Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Imperial Ponds Native Fish Monitoring
August 2009 – August 2010

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

December 2010

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Imperial Ponds Native Fish Monitoring August 2009 – August 2010

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Lower Colorado River
Multi-Species Conservation Program
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Lower Colorado Region
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Summary

The focus of the third year of monitoring, sample year (SY) 2010 (August 1, 2009 to August 31, 2010), at Imperial Ponds was to monitor habitat use of resident razorback sucker *Xyrauchen texanus* and to monitor bonytail *Gila elegans* and razorback sucker recruitment. Adult razorback sucker populations in ponds 2, 4, and 6 have persisted with no detectable mortality during the sample year. Habitat use appears to shift across seasons, but habitat preference in any given season is different for razorback sucker populations in different ponds. Biplots of contact statistics did not yield any additional insight into patterns of razorback sucker habitat use among seasons, diel periods, or ponds except during the summer when deep open water areas are preferred and little activity is detected. Razorback sucker spawning activity appears to peak in late winter/spring on the boat ramps of ponds 2, 4, and 6, and the spawning bed in Pond 6 with nearly all members of the population visiting these areas during this period (January through March). Radio telemetry conducted in ponds 2 and 4 during the summer months provided additional support to the hypothesis that razorback sucker spend their days in the summer in deep open water locations. Razorback sucker larvae continue to appear seasonally in low numbers in ponds 2, 4, and 6, and one bonytail larvae was collected in Pond 2. One untagged subadult razorback sucker was captured in Pond 2 indicating successful recruitment of razorback sucker there, while observations of the young bonytail recruitment class of 2008 confirm their persistence.

Bluegill *Lepomis macrochirus*, common carp *Cyprinus carpio*, western mosquitofish *Gambusia affinis*, redear sunfish *Lepomis microlophus*, threadfin shad *Dorosoma petenense*, and warmouth *Lepomis gulosus*, continue to persist in most ponds. In addition to the previously documented species, black crappie *Pomoxis nigromaculatus* was captured in ponds 3, 4, and 6 during autumn sampling 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 SY 2010. Attempts to eliminate non-native fishes from Pond 1 were not successful in removing mosquitofish, but the renovation was apparently completely successful in Pond 3.

Water physico-chemistry parameters in all ponds have generally remained within acceptable limits where established (DO > 4 mg/l, and temperature < 33.3° C). Only pH continues to be near or above the threshold (pH < 9.0) for many of the summer months (June – August).

Introduction

Bonytail *Gila elegans* and razorback sucker *Xyrauchen texanus* are two critically imperiled, endemic fish 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 the species may be extirpated (Mueller 2006). Razorback sucker stocked into the lower basin have met with a similar fate, although stocking more than 200,000 razorback sucker into Lake Mohave has resulted in a small, persistent repatriate population of approximately 1,500 individuals (Marsh et al. 2005). Throughout the basin, predation by nonnative fishes has played a major role in decimating populations of stocked fish of either species (Karam et al. 2007; Kesner et al. 2005; Minckley et al. 2003). Given the incompatibility of native and nonnative fishes (Clarkson et al. 2005), conservation programs on behalf of both native species have been directed towards the establishment of off-channel habitats free of nonnative fishes.

At the request of the U.S. Bureau of Reclamation (Reclamation), and under the guidance of The Lower Colorado River Multi Species Conservation Program (LCR MSCP), a group of native fish experts developed a template for the reconstruction of a series of ponds on the U.S. Fish and Wildlife Service (USFWS) Imperial National Wildlife Refuge (INWR) along the Colorado River north of Yuma, Arizona (LCR MSCP 2008). The ponds were designed and built (Figure 1) as off channel habitat for bonytail and razorback sucker, and as testing grounds for habitat features that may aid in both species persistence. In 2007, two of the six Imperial Ponds were stocked with bonytail and two with razorback sucker. Nonnative common carp *Cyprinus carpio* and western mosquitofish *Gambusia affinis* were detected prior to stocking but considered a minimal threat to stocked native fish.

The first year of monitoring, August 2007 through June 2008 (sample year [SY] 2008) was used to test a range of techniques for monitoring population status, recruitment, and habitat use (Kesner et al. 2008). Remote Passive Integrated Transponder (PIT) scanning units were developed and found to be the most effective method to monitor stocked populations of PIT tagged native fish throughout the year, and expansion of this technique to track habitat use was recommended. Abundance of stocked bonytail declined dramatically within two months of stocking. The suspected cause was bird predation. Stocked razorback sucker appeared to hold steady 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. In the second year of fish monitoring at

Imperial Ponds SY 2009 (July 1, 2008 to July 31, 2009) additional nonnative species were identified in all - ponds (Kesner et al. 2010). Efforts to remove all nonnative fishes from ponds 1 and 3 were conducted. Meanwhile, the continued presence of nonnative fishes has hampered natural recruitment events for bonytail and razorback sucker.

We report here on the third year of monitoring. No stockings occurred in SY 2010. The focus during the reporting period was on pond renovation and razorback sucker habitat use monitoring.

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 1 mile west of the refuge headquarters. The ponds range in size from 9 to 17 surface acres. Features built into the ponds are gravel-lined boat ramps, steep silt-sand shorelines, one rip-rap (boulder) lined shoreline, a water inlet and outlet, and hummocks (LCR MSCP 2008). Hummocks are raised mounds of silt-sand with gravel-cobble sides. These mounds are usually submerged and designed for planting of emergent vegetation such as California bulrush *Schoenoplectus californicus*. Shorelines were also planted or invaded by cattail *Typha* sp., phragmites *Phragmites* sp., and bulrush. Additional features added since 2007 include a spawning bed in Pond 6 (an approximately 3 x 6 m cobble area along the shoreline in 1-2 m deep water) and 3 artificial habitats in Pond 2 (PVC tables with mesh tops). Each pond since establishment (summer 2007), has had a different history of fish presence, stocking, and monitoring and will be summarized individually up to the current sample year. 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.

Pond 1

In Pond 1, western mosquitofish were observed on the surface throughout the pond and one juvenile common carp was captured. Northern crayfish *Orconectes virilis* and bullfrog *Lithobates catesbeiana* were also observed or captured. 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 autumn sampling in October 2008, the population had crashed to approximately

20 fish (~6% survival). Two razorback sucker were found dead on July 25 of that summer (2008). Water - physico-chemistry did not appear to cause the crash because no measurement exceeded established thresholds. Several species of nonnative fish were captured during autumn sampling. Bluegill *Lepomis macrochirus*, threadfin shad *Dorosoma petenense*, and warmouth *Lepomis gulosus* were captured in addition to common carp and western mosquitofish. Fourteen razorback sucker were salvaged from the pond and released into Pond 4, after which it was dewatered and treated with rotenone on April 29, 2009. The pond was treated a second time on July 9, 2009 and remained at low pool throughout the summer.

Pond 2

During September 2007 sampling, western mosquitofish were observed throughout the pond and one adult common 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 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 nonnative bluegill, threadfin shad, warmouth and western mosquitofish.

Following autumn sampling, 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. Also 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. Initial post-stocking mortality of these fish was immeasurably low by the end of SY 2009.

Pond 3

During pre-stocking sampling in 2007, common carp and western mosquitofish were found throughout the pond. The pond was stocked with 800 PIT tagged (FDX) bonytail on December 12, 2007. Pond 3 is unique among the 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. Post-stocking survival was low, with an - estimated 120 fish surviving through April 2008 (15% survival). No bonytail have been captured during autumn 2008 sampling and no fish were contacted with remote sensing equipment since June 2008. During autumn 2008 sampling, nonnative common carp, threadfin shad, warmouth and western mosquitofish were captured. Initial mortality is believed to have been caused by avian predation on recently stocked fish. It is unknown if the 120 fish that survived through April 2008 were lost to unfavorable water physico-chemistry conditions in the summer months or to avian predation. After extensive sampling in SY 2009 for native fish in with no contacts, this pond was believed to have lost all native fish. In April 2009, the pond was treated with rotenone, and is believed to be free of nonnative fishes.

Pond 4

During 2007 sampling, western 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. 2008), and seven of the stocked razorback sucker were captured during autumn 2008 sampling. Nonnative bluegill, common carp, redear sunfish *Lepomis microlophus*, threadfin shad, warmouth and western mosquitofish were also captured during autumn 2008 sampling. Percent survival dropped to 45% by June 2009, and by the end of SY 2009, survival estimates were near 13%. Declines typically occurred during the summer months (May-September). There has been little evidence of successful spawning in Pond 4. No larvae were collected during the spawning season in 2008 or 2009.

Pond 5

During 2007 sampling, western 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. For these reasons, the pond has never been stocked with native fish. 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 there have been fish kills late in the summer presumably from anoxia with the lower range of DO readings near zero in August, although average DO readings were above threshold levels. The pond is often left out of water deliveries because current water availability is restricted and cannot sustain all six ponds.

Pond 6

During the pre-stocking sampling in 2007, western mosquitofish were found throughout the pond and common carp was suspected of being present, although none was captured. The pond was stocked with 198 PIT tagged (HDX and FDX) razorback sucker on January 15, 2009. Percent survival was low in Pond 6 and estimated at 34.3% in June 2009. Three razorback sucker were found floating between February 10 and 11, 2009. The stocking event was potentially more stressful than other stockings because the fish were transported from Willow Beach National Fish Hatchery and 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.

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. These activities were conducted to meet the goals of the monitoring program (LCR MSCP 2008). PIT scanners were deployed to monitor stocked bonytail and razorback sucker abundance and more recently to monitor razorback sucker habitat use. Attempts to collect razorback sucker and bonytail 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 nonnative fish invasion. In addition to routine trips, an intensive autumn sampling effort was conducted in October 2009 to assess health and abundance of stocked native fish, to detect native fish recruitment, and to acquire additional information on nonnative invasions. Water physico-chemistry data were collected to detect if and when parameters measured were below thresholds considered inhospitable for bonytail and razorback sucker and to direct pumping activities if threshold conditions were exceeded (Kesner et al. 2008). Monthly progress reports were submitted to Reclamation and to the Imperial Ponds fishery coordination team.

Population and Habitat Use Monitoring

PIT Scanning

PIT scanner units designed in SY 2008 and SY 2009 were used in SY 2010 to monitor native fish populations in Imperial Ponds. Their design is described in detail in our SY 2009 report (Kesner et al. 2010). A slight revision to data loggers in SY 2010 allowed the scanning rate to be manipulated, and the scan rate was experimentally reduced in some interim scanner deployments to determine if PIT scanning units could run continuously under summer conditions for two weeks without a significant loss in tag contacts.

Scanner data were downloaded to a PDA or laptop computer after the end of each effort cycle. Data were 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 half-duplex (HDX) and one full-duplex (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. Double tagged fish were recorded as many as 30 times within a single minute. 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 kept in the database, all habitat use 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.

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 (Ricker 1975). The number of fish marked or captured during a sampling trip was calculated from unique PIT scanner contacts within a sampling trip and pond. Recaptures 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.

In SY 2010, habitat use was monitored on a monthly basis using remote PIT scanners in ponds 2, 4, and -6. As in the last few months of SY 2009, PIT scanner deployments were standardized during sampling trips to collect comparable habitat use data for each pond. 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, CA) and randomization of deployment sites were described in the SY 2009 report (Kesner et al 2010). 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. Scanner units were placed at the random locations and moved every evening of the sampling trip before the crepuscular period. 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.

To analyze changes in habitat use 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 exceed the threshold for summer conditions as outlined in the monitoring plan (LCR MSCP 2008).

General habitat distributions among seasons were analyzed using a two-way contingency table χ^2 analysis. The total number of contacts was summed across sampling trips within seasons and habitats to complete the 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.

To investigate diel patterns of habitat preference, remote scanning contacts associated with habitat use deployments were divided into day- and night-time contacts. This was done 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, AZ 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. 2010).

The diel replicates were used to investigate patterns in habitat use among seasons, time of day and ponds. Four statistics were used to quantify different aspects of remote sensing contact data. The most basic of these statistics was the total number of contacts "Contacts" (total count of FIDs) and the number of unique contacts for each diel replicate "Uniques" (total unique FIDs). The relationship between these two statistics was expected to differ among seasons and habitats because some habitats may be preferential for the entire population at certain times of years (high total contacts, high unique contacts), or preferential for only a subset of the population that may use a habitat only seasonally as in the spawning period (high total contacts, low unique contacts).

The two other statistics were proportions; the proportion of total unique fish in a diel replicate that was repeatedly contacted "Repeat Proportion" (number of FIDs contacted more than once divided by Uniques) and the proportion of unique contacts for the entire sampling period (within the sampling trip and pond) contacted within a single diel replicate "Trip Proportion" (the total unique FIDs for the replicate divided by the total unique FIDs for all replicates and habitats within the sampling trip and pond). These two statistics help differentiate cases with similar values of Contacts and Uniques, but different razorback sucker movement patterns. The first proportion can differentiate two apparently similar cases where Contacts is much higher than Uniques. The large number of Contacts may be due to a small proportion of total Uniques returning to the same location over and over, or nearly all of the Uniques returning to the same location at least twice. The second proportion can differentiate cases where a large number of Contacts and Uniques were found both at the level of a diel replicate and during the trip itself (seasonal trend in activity), and a case where a single point location contained the vast majority of Contacts and Uniques for a whole trip (potential hot spot). Also given the results of SY 2009 habitat use scanning, this value should be low for most diel deployments because the previous year's data showed the majority of razorback sucker were only contacted in one habitat over a 24 hour -period.

Biplots of combinations of the four statistics were developed with shapes and colors used to delineate habitats and seasons respectively, and day and nighttime replicates were plotted separately. The combinations were chosen as follows; Uniques vs Contacts, Contacts vs Repeat Proportion, Contacts vs Trip Proportion and Trip Proportion vs Repeat Proportion. Diel replicates with no contacts were not plotted. Visual inspection of the biplots was used to determine if replicates grouped together indicating a pattern of fish behavior for a given season, habitat, or both. In some cases, a functional relationship was expected, e.g. increasing Uniques with increasing Contacts with an asymptote at the population size, and the biplots were examined for different trajectories among seasons or habitats. A biplot with a shotgun pattern (random points for all replicates among seasons and habitats) or a consistent trajectory among all replicates regardless of season or habitat were considered negative results. Comparisons between ponds and diel periods for each biplot were also made.

Additional remote scanner deployments were made on boat ramps and other "hot spots" when scanners were available during routine monitoring trips. This data will be assessed for the final report but was not evaluated in the current sample year. Scanners were also redeployed at the end of a sampling week and left to scan between sampling trips, often with a cycle start and end time. This "interim" scanning provided additional contacts for population and spawning activity monitoring. 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. The number of FIDs in common between two interim periods was entered into each cell with the starting date of the interim period as the column and row headings. Each table was symmetrical along the middle diagonal, and so the top half was left blank. The cells within the middle diagonal contained the number of contacts for a given interim period (the point where row and column heading were equal). 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 was also - conducted using a table where the number of FIDs in common between the boat ramp and spawning bed for the same interim period was the diagonal.

Radio tracking

A radio telemetry study was initiated in spring 2010 due to the paucity of remote scanning contacts during the summer months. The lack of contacts was believed to be due to a lack of movement during the hot summer months, and the razorback sucker were suspected of being sedentary near the bottom of the pond in cooler water. Radio telemetry was chosen 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. Adult razorback sucker captured from the two ponds were mounted with radio transmitters (Advanced Telemetry Systems [ATS], Inc. Isanti, MN, model F-2020) and released into the pond of capture. Fish were tracked on subsequent sampling trips 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 at least once each trip. Tracking was conducted during the daytime and nighttime hours.

Annual Autumn Sampling

The second annual autumn sampling was conducted 5-9 October 2009. Hoop nets were the primary sampling technique used to capture stocked native fish as they had previously proven effective at capturing bonytail and razorback sucker in Imperial Ponds (Kesner et al. 2008). 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) were deployed, as well as three Oneida-type traps (1.2 m x 1.2 m x 1.2 m with three 3.7 m wings). Minnow traps (Gee standard, 6.4 mm mesh or exotic 3.2 mm mesh) were also deployed to detect juvenile native and nonnative fish. Hoop nets and minnow traps fished continuously but were checked at least once daily and cleared of all fish. Pond 1 was sampled using a gill net (38.1 long m x 1.8 m depth, 12.7 mm mesh) to detect potential nonnative fish invasion.

In ponds where target numbers of native fish species (25 per species and pond) could not be caught - using hoop nets, trammel nets (22.9 m long, 1.8 m deep, .38.1 mm mesh & 22.9 m long, 1.8 m tall, 76.2 mm mesh) were used to increase catch. Soak time was kept to less than three hours to minimize stress on native fish encountered.

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 (TL), sexed (juvenile, male, female, or unknown), assessed for condition, and checked for external parasites and wounds before being returned to their pond of capture. All data were recorded on "Rite in the Rain"® datasheets and later transferred into the Microsoft Access® database. Nonnative fish captured were identified to species (except juvenile sunfish that could not be reliably identified), enumerated and sacrificed.

Spawning and Recruitment

Spawning was expected by razorback sucker in ponds 2, 4, and 6 because all three ponds have adult razorback sucker populations that persist. An attempt to collect razorback sucker and bonytail larvae was made in each pond from January through May 2010 during routine monitoring trips. Fishing lights rated to 250,000 candle power were deployed in the evening after dark and aquarium dip nets were used to capture larvae, which are phototactic. Larval sampling in SY 2010 was extended through May to encompass the known spawning season of bonytail. Potential razorback sucker or bonytail larvae were preserved in 95% ethanol for genetic analysis at Arizona State University.

Snorkeling surveys were conducted when water clarity permitted, to observe spawning adults or juvenile native fish. No fish were observed during snorkeling transects in SY 2008, and so snorkeling surveys in SY 2009 and SY 2010 were opportunistic, targeting areas of potential fish concentration and were used for qualitative, not quantitative fish observations.

Invasive Species

Gill netting and hoop netting were conducted to sample and remove nonnative species from ponds prior to spring-summer spawning in Pond 6. These data supplemented nonnative 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 nonnatives. 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; nonnative fish were sacrificed.

Pond renovations which began in SY 2009 continued in SY 2010. A second attempt to renovate Pond 1 and a first attempt to renovate Pond 3 were conducted in spring 2010. Both ponds were treated with rotenone on February 17, 2010 (first application) and on April 20, 2010 (second application). Pond 1 was treated near full pool at an elevation of 184 ft, and Pond 3 was treated at full pool (186 ft).

Water Physico-chemistry

Water physico-chemistry at Imperial Ponds was monitored at least once a month throughout SY 2010, and twice a month during summer (defined as when the mean water temperature exceeded 27° C). Vertical profiles of the water column were recorded using a Hanna Instruments® (Woonsocket, RI) HI9828 multi-parameter probe, at the bottom, mid-depth, and surface at three locations in each pond; inflow, mid-pond, and near the outflow. Nominal parameters measured included temperature, 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) were also recorded.

Results

Routine sampling trips to Imperial Ponds were conducted by a minimum of two biologists twice a month except in November and December 2009, which had one trip each, resulting in a total of 24 routine sampling trips in SY 2010 (Table 1). This included the annual autumn sampling conducted in October 2009. Sampling in SY 2010 was focused on ponds 2, 4, and 6 for most of the year due to a 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.

Population and Habitat Use Monitoring

PIT Scanning

In SY 2010 a total of 496 scanner deployments and 27,686 scanning hours were conducted, resulting in 41,352 razorback sucker PIT tag contacts (Table 2) and 38 bonytail contacts. Interim PIT scanning accounted for 17,640 (49 %) of the total HDX contacts, while routine scanning accounted for 18,631 (51%) of the total HDX contacts. Pond 2 had the highest number of razorback sucker HDX contacts and the highest contacts per effort for that tag type, CPE (Catch Per Unit Effort in contacts per scanning hour), with 29,528 HDX (CPE 2.44). Pond 4 had the highest number of razorback sucker contacts and CPE for FDX tags 2,149 (CPE 0.80). Pond 6 was second in total contacts with 6,743 HDX and 727 FDX contacts. All 38 FDX bonytail contacts were from Pond 2. Pond 3 was not scanned in SY 2010.

Razorback sucker populations were remarkably stable in SY 2010 for all three ponds in which the species persists (Table 3). Two of the three ponds had statistically insignificant differences in abundance between the beginning and end of the sample year. The most recent (July 2010) population estimates for ponds 2 (33 fish) and 6 (48 fish) are within the 95% confidence intervals (CI) of estimates made for the same month in July 2009 as reported in the September 2009 monthly monitoring report; 21 to 59 fish for Pond 2 and 33 to 78 fish for Pond 6. Estimates for Pond 4 are more sporadic due to the use of only FDX PIT tags. The most recent estimate available is from March 2010 with an estimated 30 fish, an estimate that is well within the 95% CI of the estimate from October 2009 (14 to 84, November 2009 monthly monitoring report), but outside the 95% CI of the most recent estimate from SY 2009 with an estimate of 121 and a 95% CI from 75 to 206 fish (July 2009 monthly monitoring report). This apparent die-off in the summer of 2009 was followed by stability throughout SY 2010.

Habitat use scanning was conducted in ponds 2, 4, and 6 at least once each month. This resulted in a total of 437 successful habitat use PIT scanner deployments among the three ponds (Figures 2-4); 21 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 hours was 9,896 hours for a mean deployment length of 22.64 hours. These standardized deployments resulted in 2,659 FID contacts: 37 bonytail and 2,622 razorback sucker.

Habitat use based on standardized sampling for razorback sucker stocked into ponds 2, 4, and 6 was not - consistent among seasons or ponds (Figures 5-7). Two-way Pearson χ^2 analyses of habitat and season for each pond indicated significant differences (p <0.001) in seasonal habitat use for each pond. Statistical significance for Pond 4 is unreliable due to lack of contacts in the open water and hummock in the spring (expected values below 4).

Habitat use not only varied between seasons but also between ponds. A majority of contacts during winter in ponds 2 and 6 were from deployments on hummocks, while in Pond 4, the majority came from rip-rap shore. In spring, ponds 4 and 6 had most contacts in mud and rip-rap shore habitats, while most contacts were from hummock and mud shore habitats in Pond 2. In summer, Pond 2 deployments had a majority of contacts on hummocks, while Pond 4 had most contacts on mud shore and Pond 6 in open water. In autumn, a majority of contacts were from mud shore in Pond 2, open water in Pond 4, and hummocks in Pond 6.

All biplots for ponds 2 and 6 were negative for grouping patterns or changes in trajectory among seasons or habitats. A unified trend was apparent in biplots of Trip Proportion vs Contacts with all habitats and seasons scattered around an asymptotic relationship; increasing Contacts resulted in increasing Trip Proportion with an asymptotic approach to one (Figures 8 and 9). Seasons and habitats with typically the most contacts, already indicated by contingency table analysis and χ^2 tests (Figures 5-7), appeared grouped toward the top of the trend, but all replicates appeared to be along the same trajectory indicating similar fish behavior. A few summer replicates appeared well above the Contacts-Trip Proportion trend with large values for Trip Proportion and low values of Contacts in ponds 2 (Figure 8) and 6 (Figure 9) indicating that summer fish contacts were hit or miss, i.e. a single diel replicate acquired the majority of contacts for the whole sampling period. A random assortment of points was apparent in the biplot of Trip Proportion vs. Repeat Proportion in ponds 2 (Figure 10) and 6 (Figure 11), with no grouping among seasons (colors), or habitats (shapes). Biplots for Pond 4 where fish were only tagged with FDX tags generally contained too few points for evaluation. Although biplots of nighttime contacts always had markedly more points, trends were similar between the two diel periods.

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 use these locations during the spawning season from December to May (Table 4). Due to scanner problems, contact data are not available for every pond every period, but comparisons between two ponds were possible for the majority of interim sampling periods. The greatest number of fish was contacted in January in all three ponds. Total number of contacts on boat ramps varied from pond to pond. In Pond 2, the greatest number of contacts was in March whereas in Pond 4 most contacts occurred in January and in Pond 6 it was in February. Overall, the proportion of fish that were contacted multiple times was highest between December and the beginning of April. 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, from 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 of unique razorback sucker contacts also indicate that fish revisit boat ramp and spawning bed (Pond 6) locations multiple times between the months of December and May (Tables 5 – 8). As the number of razorback sucker that were contacted at boat ramp locations decreased over the spawning season, so did the number of fish that revisited the boat ramps. In general, the number of fish contacted at boat ramp locations in ponds 2, 4, and 6 was relatively high from December to March, then decreased by more half between trips in March and April and stayed relatively low until the last deployment in May (Tables 5 – 7). In Pond 4, no fish were contacted during the weeks of February 19 or March 5 (Table 4), even though scanners recorded an effort time. The absence of contacts may be due to a logger malfunction, and may not be indicative of a true absence of razorback sucker movement at that time. Unlike the trend at boat ramp locations, the number of contacts at the spawning bed in Pond 6 continued to fluctuate, and did not decrease by more than half over the course of the spawning season (Table 8).

Cross trip comparisons for the boat ramp and spawning bed locations in Pond 6 indicate that razorback sucker visited both locations throughout the spawning season (Tables 7 and 8). On average, more fish were contacted on the boat ramp than the spawning bed from the beginning of January to mid-February. Then, the trend switched so that, on average, more fish were contacted on the spawning bed from mid-February to the end of May. Comparisons of any two trips indicate that between 10 and 29 fish were contacted at both the spawning bed and boat ramp locations (Table 9).

Radio tracking

Four razorback sucker in Pond 2 and three razorback sucker in Pond 4 were captured and radio tagged on April 12, 2010 (Table 10). A single specimen of nonnative striped bass *Morone saxatilis* (430 mm TL) was also captured in Pond 2 during this sampling, the first known occurrence of this species at Imperial Ponds. Fish were tracked every trip from mid April thru mid July. A total of 339 and 450 minutes were spent tracking resulting in 22 and 8 total contacts in ponds 2 and 4, respectively. All seven fish tagged 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). Fifty percent of fish contacts in Pond 4 were during the crepuscular period or during hours of complete darkness. Of these 60% were active. There was only one contact that was not active (sedentary) during night time hours. This fish had been active during night time hours and dusk in April and May respectively. It was contacted in Pond 2 in July very close to the inlet pipe while the pump was running. Eighty-six percent of fish contacts were in open water in Pond 2. Sixty percent of fish contacted during the daytime hours were inactive in Pond 2. All fish that were inactive in Pond 2 were located in open water approximately 3 m in depth. All contacts in Pond 4 were in open water on the south side of the pond. All daytime fish contacts in Pond 4 were inactive.

Annual Autumn Sampling

A total of 3,456.3 hours netting resulted in the capture of 2,530 fish (Tables 11 [effort] and 12 [catch]). No fish were captured in Pond 1, but western mosquitofish were observed there. In ponds 2, 4, and 6 razorback sucker represented 2.0, 2.1, and 2.7% of the catch respectively. No bonytail were captured. A notable find during sampling was the first capture of a juvenile razorback sucker at Imperial Ponds. The juvenile measured 315 mm TL and was captured in Pond 2. It was marked with a FDX PIT tag and released. This is the first evidence of survival beyond the larval stage for razorback sucker in Imperial Ponds. Aside from native fish, all nonnative species captured during 2008 autumn sampling also were found in 2009 sampling (Table 2). In addition to the previously documented species, black crappie was captured in ponds 3, 4, and 6. This was the first observation of black crappie in the ponds.

Spawning and Recruitment

Eleven razorback sucker larvae and one bonytail larva were collected in Pond 2 in 461 minutes of night-lighting, one razorback sucker larva in Pond 4 in 225 minutes, and no larvae in 285 minutes in Pond 6 over the sampled spawning season, January through April (May in Pond 2). Hundreds of fish larvae were - observed in Pond 2. These were assumed to be threadfin shad based on their size, approximately 2 mm TL and shape (laterally compressed). In May, threadfin shad post-larvae and juveniles were positively identified and were abundant with TLs ranging from 10 to 25 mm. Schools of adult sunfish *Lepomis* spp. were observed in daylight hours guarding their nests on boat ramps and hummocks in April in ponds 2 and 6. Samples of larvae were identified in the lab and sent for genetic analysis (T. Dowling, Arizona State University). Only positively identified native fish larvae were reported.

Three razorback sucker without PIT tags were captured in Pond 4 during netting for radio telemetry fish in April 2010. Whether these fish were recruits from 2008 or 2009 is unclear, but it is likely they were stocked fish that had lost their tags because they were all over 425 mm TL.

A successful bonytail recruitment event was documented in Pond 2, but its size was never determined. More than 100 juveniles were captured and processed without a single recapture (Kesner et al. 2010). During larval sampling in SY 2010, a school of 30-40 bonytail was observed around the boat ramp area. These bonytail are likely surviving recruits from the 2008 spawning event. One bonytail was captured as incidental catch during April radio telemetry netting. No PIT tag was detected in that fish, which was 364 mm TL, ripe and tuberculate male. It was implanted with an FDX PIT tag and released, and has been scanned 12 times since (April to June 2010).

Invasive Species

No sampling outside of the annual autumn sampling was conducted to control or detect nonnative fishes in monitored ponds. Minnow traps were deployed by M&A and Reclamation personnel in renovated ponds (ponds 1 and 3) to determine if the renovation was successful. Uncounted numbers of western mosquitofish captured in post-renovated Pond 1 were the only fish discovered to date and the renovation in Pond 3 appears successful. The suite of nonnatives captured during autumn sampling likely remain in all other ponds.

Water Physico-chemistry

Means of most physico-chemical variables: DO, temperature, conductivity, and TDS for Imperial Ponds have remained within acceptable limits where established (Figures 12-16); pH < 9.0, DO > 4 mg/l, and temperature < 33.3° C. In SY 2010, mean DO went below its threshold to 3.96 mg/l, in the second trip of August 2010 for Pond 3. Mean DO ranged from 3.96 (Pond 3, August 2010) to 16.67 mg/l (Pond 2, June 2010). Mean pH for all ponds ranged from 7.48 (Pond 1, July 2010) to 9.21 (Pond 3, July 2010). Mean pH exceeded the threshold of 9.0 in Pond 2 October 2009 (9.10) and June 2010 (9.03), in Pond 3 in July 2010 (9.21) and Pond 6 in June and August 2010 (9.04 and 9.05, respectively). Mean temperature for all ponds ranged from 11.53 (Pond 5, January 2010) to 32.07°C (Pond 2, August 2010). Mean TDS reached a maximum of 2,743 mg/l (Pond 5, December 2009) and a minimum of 484 mg/l (Pond 2, August 2010). Finally, mean conductivity ranged from 968 (Pond 2, August 2010) to 5,486 µS/cm (Pond 5, December 2009).

Minimum and maximum values of pH, DO, and temperature have, however, exceeded established thresholds multiple times within the sampling year, most notably during summer months. Maximum values of pH above 9.0 have been recorded in August through November of 2009 and June through August 2010. Values ranging from 9.04 to 9.75 have been recorded multiple times in ponds 2, 3, 4, and 6. Minimum values of DO below 4 mg/l have been recorded in seven months from August 2009 through August 2010 and at least twice in each pond. Most values below the threshold have been at the bottom at the same locations that have DO above the threshold at the middle and surface of the water column. Maximum temperature of 33.4 to 34.5° C was recorded in August 2009 and 2010, respectively.
Water elevation in all ponds remained consistent, not fluctuating more than two feet (0.61 meters), throughout SY 2010 (Table 13). Water clarity fluctuated in all ponds, except for Pond 2, by a meter or more throughout the year. Water clarity in Pond 2 was high enough that the Secchi disk was seen from the pond bottom on 69% of the sampling trips. Ponds 1 and 3 had notable changes in water clarity around March, when Secchi depth started decreasing in Pond 1 and increasing in Pond 3. Secchi disk and staff gauge readings were not taken in Pond 1 in August and September 2009 due to remediation efforts.

Discussion

Results from the third year of fish and habitat monitoring at Imperial Ponds show that native razorback sucker and bonytail are able to survive, reproduce, and recruit there with minimal management if proper water physico-chemistry is maintained. Mortality for razorback sucker in all three ponds where they persisted was virtually undetectable during SY 2010. Stocked individuals of bonytail continue to be absent from capture and remote sensing data, and few if any persist, but a population of bonytail recruits persists in Pond 2. Recruitment of bonytail and razorback sucker has been detected in Pond 2, despite the presence of a suite of nonnative fishes. The capture of a single striped bass, a known predator of adult razorback sucker and bonytail, is alarming, but only if it is indicative of a larger population and not an isolated incident.

Although SY 2009 was wrought with high razorback sucker mortality rates, SY 2010 had little. In fact, estimates of survival during the sample year in all ponds (range 80 to 90%) exceed the estimate of adult razorback sucker annual survival in Lake Mohave, about 75% (Marsh et al. 2005; Marsh et al. 2003). This high survivorship may be due to water management changes in SY 2010. Well water was the major source of remedial water during the hot summer months for all ponds with native fish during SY 2010. In previous years, a mix of slough and well water was used. The single well pump does not appear capable of maintaining adequate water physico-chemistry for all six ponds, but currently it is the only pump connected to the pond system. This was done because the slough pump is a source for nonnative fish species introductions (McDonald and Karchesky 2010). However, relying on a single pump does have its risks. For example, a pump failure could lead to extremely stressful water conditions in the ponds during the hot summer months. A second well may provide enough water to manage all six ponds properly and a backup pump, either shared or for each well, would reduce the risk of native fish losses in the ponds. Recruitment, although detected, is still highly limited likely due to the presence of sunfish, common carp and western mosquitofish which are all known ovivores or larvivores (Christopherson et al. 2004; Johnson et al. 1993; Schooley et al. 2008). These issues will likely be alleviated as pond renovations continue, native fish stockings resume, and water supplies continue to improve.

Successful recruitment of both razorback sucker and bonytail in Pond 2 was unexpected. The reasons for success in Pond 2 and not in other ponds can only be speculated. Pond 2 had the largest aquatic vegetation bloom in summer for the first three years (but not in 2010), and this may have provided - adequate cover for larval and juvenile bonytail and razorback sucker to avoid predation while at a vulnerable size. Yet, attempts to estimate number of recruits for bonytail and razorback sucker have failed because of a lack of adequate numbers of recaptures.

A full year of habitat use data was acquired in SY 2010, and generally razorback sucker appear to shift habitat preferences as seasons change. These shifts are not consistent among ponds, and more informative patterns have not been elucidated from remote scanning data. Remote scanning equipment can apparently contact razorback sucker with HDX tags on a consistent basis regardless of location, except during the hot summer months when activity appears minimal. Continuation of the time-intensive random deployments of remote scanners on a daily basis does not appear necessary to contact the majority of the population during much of the year, and seasonal habitat shifts may be detectable with more semi-permanent remote scanning deployments. The focus of future deployment will likely shift to more specific features of the ponds as these are added (spawning beds, artificial habitats) given the proportion of the population contacted during interim scanning on boat ramps and the spawning bed in SY 2010.

Water physico-chemistry, in general, has been adequate, but pH continues to be near or above threshold values for many of the summer months (June – August). Supplemental well water pumping was effective in lowering pH when thresholds were exceeded in June 2010, especially in Pond 6 where the maximum pH dropped from 9.74 at the end of June to 9.04 at the end of July. Well water pumping also was effective in keeping water temperature under the threshold values. A decrease in water clarity in Pond 1 corresponds to the timing of rotenone treatment in April.

Recommendations

As evidenced by the excellent native fish survival rate in SY 2010, well water should continue to be used as the only source of water for all ponds stocked with native fish.

Given the success of the renovation effort in Pond 3, renovation of all other ponds should be scheduled as soon as possible.

A new well should be installed and operational before the number of renovated ponds exceeds the capacity of the single well. In addition, a backup well pump for the existing well should be purchased or made available.

All stockings of razorback sucker and bonytail should contain at least a portion of HDX tagged fish. Analysis of scanning data from locations of increased activity (boat ramps, spawning beds) is facilitated by the use of HDX tags. Comparative re-contact data between HDX and FDX tagged bonytail can provide information on the impact the larger HDX tag has on bonytail survival.

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Table 1. Trip summaries for twenty-four routine monitoring trips conducted by Marsh & Associates at Imperial Ponds, Imperial NWR, AZ in sample year 2010 (August 1, 2009 through August 31, 2010).

Trip Dates	Activities
8-10 August 2009	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed minnow traps in Pond 1 to assess remediation success.
24-27 August 2009	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed minnow traps in Pond 1 to assess remediation success.
8-11 September 2009	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning.
21-24 September 2009	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning.
5-9 October 2009	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Conducted yearly sampling of all ponds. Deployed trammel and gill nets and set hoop nets and minnow traps in all ponds with native fish.
19-22 October 2009	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning.
9-13 November 2009	Collected water physico-chemistry data and deployed remote PIT scanner units.
14-18 December 2009	Collected water physico-chemistry data Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed trammel nets. Snorkeled.
4-8 January 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed trammel nets. Spot-lighted for larvae.
19-22 January 2010	Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed trammel nets. Spot-lighted for larvae.
1-5 February 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed trammel nets. Spot-lighted for larvae.

16-19 February 2010	Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed hoop nets. Spot-lighted for larvae. Scanned hummocks of Pond 6 with hand held antenna.
1-5 March 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed hoop nets. Deployed minnow traps. Spot-lighted for larvae. Snorkeled.
29-2 Mar/Apr 2010	Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed minnow traps. Snorkeled. Spot-lighted for larvae.
12-16 April 2010	Deployed remote PIT scanner units. . Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Deployed trammel nets. Spot-lighted for larvae.
26-30 April 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Conducted radio tracking.
10-13 May 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Spot-lighted for larvae. Conducted radio tracking.
24-28 May 2010	Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Spot-lighted for larvae. Conducted radio tracking.
7-11 June 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Conducted radio tracking.
20-23 June 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Conducted radio tracking.
5-8 July 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning. Conducted radio tracking.
19-22 July 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning.
2-5 August 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning.
16-20 August 2010	Collected water physico-chemistry data. Deployed remote PIT scanner units for habitat use scanning and trip interim scanning.

Table 2. Contact and effort summary for remote PIT scanner deployments conducted during routine sampling trips (Trip Monitoring) and between sampling trips (Interim Monitoring) to track population status and habitat use of stocked razorback sucker and bonytail at Imperial Ponds, Imperial NWR, AZ in sample year 2010 (August 1, 2009 through August 31, 2010). Razorback sucker and bonytail were tagged with either full duplex (FDX) or half duplex (HDX) tags, or both. Dashes indicate either an absence of scanning or absence of tag type for the given pond and month. Ponds without native fish were excluded (ponds 1, 3, and 5).

		Pond 2		**Pond 4**		**Pond 6**	
Year	**Month**	**FDX**	**HDX**	**FDX**	**HDX**	**FDX**	**HDX**
Trip Monitoring							
2009	August	-	26	1	-	39	106
	September	9	74	-	-	97	66
	October	6	200	12	-	225	183
	November	7	180	111	-	70	136
	December	18	151	38	-	92	307
2010	January	43	248	204	-	203	895
	February	121	4,274	151	-	200	551
	March	152	7,833	465	-	112	578
	April	67	832	133	-	76	443
	May	27	197	1	-	89	808
	June	50	326	13	-	8	52
	July	7	43	44	-	43	81
	August	4	24	8	-	5	17
Interim Monitoring		473	15,120	968		727	2,520
Totals		984	29,528	2,149	-	1,986	6,743
Scanning effort (hours)		12,069.4		7,184.4		8,433.8	
CPE (contacts per hour)		0.08	2.44	0.30	-	0.26	0.73

Table 3. Population (top) and survival (bottom) estimates calculated using remote monitoring data and the adjusted Peterson's mark-recapture formula (Ricker 1975) for stocked razorback sucker at Imperial Ponds, Imperial NWR, AZ in sample year 2010 (August 1, 2009 through August 31, 2010). Dashes indicate months without a population estimate due to a lack of recaptures.

		2009					**2010**						
Pond	**No. Stocked (Date)**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
2	59 (Dec 2008)	51	52	40	49	52	44	47	47	46		47	33
4	272 (Nov 2007)			34	29		28	32	30				
6	198 (Jan 2009)	50	55	57	55	54	55	55	54	55	51	43	48

		2009					**2010**						
Pond	**No. Stocked (Date)**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
2	59 (Dec 2008)	86	88	68	83	88	75	80	80	78		80	56
4	272 (Nov 2007)			13	11		10	12	11				
6	198 (Jan2009)	25	28	29	28	27	28	28	27	28	26	22	24

Table 4. Summary of razorback sucker contacts from remote scanning on boat ramps in ponds 2, 4, and 6 and on the spawning bed in Pond 6. Contacts per effort (CPE) represents the number of contacts per hour. 'FIDs above threshold' is defined as the number of unique fish (unique FIDs) that were contacted more than once for ponds 4 and 6, and more than five times for Pond 2.

Pond	Date	Total contacts	Effort hours	CPE	Unique FIDs	FIDs above threshold
Boat ramp						
2	18-Dec-09	1,309	155.60	8.41	44	41
	08-Jan-10	153	49.62	3.08	36	9
	22-Jan-10	837	87.83	9.53	47	39
	05-Feb-10	1,686	95.93	17.57	42	31
	19-Feb-10	361	87.20	4.14	38	22
	05-Mar-10	2,532	44.97	56.31	42	33
	01-Apr-10	758	48.02	15.79	36	26
	29-Apr-10	21	96.08	0.22	12	0
	12-May-10	32	96.07	0.33	7	2
	27-May-10	30	70.08	0.43	12	2
4	18-Dec-09	1	144.03	0.01	1	0
	08-Jan-10	89	96.02	0.93	24	22
	22-Jan-10	31	89.40	0.35	14	7
	05-Feb-10	31	138.17	0.22	17	7
	19-Feb-10	0	88.88	0.00	0	0
	05-Mar-10	0	192.08	0.00	0	0
	01-Apr-10	8	96.05	0.08	4	3
	12-May-10	5	288.08	0.02	4	1
	27-May-10	1	138.48	0.01	1	0
6	08-Jan-10	249	90.78	2.74	44	38
	05-Feb-10	293	96.18	3.05	40	31
	19-Feb-10	111	102.17	1.09	25	21
	05-Mar-10	0	192.18	0.00	0	0
	15-Apr-10	129	96.00	1.34	29	19
	29-Apr-10	15	96.10	0.16	11	1
	13-May-10	23	137.37	0.17	17	3
	27-May-10	45	266.68	0.17	22	9
Spawning bed						
6	18-Dec-09	99	144.05	0.69	36	26
	08-Jan-10	55	96.00	0.57	25	15
	22-Jan-10	30	87.55	0.34	17	9
	05-Feb-10	79	137.62	0.57	35	22
	19-Feb-10	113	72.05	1.57	31	19
	05-Mar-10	183	192.10	0.95	39	34
	01-Apr-10	47	96.02	0.49	20	12
	13-May-10	102	266.75	0.38	29	19

Table 5. Cross trips comparison of razorback sucker contacted on the boat ramp of Pond 2. Dates given are the first day of antenna deployment. Values in the diagonal are the total number of FIDs contacted on the trip of the corresponding date (row and column heading are equal).

	18-Dec-09	08-Jan-10	22-Jan-10	05-Feb-10	19-Feb-10	05-Mar-10	01-Apr-10	29-Apr-10	12-May-10	27-May-10
18-Dec-09	44									
08-Jan-10	35	36								
22-Jan-10	44	36	47							
05-Feb-10	39	32	42	42						
19-Feb-10	35	30	38	36	38					
05-Mar-10	40	32	42	39	36	42				
01-Apr-10	33	26	36	35	33	33	36			
29-Apr-10	12	9	12	11	12	12	11	12		
12-May-10	7	6	7	6	5	6	5	3	7	
27-May-10	12	11	12	9	8	10	7	3	3	12

Table 6. Cross trips comparison of razorback sucker contacted on the boat ramp of Pond 4. Dates given are the first day of antenna deployment. Values in the diagonal are the total number of FIDs contacted on the trip of the corresponding date (row and column heading are equal).

	18-Dec-09	08-Jan-10	22-Jan-10	05-Feb-10	19-Feb-10	05-Mar-10	01-Apr-10	12-May-10	27-May-10
18-Dec-09	1								
08-Jan-10	1	24							
22-Jan-10	0	13	14						
05-Feb-10	0	15	9	17					
19-Feb-10	0	0	0	0	0				
05-Mar-10	0	0	0	0	0	0			
01-Apr-10	0	3	1	4	0	0	4		
12-May-10	0	3	2	3	0	0	0	4	
27-May-10	0	0	0	1	0	0	1	0	1

Table 7. Cross trips comparison of razorback sucker contacted on the boat ramp of Pond 6. Dates given are the first day of antenna deployment. Values in the diagonal are the total number of FIDs contacted on the trip of the corresponding date.

	08-Jan-10	05-Feb-10	19-Feb-10	05-Mar-10	15-Apr-10	29-Apr-10	13-May-10	27-May-10
08-Jan-10	44							
05-Feb-10	33	40						
19-Feb-10	34	34	25					
05-Mar-10	0	0	0	0				
15-Apr-10	27	21	22	0	29			
29-Apr-10	11	9	9	0	8	11		
13-May-10	14	14	14	0	11	5	17	
27-May-10	20	17	18	0	15	7	10	22

Table 8. Cross trips comparison of razorback sucker contacted on the spawning bed of Pond 6. Dates given are the first day of antenna deployment. Values in the diagonal are the total number of FIDs contacted on the trip of the corresponding date.

	18-Dec-09	08-Jan-10	22-Jan-10	05-Feb-10	19-Feb-10	05-Mar-10	01-Apr-10	13-May-10
18-Dec-09	36							
08-Jan-10	17	25						
22-Jan-10	10	9	17					
05-Feb-10	22	14	11	35				
19-Feb-10	23	17	12	21	31			
05-Mar-10	26	20	11	27	27	39		
01-Apr-10	15	7	7	11	13	14	20	
13-May-10	22	15	12	19	16	20	11	29

Table 9. Cross trips comparison of razorback sucker contacted on both the spawning bed and boat ramp of Pond 6. Dates given are the first day of antenna deployment. Only trips during which antennas were deployed in both locations and during which razorback sucker were contacted are displayed. Values in the diagonal are the total number of FIDs contacted in both locations on the trip of the corresponding date. The total number of razorback sucker contacts for the boat ramp or spawning bed on a given trip date can be found in Tables 7 and 8, respectively.

		Spawning bed			
		08-Jan-10	05-Feb-10	19-Feb-10	13-May-10
Boat ramp	08-Jan-10	23	29	26	27
	05-Feb-10	20	28	29	23
	19-Feb-10	21	27	29	22
	13-May-10	11	10	12	11

Table 10. 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, Imperial NWR, AZ.

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 11. Sampling effort summary (hours of netting) for annual autumn sampling conducted October 5-9, 2009 at Imperial Ponds, Imperial NWR, AZ.

Pond	Hoop Nets	Trammel Nets	Box Traps	Minnow Traps	Total
2	821.3	22.2	66.1	604.1	1,513.7
3	591.7	5.5	31.8	444.8	1,073.3
4	193.2	14.5	74.8	147.2	429.6
6	253.8	8.0	28.7	149.3	439.7
Total	**1,859.5**	**50.1**	**201.3**	**1,345.4**	**3,456.3**

Table 12. Species capture summary for annual autumn sampling conducted October 5-9, 2009, at Imperial Ponds, Imperial NWR, AZ. A dash indicates a lack of effort or capture of that species for the given pond and method.

Species	Hoop Net	Box Trap	Minnow Trap	Trammel Net	Total
Pond 2					
Bluegill	66	2	50	--	118
Juvenile sunfish	25	--	147	--	172
Mosquitofish	--	--	9	--	9
Redear sunfish	29	9	--	--	38
Threadfin shad	3	--	--	--	3
Warmouth	329	4	175	1	509
Razorback sucker	1	--	--	16	17
Total	**453**	**15**	**381**	**17**	**866**
Pond 3					
Black crappie	6	--	--	1	7
Bluegill	18	14	--	--	32
Common carp	--	9	--	1	10
Juvenile sunfish	--	--	62	--	62
Mosquitofish	--	--	1	--	1
Redear sunfish	16	3	2	--	21
Threadfin shad	2	3	--	--	5
Warmouth	161	12	143	--	316
Total	**203**	**41**	**208**	**2**	**454**
Pond 4					
Black crappie	--	--	--	1	1
Bluegill	51	177	--	--	228
Juvenile sunfish	--	--	9	--	9
Redear sunfish	103	21	39	1	164
Threadfin shad	--	2	--	--	2
Warmouth	302	57	64	--	423
Razorback sucker	--	1	--	17	18
Total	**456**	**258**	**112**	**19**	**845**
Pond 6					
Black crappie	--	1	--	--	1
Bluegill	129	18	8	--	155
Juvenile sunfish	--	--	125	--	125
Redear sunfish	14	--	--	--	14
Warmouth	41	7	12	--	60
Razorback sucker	1	--	--	9	10
Total	**185**	**26**	**145**	**9**	**365**

Table 13. Water clarity, measured by Secchi depth in meters (top) and water elevation measured by staff gauge elevation in feet (bottom) for SY 2010 at Imperial Ponds. Asterisk (*) indicates that the Secchi disk was visible from the bottom of the pond. A dash indicates no readings were taken for the given pond and month. Plus (+) indicates water level exceeded the level of the staff gauge.

Secchi Depth (m)	**Pond 1**	**Pond 2**	**Pond 3**	**Pond 4**	**Pond 5**	**Pond 6**
August 2009	--	2.03*	0.62	3.17*	0.64	2.62
September 2009	--	2.59	0.87	2.98	0.78	3.12*
October 2009	1.39	2.62*	0.51	2.95*	0.52	2.8*
November 2009	0.88	2.29*	0.69	1.95	0.42	1.27
December 2009	1.33	2.36*	0.76	1.91	0.57	0.53
January 2010	1.80	3.10*	0.89	2.24	0.56	0.73
February 2010	2.67*	2.97*	0.64	2.44	0.43	2.54
March 2010	1.32	2.91*	1.36	1.40	0.79	2.13
April 2010	0.55	1.74	1.07	1.34	0.62	1.07
May 2010	1.13	2.39	1.54	2.04	1.07	2.75*
June 2010	0.73	2.24	1.55	2.62	0.73	2.13
July 2010	0.61	2.73*	1.28	3.09*	1.39	2.74*
August 2010	0.56	2.85*	1.42	3.01	1.49	3.20*
Staff Gauge (ft)						
August 2009	--	186.5+	183.8	186.5+	183.8	184.8
September 2009	--	186.5+	184.0	186.5+	183.9	185.1
October 2009	183.0	186.5+	186.1	186.4	184.0	185.0
November 2009	182.8	184.9	184.3	185.3	183.8	185.7
December 2009	183.1	184.9	183.9	184.5	183.4	183.6
January 2010	183.2	185.9	183.9	184.3	183.2	183.7
February 2010	183.9	185.7	184.5	186.1	183.7	184.8
March 2010	184.0	185.1	184.5	186.2	185.0	186.1
April 2010	184.0	185.8	186.5+	185.6	184.9	185.0
May 2010	185.0	185.5	185.5	185.8	184.8	184.5
June 2010	185.4	186.4	186.5	186	185.1	185.2
July 2010	185.2	186.5+	186.5+	186.5+	185	186.5+
August 2010	185.0	186.5+	185.9	186.5+	184.6	186.3

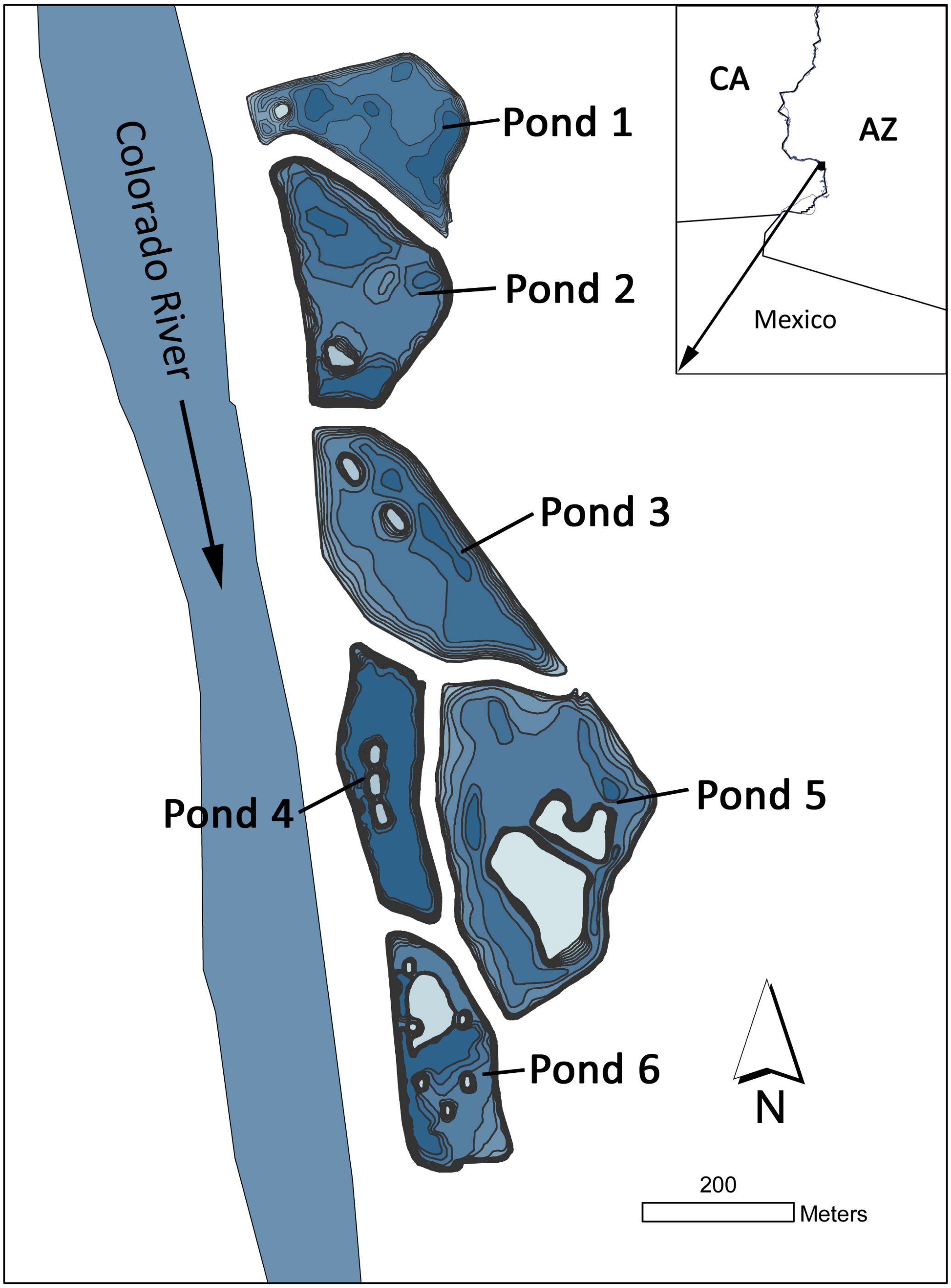

Figure 1. Bathymetric map of the six Imperial Ponds located at Imperial NWR, AZ, and area map (inset). Contour lines represent a change in elevation (pond depth) of one foot.

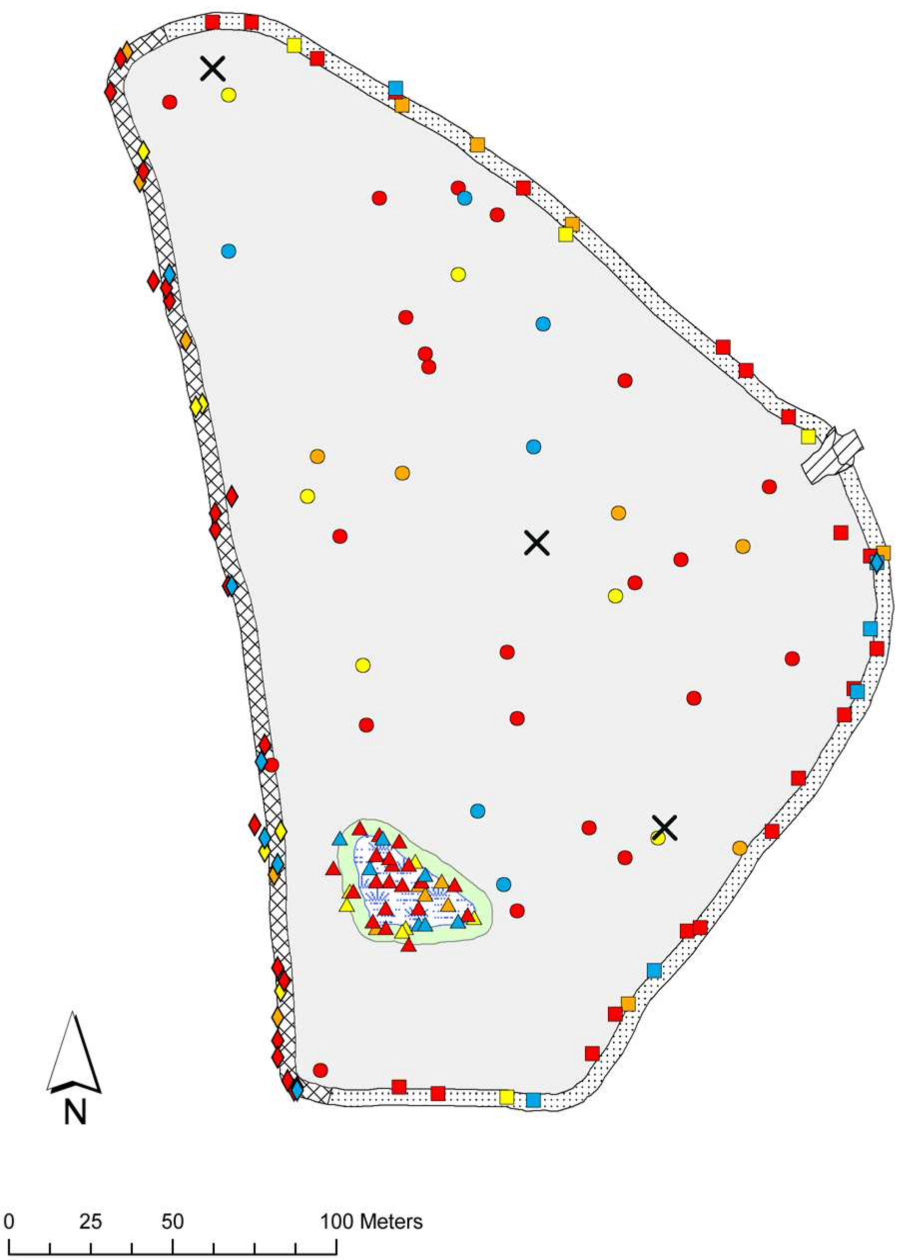

Figure 2. PIT scanner deployment locations in Pond 2 used to track razorback sucker habitat use in SY 2010 (August 1, 2009 to August 31, 2010). Mapped habitats are delineated by patterns and deployment locations by shapes rip-rap shore (checker pattern, diamonds), mud shore (dotted pattern, squares), hummock (vegetation pattern and green area, triangles), and open water (grey area, circles). Boat ramps were scanned as well (lined area), but treated as a single point location. Artificial habitat locations are indicated by the large X's. The season of scanning was indicated by color; summer (red), autumn (orange), winter (blue) and spring (yellow).

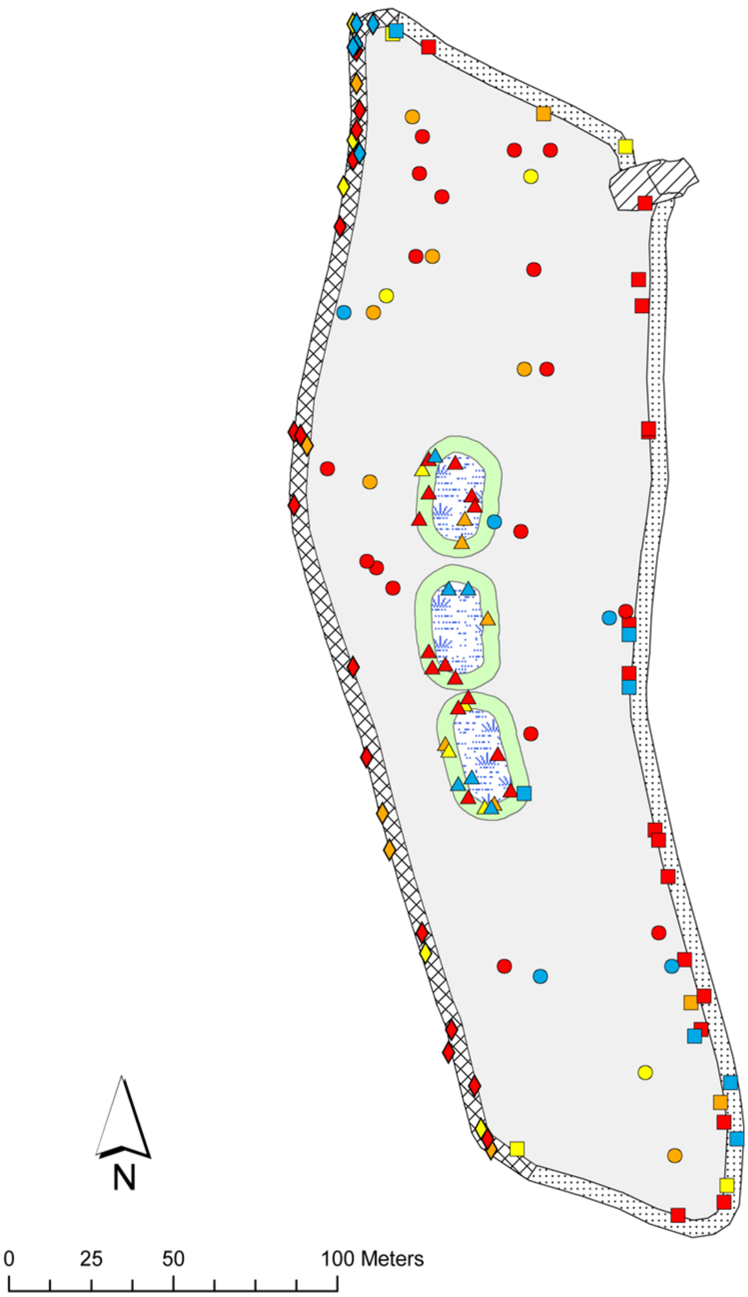

Figure 3. PIT scanner deployment locations in Pond 4 used to track razorback sucker habitat use in SY 2010 (August 1, 2009 to August 31, 2010). Mapped habitats are delineated by patterns and deployment locations by shapes rip-rap shore (checker pattern, diamonds), mud shore (dotted pattern, squares), hummock (vegetation pattern and green area, triangles), and open water (grey area, circles). Boat ramps were scanned as well (lined area), but treated as a single point location. The season of scanning was indicated by color; summer (red), autumn (orange), winter (blue) and spring (yellow).

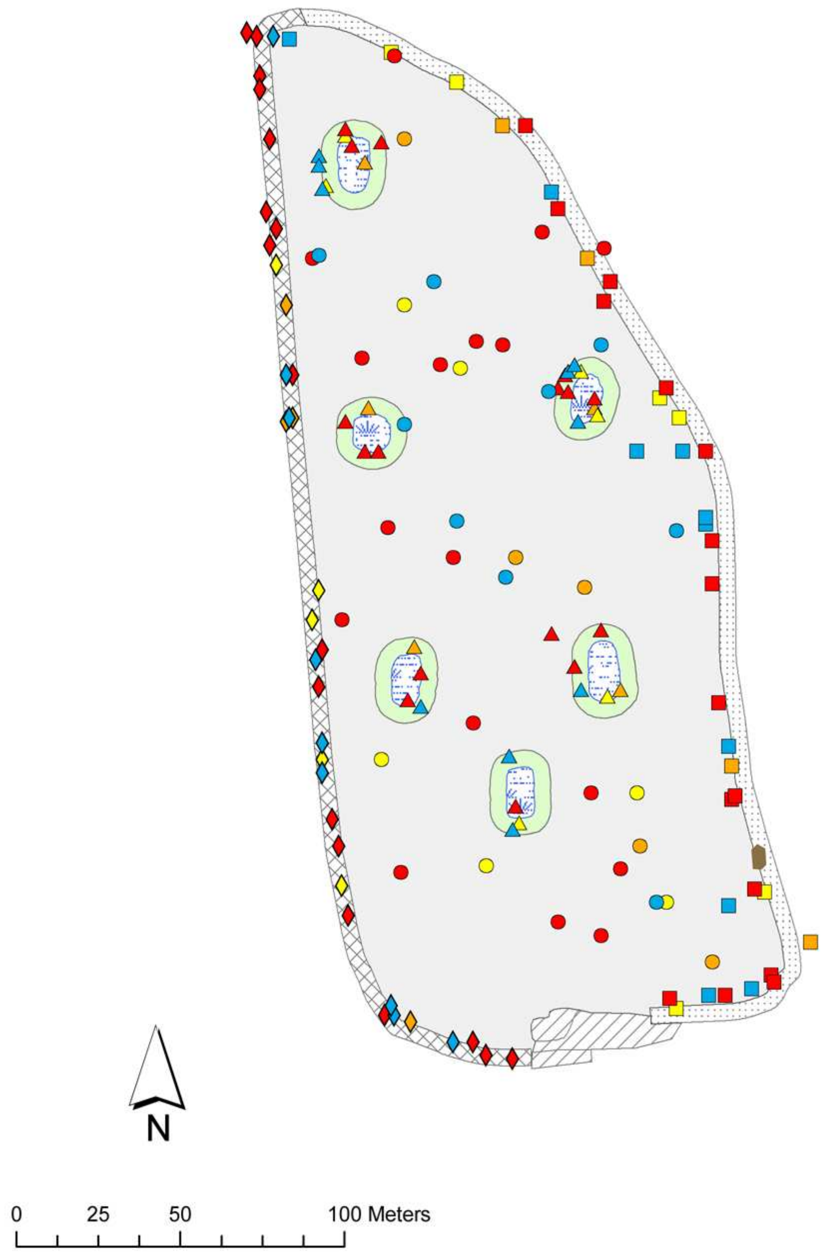

Figure 4. PIT scanner deployment locations in Pond 6 used to track razorback sucker habitat use in SY 2010 (August 1, 2009 to August 31, 2010). Mapped habitats are delineated by patterns and deployment locations by shapes rip-rap shore (checker pattern, diamonds), mud shore (dotted pattern, squares), hummock (vegetation pattern and green area, triangles), and open water (grey area, circles). Boat ramps were scanned as well (lined area), but treated as a single point location. The season of scanning was indicated by color; summer (red), autumn (orange), winter (blue) and spring (yellow).

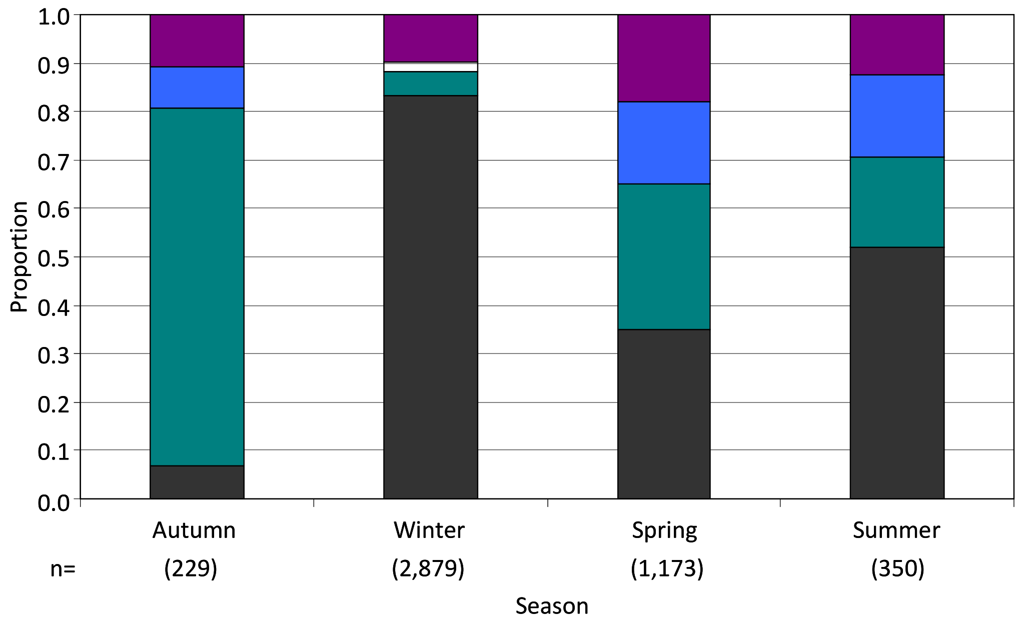

Figure 5. Seasonal PIT scanner contacts of razorback sucker from habitat use sampling in Pond 2 among four habitat types; hummock (dark grey), mud shore (teal), open water (blue), and rip-rap shore (purple). Two-way Pearson χ^2 test indicated significant differences ($p < 0.0001$) in seasonal habitat preference.

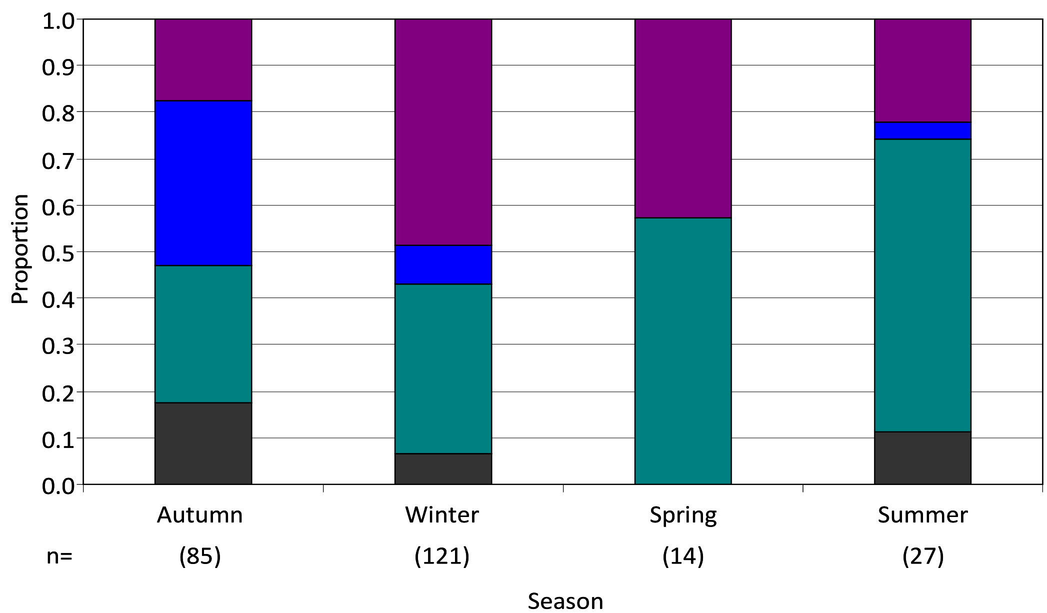

Figure 6. Seasonal PIT scanner contacts of razorback sucker from standardized habitat use sampling in Pond 4 among four habitat types hummock (dark grey), mud shore (teal), open water (blue), and rip-rap shore (purple). Two-way Pearson χ^2 test indicated significant differences ($p < 0.0001$) in seasonal habitat preference. χ^2 approximation may be inaccurate due to the absence of contacts in open water and hummock habitats.

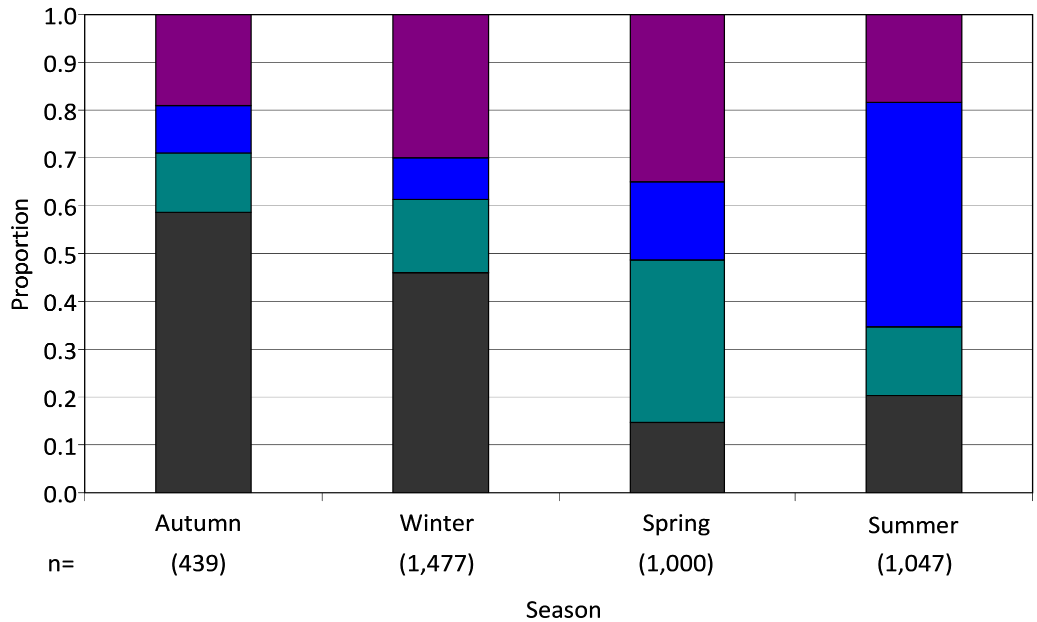

Figure 7. Seasonal PIT scanner contacts of razorback sucker from standardized habitat use sampling in Pond 6 among four habitat types hummock (dark grey), mud shore (teal), open water (blue), and rip-rap shore (purple). Two-way Pearson χ^2 test indicated significant differences (p < 0.0001) in seasonal habitat preference.

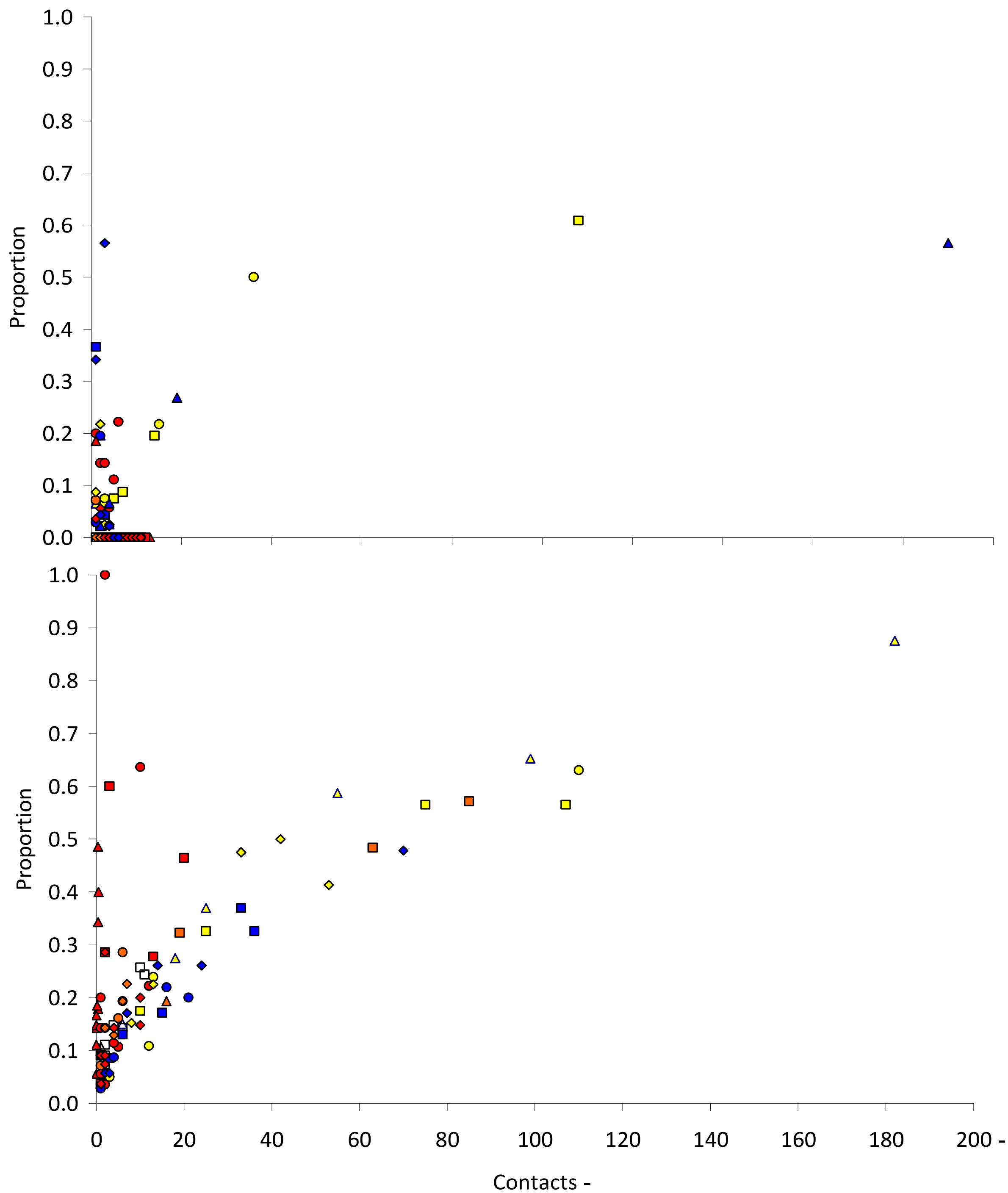

Figure 8. Biplot of Contacts versus Trip Proportion for Pond 2 daytime (top) and nighttime (bottom). -

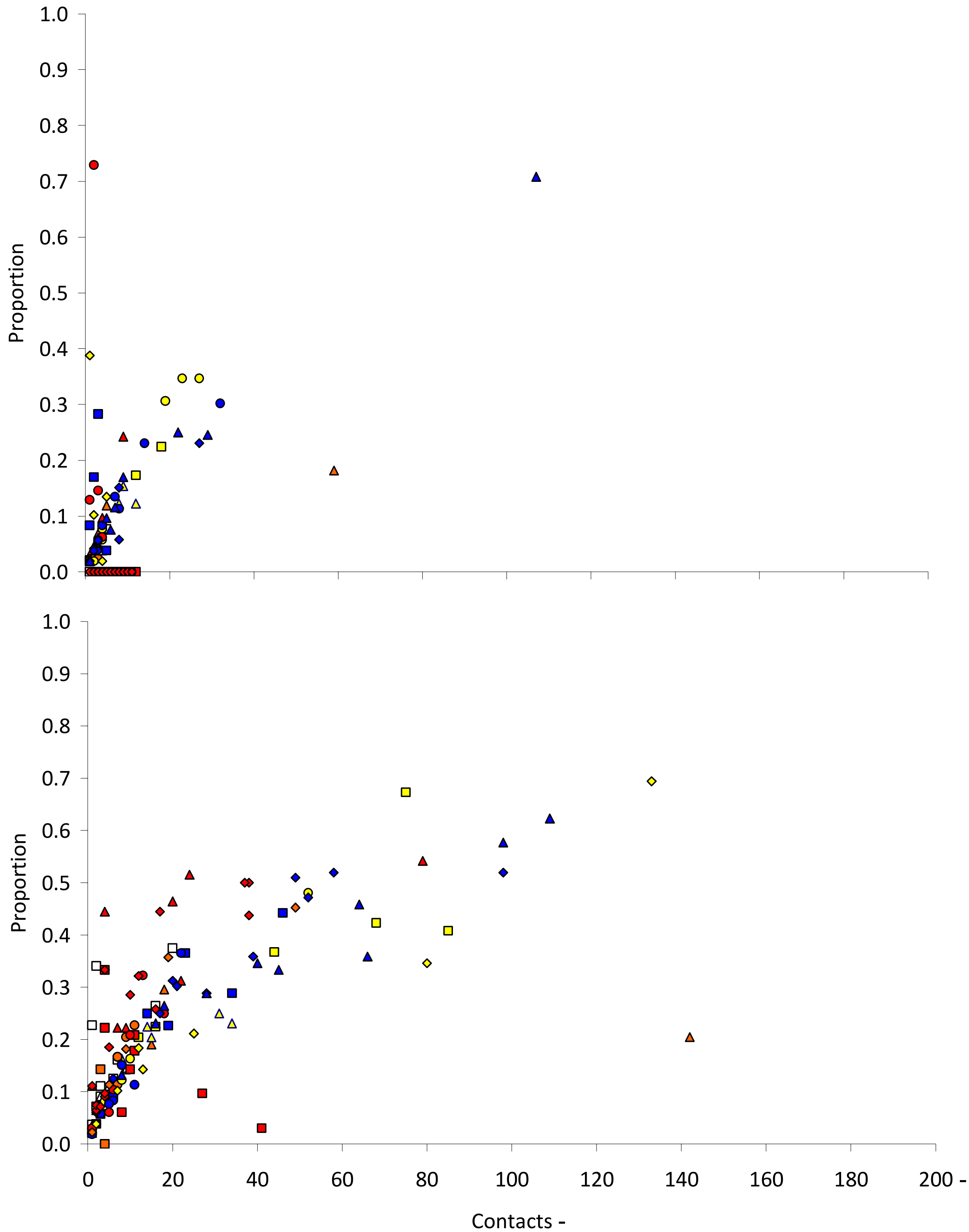

Figure 9. Biplot of Contacts versus Trip Proportion for Pond 6 daytime (top) and nighttime (bottom). -

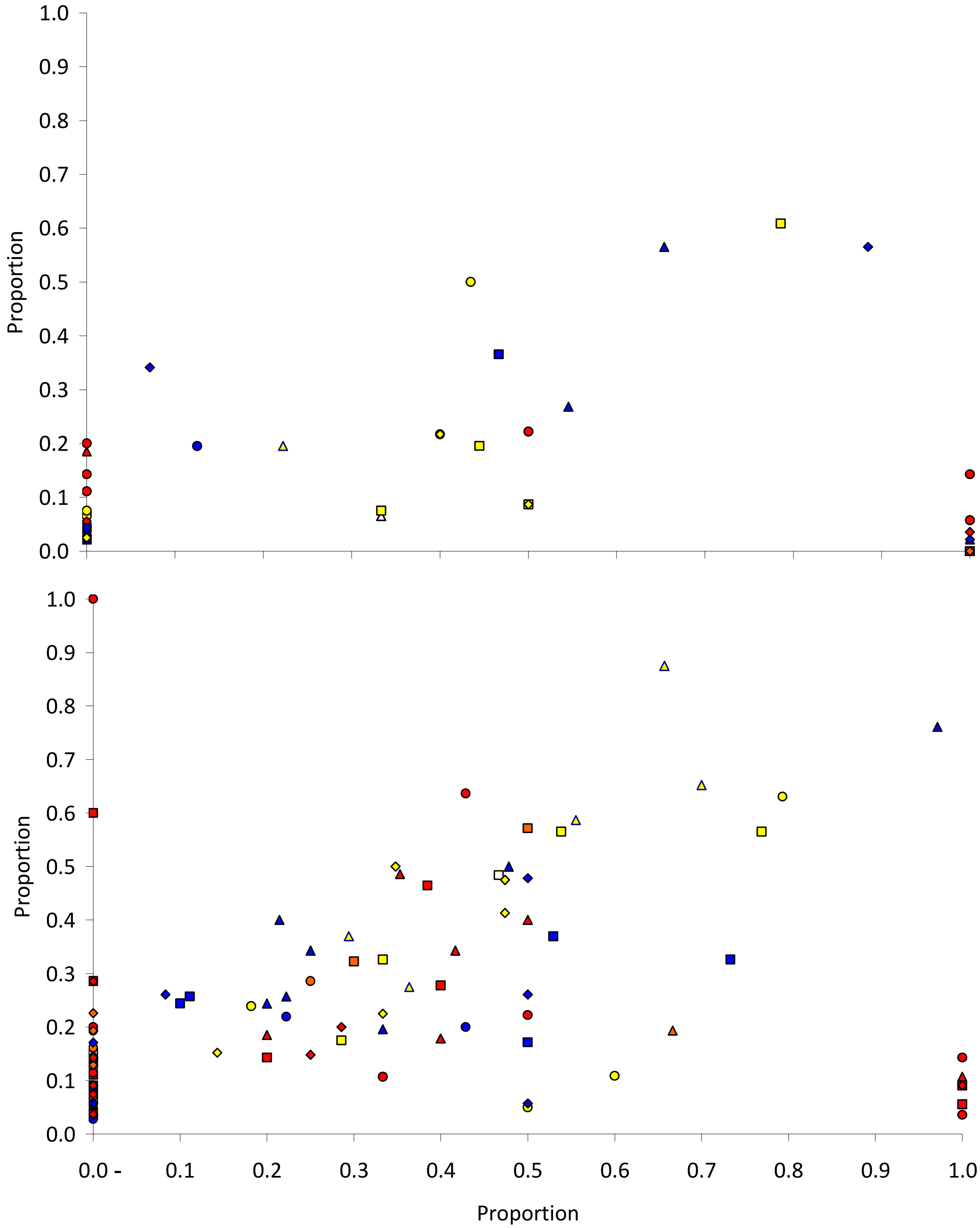

Figure 10. Biplot of Repeat Proportion versus Trip Proportion for Pond 2 daytime (top) and nighttime (bottom).

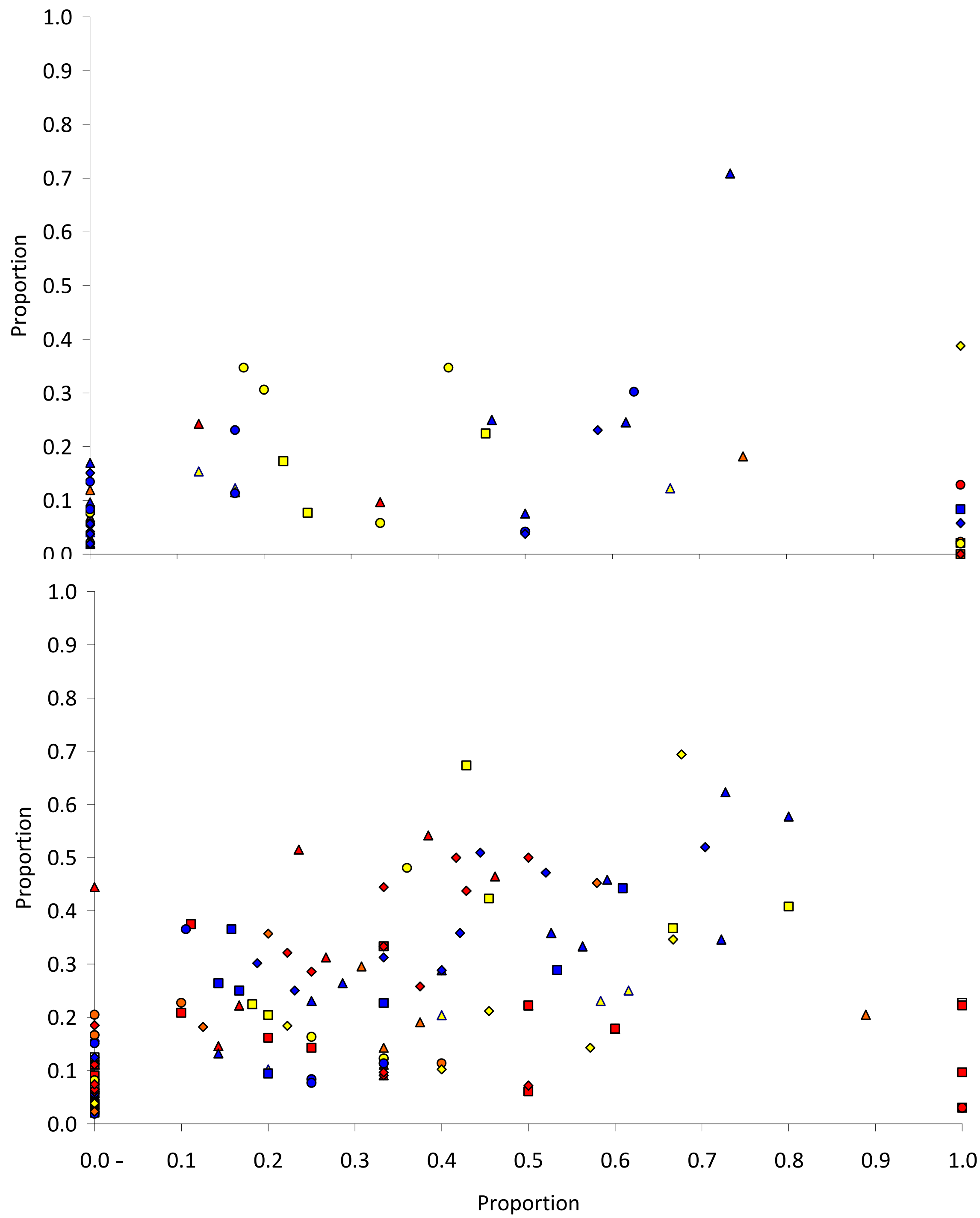

Figure 11. Biplot of Repeat Proportion versus Trip Proportion for Pond 6 daytime (top) and nighttime (bottom).

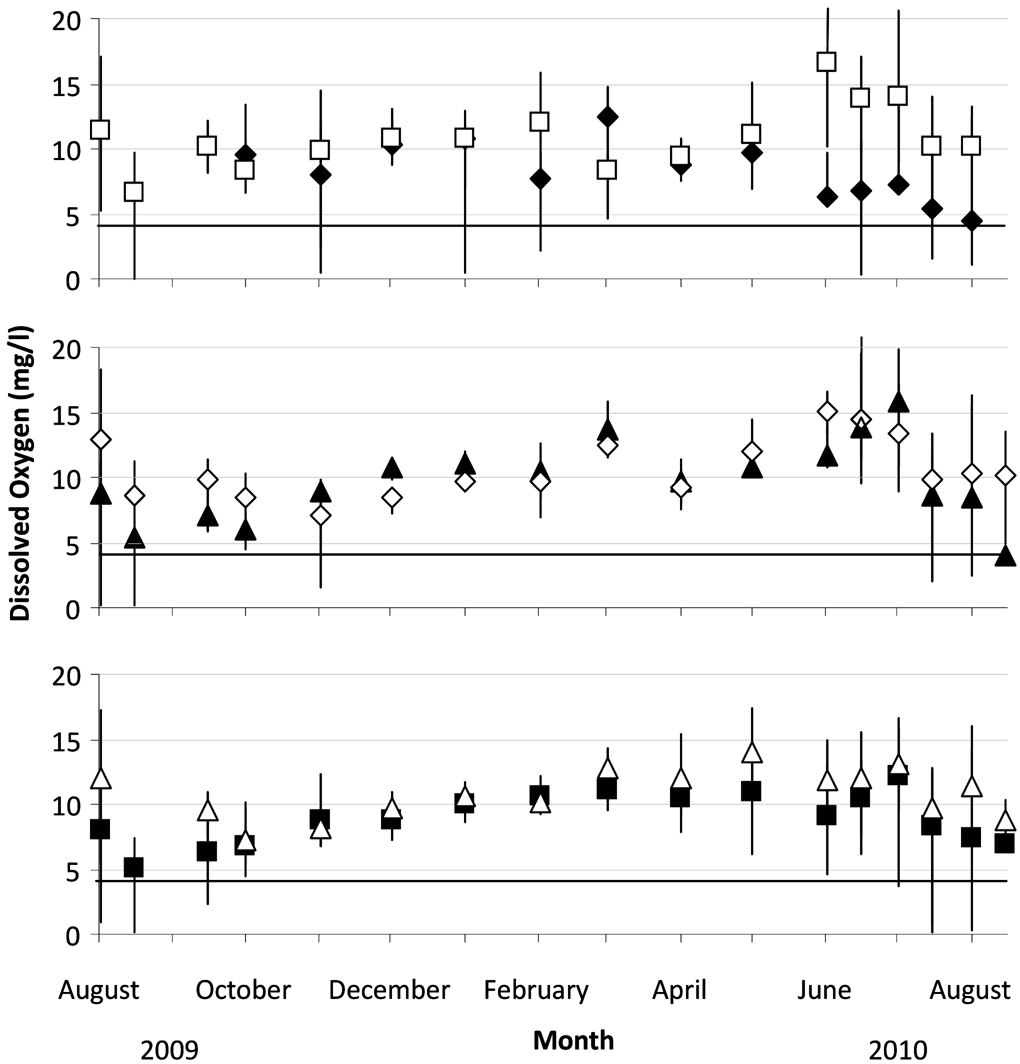

Figure 12. Mean dissolved oxygen (DO) and range (line projections) as measured during routine monitoring for ponds 1 (black diamond), 2 (white square), 3 (black triangle), 4 (white diamond), 5 (black square), and 6 (white triangle). The black horizontal line indicates the threshold value of 4 mg/L.

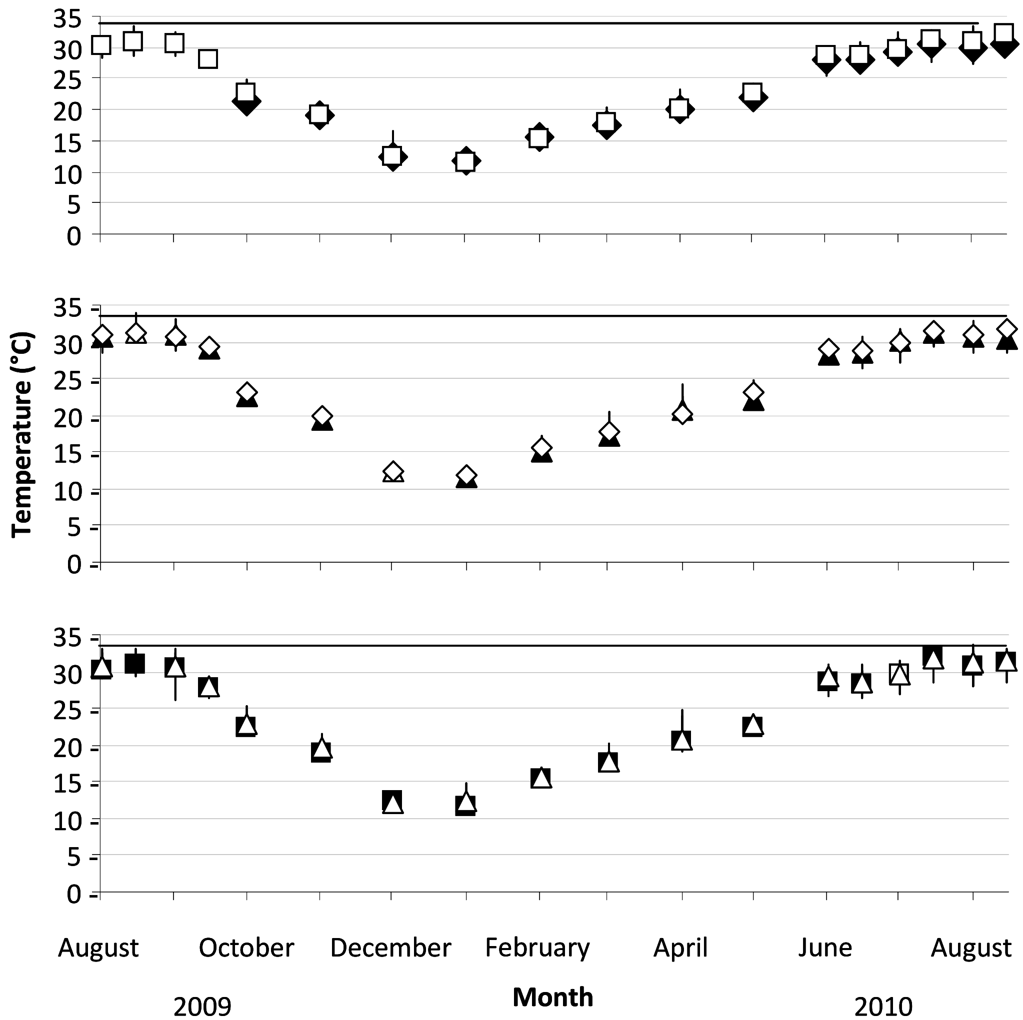

Figure 13. Mean temperature and range (line projections) for ponds 1 through 6. Pond symbols are the same as for Figure 12. The black horizontal line indicates the threshold value (33.3° C).

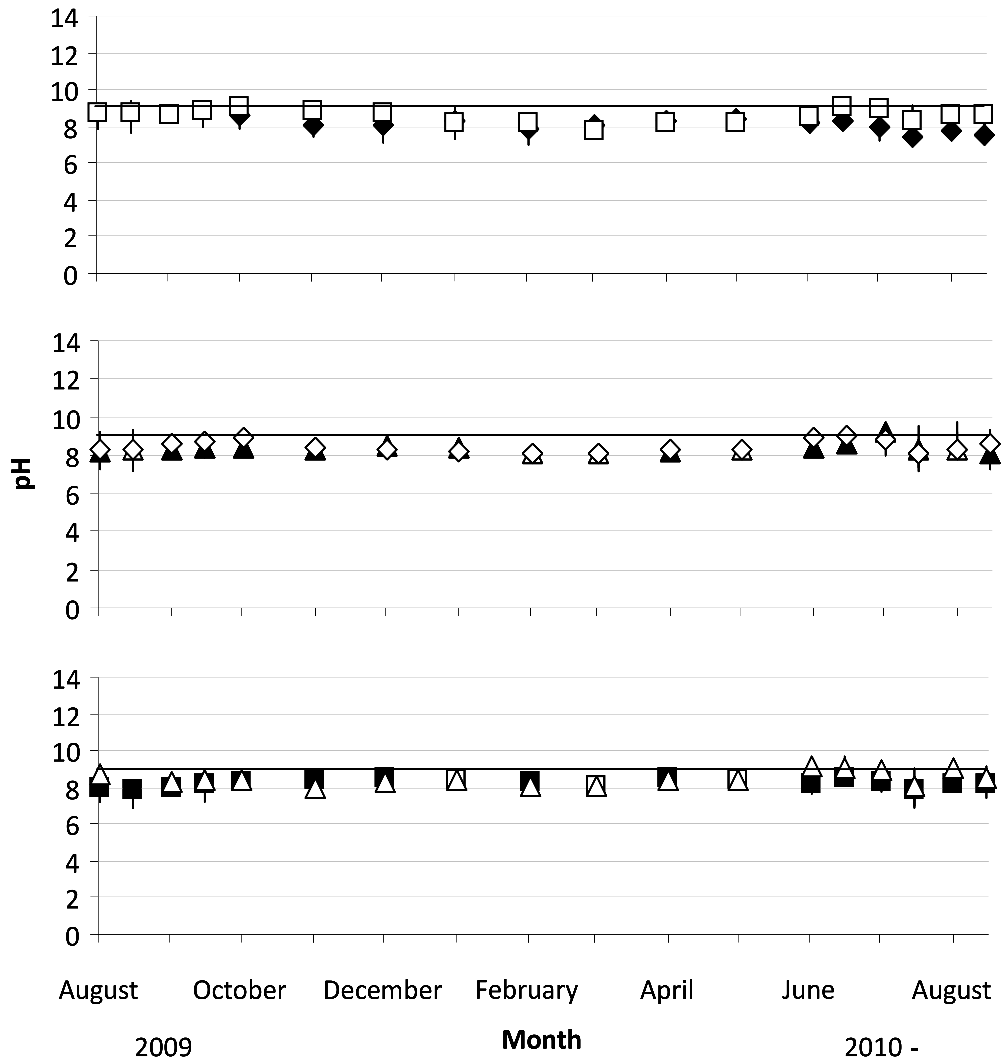

Figure 14. Mean pH and range (line projections) for ponds 1 through 6. Pond symbols are the same as for Figure 12. The black horizontal line indicates the threshold value of 9.0.

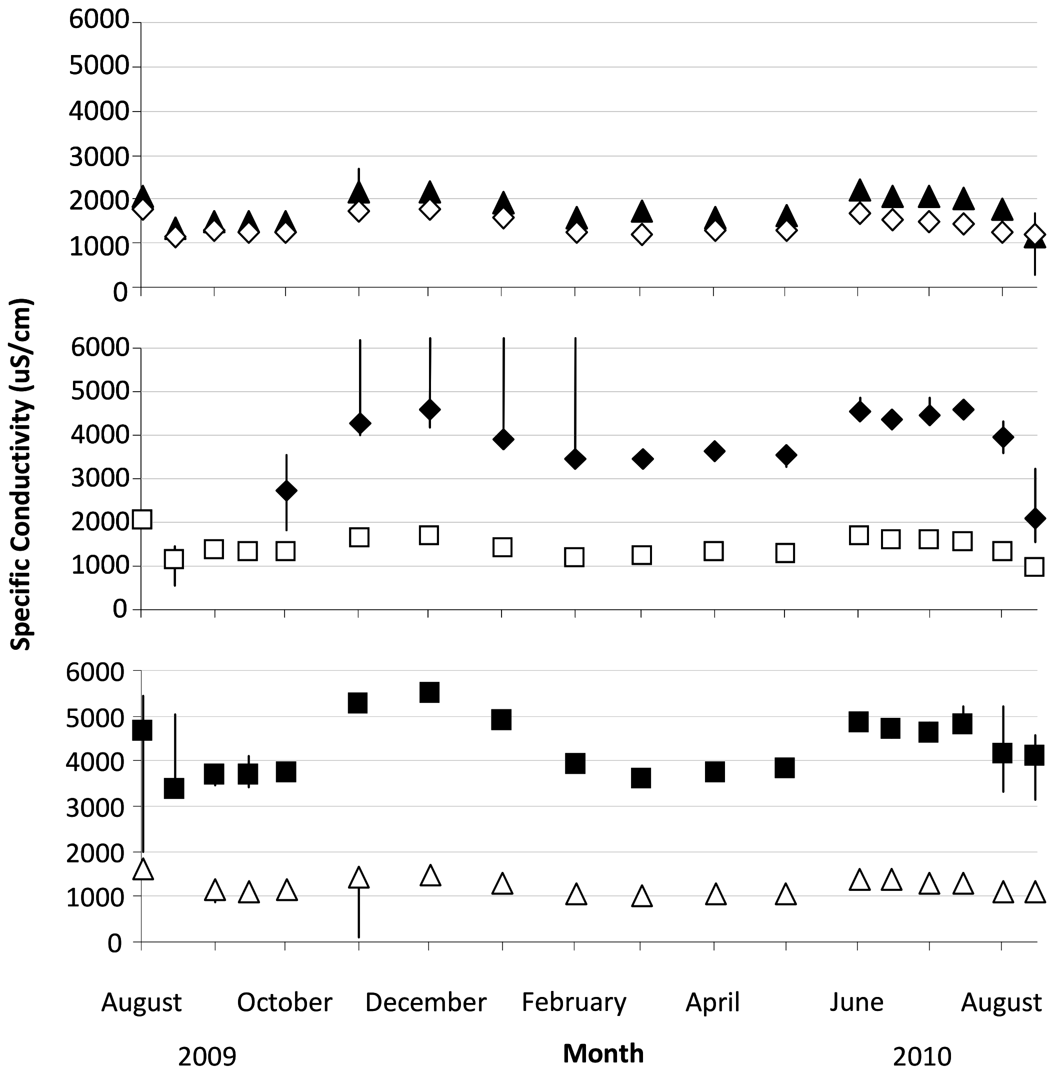

Figure 15. Mean conductivity and range (line projections) for ponds 1 through 6. Pond symbols are the same as for Figure 12. No threshold value for conductivity has been established.

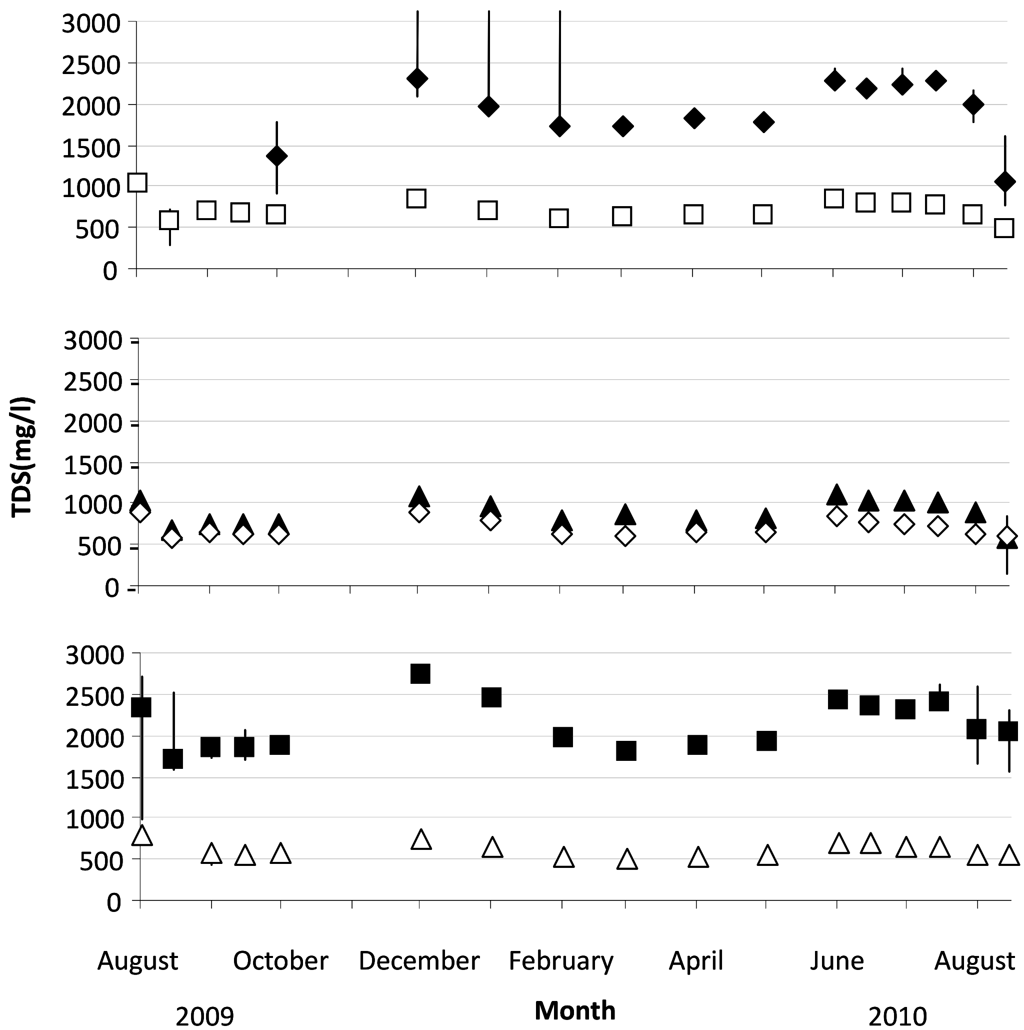

Figure 16. Mean total dissolved solids (TDS) and range (line projections) for ponds 1 through 6. Pond symbols are the same as for Figure 12. No threshold value for total dissolved solids has been established.