival of stocked razorback sucker dropped to 45% by June 2009, and by July 2009, survival estimates were 13%. The decline was associated with hot summer conditions (May-September). No larvae were collected during the spawning season in 2008 or 2009. In autumn 2009, 18 adult razorback sucker were captured, and black crappie was added to the list of non-native species captured within Pond 4. Twenty-six razorback sucker were captured during autumn 2010 and spring 2011 consolidation efforts and moved to Pond 1. Two razorback sucker were captured untagged in Pond 4. It is unclear whether they were products of natural recruitment or stocked fish that shed their tags.

Pond 5

During pre-stocking sampling in 2007, mosquitofish were found throughout the pond. Pond 5 is the largest pond of the Imperial Ponds complex, and has a complexity of habitat not seen in other ponds including a large cattail marsh. The pond has never been stocked with native fish. Carp, bluegill and warmouth have been captured during minimal netting efforts since monitoring began. Threadfin shad have also been observed dead on shore in the summer months. During the past two summers (2009, 2010) there have been fish kills in late summer presumably from anoxia (average DO below threshold in August). The pond is often left out of water deliveries because water availability during most of the study period was restricted.

Pond 6

During pre-stocking sampling in 2007, mosquitofish were found throughout the pond and carp was suspected of being present, although none was captured. Sampling conducted in November 2009 captured non-native threadfin shad, bluegill, redear sunfish, warmouth, and mosquitofish. The pond was stocked with 198 PIT tagged (HDX and FDX) razorback sucker on January 15, 2009. Initial survival was low in Pond 6, estimated at 34.3% in June 2009. Three razorback sucker were found floating between February 10 and 11, 2009. The stocking event was particularly stressful because these fish were handled and PIT scanned two to four times at the release site due to a data recording error. Because HDX tagging had no measurable impact on survival of fish stocked into Pond 2, it is suspected that the treatment prior to release of Pond 6 fish was the major cause of their high post-stocking mortality. The population stabilized at approximately 50 individuals. Autumn sampling in 2009 captured 10 adult razorback sucker as well as non-native bluegill, warmouth, and black crappie. During consolidation efforts in autumn 2010, 49 razorback sucker were captured in Pond 6 and released into Pond 1. Two razorback sucker were untagged. It is unclear whether these fish were natural recruits or fish that shed both FDX and HDX tags, although the latter seems unlikely.