# Lower Colorado River Multi-Species Conservation Program

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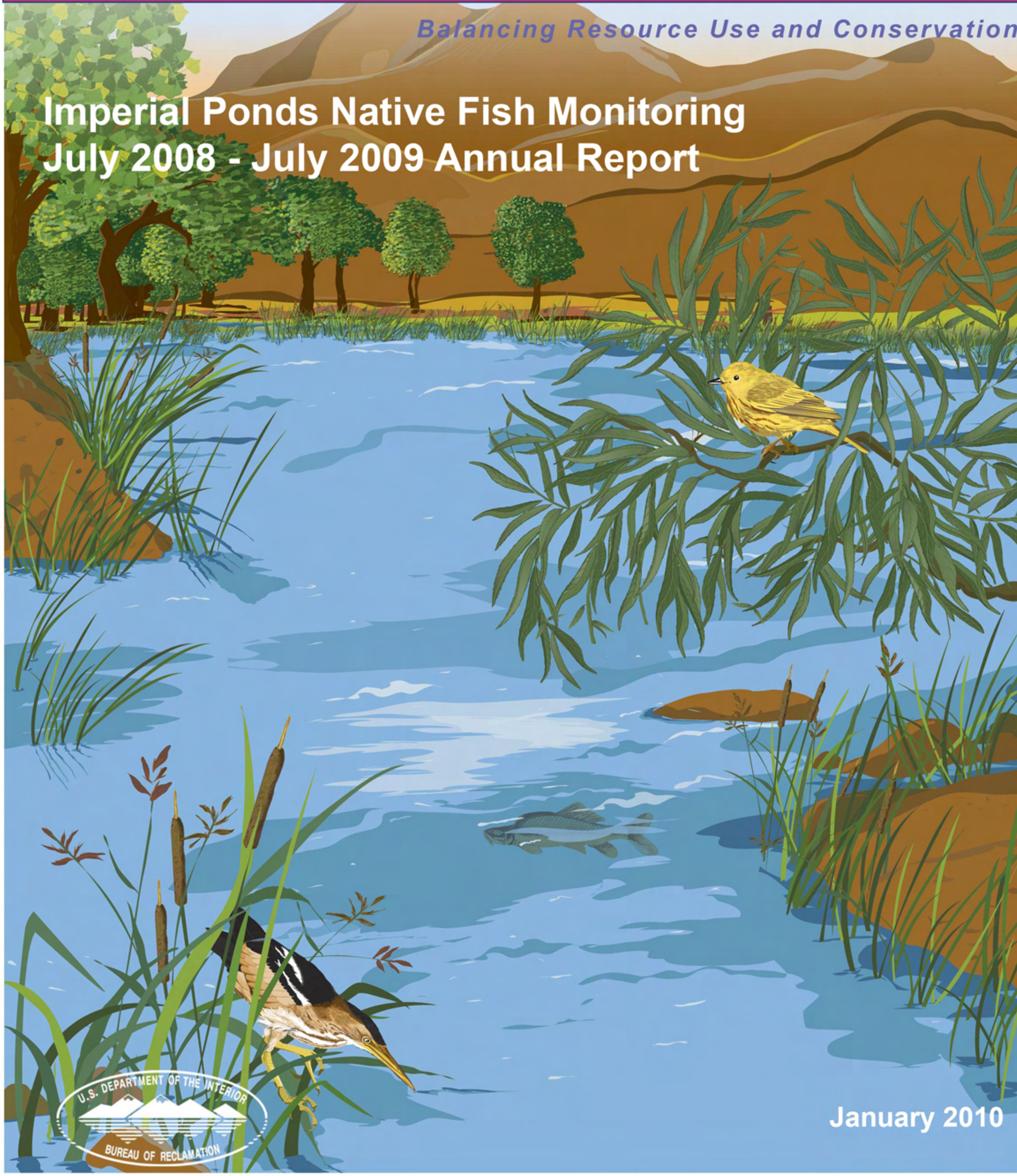
*Balancing Resource Use and Conservation*

## Imperial Ponds Native Fish Monitoring July 2008 - July 2009 Annual Report



U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

January 2010

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# Lower Colorado River Multi-Species Conservation Program

## Imperial Ponds Native Fish Monitoring July 2008 – July 2009 Annual Report

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**Lower Colorado River**
**Multi-Species Conservation Program**
**Bureau of Reclamation**
**Lower Colorado Region**
**Boulder City, Nevada**
**http://www.lcrmscp.gov**

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# Summary

Results are mixed from the second year of monitoring Imperial Ponds, six ponds located on Imperial National Wildlife Refuge (INWR), Arizona. The ponds were designed to provide suitable habitat for life cycle completion by bonytail *Gila elegans* and razorback sucker *Xyrauchen texanus*. However, bluegill *Lepomis macrochirus*, common carp *Cyprinus carpio*, mosquitofish *Gambusia affinis*, redear sunfish *Lepomis microlophus*, threadfin shad *Dorosoma petenense*, and warmouth *Lepomis gulosus*, have been routinely captured in one or more ponds. These nonnative species appear to inhibit recruitment in most of the ponds, although 80 juvenile bonytail were captured in Pond 2. Continued development and deployment of remote PIT scanning units has provided multiple population estimates for all ponds stocked with native fish as well as preliminary habitat use data for stocked razorback sucker. Populations of stocked bonytail in ponds 2 and 3 declined rapidly in the previous sample year, and only young of year were captured during the current sample year. Adult razorback sucker populations in ponds 2, 4 and 6 have persisted, while the population in Pond 1 declined over 90% before renovation efforts began. Water physico-chemistry parameters in all ponds have generally remained within acceptable limits where established (pH < 9, DO > 4 mg/l, and temperature < 33.3° C) and no signs of fish stress have been evident.

# 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 apparent incompatibility of native and nonnative fishes, 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 (USBR), 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 (Fig. 1) as off channel habitat for bonytail and razorback sucker, and as testing grounds for habitat features that may aid in both species persistence. Two of the six Imperial Ponds were stocked with bonytail and two with razorback sucker in 2007. Nonnative common carp *Cyprinus carpio* and 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 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.

We report here on our second year of fish monitoring at Imperial Ponds from July 1, 2008 to July 31, 2009; SY 2009. Additional nonnative species were identified in all ponds during annual sampling in October 2008. Efforts to remove all nonnative fishes from the ponds were just recently initiated and continued presence of nonnative fishes has hampered natural recruitment events for bonytail and razorback sucker.

## Study Area

Imperial National Wildlife Refuge (INWR) is located approximately 30 miles north of Yuma, Arizona (Fig. 1). The six ponds that comprise Imperial Ponds are located adjacent to the Colorado River less than a mile west of the refuge headquarters. The ponds range in size from 9 to 17 surface acres. Habitat 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.

# Methods

Monitoring activities during routine trips included deploying 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 larvae were made to detect spawning success and collect material for genetic analysis. Minnow trapping and hoop netting was conducted to assess native fish recruitment and nonnative fish invasion. In addition to routine trips, an intensive autumn sampling effort was conducted in October 2008 to assess health and abundance of stocked native fish, and to detect native fish recruitment and nonnative invasion. Water physico-chemistry data were collected to ensure 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 United States Bureau of Reclamation.

## Population and Habitat Use Monitoring

### *PIT Scanning*

PIT scanner units designed during SY 2008 were modified further and used extensively in SY 2009 to monitor native fish populations in Imperial Ponds. 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, CA) 12 volt, 26 Amp-Hr. battery or similar battery. The Allflex® scanner was stored in a model 1520, Pelican™ case (Pelican Products, Torrance, CA) 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 prototypes provided by Cross Country Consulting Inc. (Phoenix, AZ). 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.

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 due to razorback sucker being 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.

Scanner units were generally deployed among different habitats within the ponds. They were placed off the rip-rap, on the hummocks, off cattails or phragmites stands, off boat ramps, or sunk in open water. The purpose of much of the work conducted in SY 2009 was to test different antenna configurations and scanner units, and to standardize the sampling protocol to monitor habitat use. 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.

When sufficient mark-recapture data were collected among two subsequent trip samples, population estimates were made for any ponds stocked with native fish 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.

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 USBR personnel using ArcGIS® software (ESRI, Redlands, CA). 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 (Appendix – March 2009 Report). One spawning bed was created in Pond 6 in February 2009 (Appendix – February 2009 Report).

Random scanner deployment sites within each habitat were determined using Hawth's tool-set a free ArcMap 9.1 extension for spatial analysis (www.spatialecology.com). Three random points were generated for each of the four designated habitats per sampling trip, and one pond was sampled per sampling trip. Scanner units were placed at the random locations and moved every evening of the sampling trip before the crepuscular period. A typical sampling trip included 12 scanner deployments, three replicates for each habitat. In ponds stocked with razorback sucker, the hummock habitat was not scanned during the spawning season (February to April 2009), due to deployment of a scanner on the boat ramp. Boat ramps were considered potential spawning sites due to visual observations of razorback sucker congregations there. Effort hours for the final replicate on each trip were generally 10 hours less than the nearly 24 hour cycle of most replicates since scanners were pulled or moved the morning of the last sampling day. Since the majority of contacts occurred between sunset and sunrise, - no adjustment was made to account for this discrepancy.

The habitat use data were summarized using two approaches. The first approach focused on contact distribution among the habitats, looking for monthly and diel patterns. For diel patterns, fish contacts were grouped within the hour of contact. Only complete hours of scanning were used, i.e. the hour the scanner was deployed and the hour the scanner was recovered were removed. This was done because the calculation of contacts per hour for a time period in which the entire hour was not scanned would artificially reduce the mean number of contacts for that hour. The second approach looked at individual fish movement across habitats within a given 24 hour period. Since the majority of contacts occurred overnight, the 24 hour period was timed from noon to 11:59 am encompassing one complete overnight period for any given pond and month. All contacts for tags that were detected in more than one habitat for a given 24 hour period were plotted to illustrate individual fish movement among habitats.

*Annual Autumn Sampling*

The first annual autumn sampling was conducted from 20-24 October 2008. 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). Hoop nets were either double throated, 1.2 m long, 0.8 m diameter, 13 mm mesh nets or single throated, 1.2 m long, 0.8 m diameter, 38 mm mesh nets. 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.

In ponds where target numbers of native fish species (25 per species and pond) could not be caught using hoop nets, experimental gill nets (5 – 7.6 m long x 1.8 m tall panels with mesh sizes from 6.4 mm to 50.8 mm) and trammel nets (22.9 m long, 1.8 m tall, 12.7 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 at most two hours before being placed in floating live cars. Native fish were processed and released into the pond of capture after all sampling equipment was removed. 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. 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 adult razorback sucker stocked in ponds 2, 4 and 6 because Pond 4 was stocked in 2007 with adult razorback sucker (445 mm mean TL), and ponds 2 and 6 were stocked with adult razorback sucker in December 2008 and January 2009 respectively (419 mm and 469 mm mean TL respectively). An attempt to collect razorback sucker larvae was made in each pond from February through April 2009 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. Potential razorback sucker larvae were preserved in 95% ethanol for genetic analysis at Arizona State University. The capture of bonytail larvae was also possible, but this species was not specifically targeted.

In ponds with known juvenile native fish, minnow trapping and hoop netting were conducted throughout the winter 2008-09 to estimate abundance. Hoop nets and minnow traps were of the same design as used in annual sampling, and the nets were deployed during routine trips, fished continuously, and checked daily for fishes. At least one mark and one recapture trip were conducted. Marks included FDX PIT tags for fish over 175 mm TL, and left pelvic fin clips for smaller individuals. In addition to marking, fish captured were measured (TL), assessed for condition, and checked for external parasites and wounds. If recaptures were not encountered in significant numbers, short-term (less than 3 hours) gill and trammel netting was conducted. Nonnative fish captured were enumerated by species and sacrificed.

Hoop netting was conducted late in the spawning season in April to assess spawning condition of captured adult bonytail and razorback sucker. In addition, standardized minnow trapping was conducted throughout summer 2009 (May through July) to assess 2009 spawning success. Four sets of minnow traps strung together at different depths (surface, mid, bottom) were deployed haphazardly in the pond during routine monitoring trips. Native and nonnative captures were processed using the same protocol described above to estimate juvenile native fish abundance in winter 2008-2009.

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 in SY 2009 was opportunistic, targeting areas of potential fish concentration and were used for qualitative, not quantitative fish observations.

**Invasive Species**

Minnow trapping and hoop netting was conducted to sample and remove nonnative species from ponds prior to spawning (Pond 4) or prior to stocking with razorback sucker (Pond 6). These data supplemented nonnative captures from annual monitoring and recruitment assessment. Hoop nets and minnow traps 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.

**Water Physico-chemistry**

Water physico-chemistry at Imperial Ponds was monitored at least once a month, and twice a month during summer (defined as when the mean water temperature exceeded 27° C) using a Hanna Instruments® (Woonsocket, RI) HI9828 multi-parameter probe. Vertical profiles were recorded in 0.5 meter increments 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 gage 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 2008, which had one trip each, resulting in a total of 24 routine sampling trips in SY 2009 (Table 1). This included the annual autumn sampling conducted in October 2008. Sampling in SY 2009 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 2009 a total of 284 scanner deployments and 9,379.9 scanning hours were conducted, resulting in 18,409 razorback sucker PIT tag contacts (Table 2) and 77 bonytail contacts. Interim PIT scanning accounted for a majority of contacts, 14,391 (78.2%), while routine monitoring accounted for 4,018 contacts. Pond 6 had the highest number of razorback sucker contacts and the highest contacts per effort, CPE (contacts per scanning hour), with 8,519 HDX (CPE 2.92) and 1,892 FDX (CPE 0.65) contacts. All razorback sucker in Pond 6 were tagged with both tag types. Pond 2 was second in total contacts with 6,000 HDX and 426 FDX contacts. All razorback sucker in Pond 2 are tagged with HDX tags, and an unknown number are double tagged. Pond 4 FDX tagged razorback sucker were contacted 1,509 times, and FDX tagged razorback sucker in Pond 1 were contacted 63 times. Pond 1 was renovated in early 2009 limiting scanning effort to 2008. All razorback sucker were removed from Pond 1 and stocked into Pond 4. All 77 FDX bonytail contacts were from Pond 2. Pond 3 was scanned in September, October and November of 2008 for a total of 493.5 scanning hours, but no contacts were recorded.

Multiple mark-recapture population estimates and post-stocking survival estimates were calculated in SY 2009 using PIT scanning data acquired during routine sampling trips (Fig. 2 and Table 3). Ponds 1 and 4 were stocked with razorback sucker in November 2007, and while long term survivorship remains high in Pond 4, estimated at 44.5% as of June 2009, the population in Pond 1 declined to less than 10% of the number stocked before renovation was initiated in April 2009. Ponds 2 and 3 each were stocked with approximately 800 bonytail in winter 2007, but abundance declined more than 75% in SY 2008 (Kesner et al. 2008) and only 21 unique bonytail have been contacted in Pond 2 for SY 2009. Survivorship has remained high at 84.7% through May 2009 for razorback sucker stocked into Pond 2 in December 2009, while razorback sucker numbers stocked into Pond 6 in January 2009 declined 65.7% by June 2009.

A total of 11 sampling trips were conducted in SY 2009 since initiation of standardized habitat sampling in mid-February 2009 (trip 20). The addition of four new scanners allowed for the sampling of two ponds during the second trip in July 2009 for a total of 12 standardized sampling events (Ponds 2, 4, and

6 were each sampled four times). This resulted in a total of 134 successful habitat use PIT scanner - deployments among the three ponds (Figs. 3-5); nine 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 2,630 hours for a mean deployment length of 19.6 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 ponds (Fig. 6). A majority of contacts during late spring and early summer in Pond 2 came from mud shore deployments, while Pond 4 received a majority from rip-rap shore and open water, and Pond 6 was undifferentiated except for contacts on the boat ramp, which likely coincided with spawning activity. The boat ramp in all three ponds received a majority of the contacts in at least one month in which it was scanned (boat ramp scanning was conducted only through May).

The vast majority of habitat contacts occurred between 6:00 pm and 6:00 am in all six ponds (Fig. 7). The few contacts that were recorded during the day were in mostly open water, but during the active nighttime period contacts were distributed mostly among the three other habitats.

A total of 933 razorback sucker habitat movement records were derived from the 2,622 FID razorback sucker scans stated above. The vast majority of these records representing a single fish over a 24 hour period have contacts within only one habitat (70%; Table 4). This proportion was greatest in Pond 4 (87%), and lowest in Pond 2 (64%). The number of multiple habitat detections in ponds 2 (Figs. 8-11) and 4 (Figs. 12 and 13) markedly decreased from winter-spring (February to May) to summer (June to July). In contrast Pond 6 the greatest number of multiple habitat contacts occurred in June.

*Annual Autumn Sampling*

A total of 4,725 hours of netting (Table 5) resulted in the capture of 2,193 fish (Table 6). In ponds 1 and 4 razorback sucker represented 0.1% and 1.6% of the catch respectively. In ponds 2 and 3 bonytail represented 22.8% and 0% of the catch respectively. The high percentage of bonytail catch in Pond 2 was due to capture of young-of-year bonytail (< 200 mm TL) that were the result of a successful spawn. All but one of the bonytail captured were young-of-year. Young of year were not seen or captured in any other pond. In addition to native fish, a suite of nonnative fish was captured during sampling;

bluegill *Lepomis macrochirus*, redear sunfish *Lepomis microlophus*, threadfin shad *Dorosoma petenense*, and warmouth *Lepomis gulosus* (Table 6).

**Spawning and Recruitment**

Three larvae were collected in Pond 2 in 272 minutes of night-lighting, 52 in Pond 4 in 162 minutes, and no larvae in 234 minutes in Pond 6 over the spawning season (February through April). Hundreds of small fish larvae (approximately 2 mm long) in Pond 2, presumably sunfish, were observed in April. Schools of adult sunfish were also observed in daylight hours guarding their nests on the boat ramps of ponds 2 and 6. Samples of larvae were identified in the lab and sent for genetic analysis; no larvae collected were identified as bonytail or razorback sucker larvae.

The marking effort for juvenile bonytail abundance estimation in Pond 2 was conducted in December 2008. Up to 30 hoop nets were deployed for a total effort of 2,251 hours of netting resulting in the capture of 28 juvenile bonytail. Nonnative catch comprised 262 bluegill, 57 warmouth, and 1 threadfin shad. All bonytail were measured, weighed, marked (left pelvic fin clip) and released back into Pond 2. The recapture effort was conducted in January 2009 over two routine sampling trips. As many as 24 hoop nets were deployed in Pond 2 along with short-term trammel and gillnet sets in an attempt to assess juvenile bonytail abundance using mark-recapture estimates. Total effort of 1,952 netting hours resulted in the catch of 59 juvenile bonytail (zero recaptures), one tuberculate, ripe male razorback sucker (454 mm TL) and one female razorback sucker (427 mm TL). Nonnative catch was comprised of 128 bluegill and 17 warmouth.

Ten hoop nets were deployed over one night in Pond 2 during each trip in April to assess spawning condition of resident bonytail and razorback sucker. This resulted in a total netting effort of 350 net-hours and a catch of 194 fish representing four species including 21 juvenile bonytail and two adult razorback sucker. Both razorback sucker were tuberculate males (465 and 473 mm TL) and one was ripe. None of the juvenile bonytail were identified as recaptures (pelvic fin clip). Nonnative catch was 158 bluegill and 13 warmouth.

Standardized minnow trap sets in Pond 2 were deployed from April through July for a total effort of 1,789 trap hours and a catch of 2,911 fish. One juvenile bonytail was captured but was most likely from the previous year's recruitment class based on its size, 180 mm TL. The bonytail was FDX PIT tagged prior to release. The rest of the catch was comprised of juvenile sunfish and mosquitofish.

**Invasive Species**

Sampling in Pond 4 was conducted from January to February 2009 prior to razorback sucker spawning. Up to ten hoop nets and five minnow traps were set for a total of 712 hours of effort which culminated in a total catch of 179 fish including five female razorback sucker (496 to 527 mm TL), one of which was ripe (515 mm TL). Nonnative catch included 100 mosquitofish, 46 bluegill, 20 warmouth, six threadfin shad, and two redear sunfish. Razorback sucker were processed and released, all nonnatives were sacrificed.

In January 2009, six minnow traps, two trammel nets, and three experimental gillnets were set in Pond 6 for a total of 483 hours of effort to assess nonnative fish assemblage prior to stocking the pond with razorback sucker. This led to the catch of 58 fish; 23 bluegill, 18 warmouth, nine redear sunfish and eight threadfin shad. All fish were sacrificed.

**Water Physico-chemistry**

To date, most physico-chemical variable means (DO, temperature, conductivity, and TDS) for Imperial Ponds have remained within acceptable limits where established (Figs. 17-21); pH < 9, DO > 4 mg/l, and temperature < 33.3° C. One notable exception has been pH, which reached values exceeding 9 in ponds 1, 2, 3, 4 and 5 at least once per pond since the start of monitoring. Mean pH for all ponds has ranged from 7.5 (Pond 5, August 2008) to 9.4 (Pond 2, November 2008). Mean DO has ranged from 5.4 (Pond 5, March 2009) to 12.8 mg/l (Pond 2, June 2009). A few individual measurements of DO were below the threshold (4mg/l) in ponds 2, 3, 4, and 5; however, these low DO values were taken at or near the bottom of the pond (Figs. 8-12). The mean temperature for all ponds ranged from 12.2 (Pond 2, January 2009) to 33.4°C (Pond 6, July 2009). Mean TDS reached a maximum of 2,072 mg/l (Pond 5, July 2009) and a minimum of 680 mg/l (Pond 6, August 2008). Finally, mean conductivity ranged from 1,364 (Pond 6, September 2008) to 4,144 µS/cm (Pond 5, July 2009).

Secchi depth has fluctuated at a relatively constant rate throughout the sample year (Table 7). Water - clarity in pond 2 was the most consistent and was high enough that the Secchi disk was seen from the pond bottom on 82% of the sampling trips. Water elevation has declined between 0.1 – 1.9 ft among all ponds from beginning July 2008 to end July 2009. Secchi disk and staff gauge readings were discontinued in pond 1 after January 2009 due to dewatering and remediation efforts.

## Discussion

The results from the second year of monitoring at Imperial Ponds have been encouraging as well as challenging. Stocked populations of bonytail were difficult to detect in SY 2009, and few if any are expected to be surviving. Razorback sucker stockings have resulted in healthy populations of adults in ponds 2 and 4, while stockings appear to have succumbed to as of yet unknown mortality factors in ponds 1 and 6. Stocked bonytail were likely susceptible to predation from birds given their small stocking size (Kesner et al. 2008; Schooley et al. 2008), such a threat was expected to be minimal for adult razorback sucker stocked at 42 cm TL or longer. The declines in razorback sucker came in late spring and early summer, a time when water quality appeared adequate, and the size of the fish by this time was presumably large enough to avoid the majority of avian predation. Disease outbreak or resource limitation are two possibilities, given the number of nonnative competitors established in all the ponds. However, this has not appeared to affect razorback sucker numbers in ponds 2 and 4, and all handled razorback and bonytail have been in good health with growth rates similar to fish stocked elsewhere (Fig. 22). Large nonnative piscivorous fishes are absent from all six ponds, so these were not a factor.

Higher than expected adult razorback sucker mortality in ponds 1 and 6 is less important than the apparent lack of recruitment. Without recruitment, all stocked populations will eventually disappear even with low levels of adult mortality. The apparent paucity of larval and juvenile bonytail and razorback sucker is likely due to predation by sunfish and other nonnative fish species in all the ponds. Razorback sucker have successfully spawned in Imperial Ponds as indicated by larval collections, fish congregations around boat ramps, and the capture of ripe individuals in late spring, but no juveniles were captured or observed. Sunfish, carp and mosquitofish are all known ovivores or larvivores (Christopherson et al. 2004; Johnson et al. 1993; Schooley et al. 2008). Still, adult mortality should be reduced if feasible, and annual survivorship of adult razorback sucker in the absence of predators should at least attain levels similar to reservoir populations, about 75% (Marsh et al. 2005; Marsh et al. 2003).

Considering the nonnative threats in all ponds, the appearance of juvenile bonytail in Pond 2 was a surprise. The reasons for success there and not elsewhere can only be speculated. Pond 2 was the only pond to be nearly completely choked with aquatic vegetation in the summer. This may have provided adequate cover for larval and juvenile bonytail to avoid predation while at a vulnerable size. Unfortunately, the abundance of juvenile bonytail in Pond 2 could not be estimated using mark-recapture since not a single recapture was found among the 80 juveniles handled post-marking. The number marked was small (28), and so the likelihood of a recapture if the recruitment class was a few thousand would have been low. Another possibility is that the marking method turned out to be lethal to most of the fish marked. Pelvic fin clipping can impact survival significantly, and bonytail in general are easily stressed while being handled. If recapturing marked bonytail continues to be problematic, recruitment class will only be qualitatively assessed by comparing year to year standardized catch data.

The autumn sampling effort in October 2008 (SY 2009) was effective in detecting native fish recruitment in Pond 2 and previously unknown nonnative fish species presence. However, the overall catch of native fishes was low. For bonytail in ponds 2 and 3, and razorback sucker in Pond 1, this may have been due to a lack of fish available for capture. However Pond 4 had a population well over 100 individuals and only 7 adults were handled during the sampling effort. PIT scanner fish contacts declined dramatically in late summer as the dissolved oxygen in the ponds bottomed out (Fig. 17). This lack of activity carried over through October and may affect catch, but this is yet to be determined.

PIT scanning units continue to be effective in monitoring PIT tagged populations of razorback sucker in all ponds in which they were stocked and are likely in the future to provide month to month estimates for any sizable PIT tagged population. However, the use of HDX PIT tags markedly increase contact rate as indicated by the 4 fold difference in CPE between HDX and FDX tags in Pond 6, where all razorback sucker are double tagged. These tags also led to the majority of movement specific habitat data (Figs. 8-16) and may be necessary to collect adequate real-time habitat use data. No habitat use data can be collected for bonytail until they are stocked. HDX tags should be used in at least one future bonytail stocking, but HDX tagging of bonytail may prove problematic given the tag's larger size and the species sensitivity to handling.

Habitat contacts within a given month appear to show a fairly homogenized view of habitat use during nighttime hours, but the movement data indicate that this is not due to the majority of fish being contacted across all four habitats every night. On the contrary, the majority of fish are only contacted in one habitat in any 24 hour period. This result could reflect different habitat choices among individual razorback sucker, or movement between habitats on a timescale of days instead of hours. Although a lack of contacts in multiple habitats for a given fish doesn't necessarily indicate a lack of movement, the difference between general population contact distribution among habitats and apparent individual habitat movement indicates that individual fish are behaving as if the delineated habitats are at least somewhat distinct. The additional four scanners added in July 2009 will allow for up to four ponds to be scanned every month, and direct comparisons between ponds on a month to month basis will be possible.

Water physico-chemistry in general has been adequate, but pH continues to be at or near threshold values for much of the year. Supplemental well water pumping was effective in lowering pH and temperature when thresholds were exceeded in summer 2009 (Appendix A – June 2009 Report). Earlier test well water pumping in August 2008 proved effective in reducing pond temperature and creating a "bubble" of cool, oxygenated water above the substrate near the inlet to the pond (Appendix A – August 2008 Report). Pumping from the slough appears to have little effect on pond temperature during the summer since slough temperatures tend to be similar to temperatures in the ponds.

## Recommendations

Given the abundance of nonnative sunfish in all ponds and their impact on larval survival, renovation of each pond is necessary for the program's success.

If adequate sample sizes of native adults are not attained in autumn 2009 (SY 2010), annual sampling events should be scheduled later in the year when dissolved oxygen and PIT scanner activity are relatively high.

All stockings of razorback sucker should contain at least a portion of HDX tagged fish for habitat use - monitoring and research. A trial bonytail HDX tagging should be conducted to determine if the tagging procedure causes unacceptable levels of mortality.

As experimental pumping has shown promise in the well water's ability to maintain proper pond levels and provide exceptional water quality, well water should be used as the main source of water for all ponds stocked with native fish.

## Acknowledgments

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Table 1. Routine monitoring trip dates and a summary of activities conducted by Marsh & Associates at Imperial Ponds, Imperial NWR, AZ from July 2008 through July 2009.

| Trip Dates | Activities |
|---|---|
| 8-10 July 2008 | Collected water physico-chemistry data. |
| 22-25 July 2008 | Collected water physico-chemistry data and deployed remote PIT scanner units. Installed solar panels on prototype cases and started testing long term deployment. |
| 4-7 August 2008 | Collected water physico-chemistry data and deployed remote PIT scanner units. |
| 18-21 August 2008 | Collected water physico-chemistry data and deployed remote PIT scanner units. |
| 22-25 September 2008 | Collected water physico-chemistry data and deployed remote PIT scanner units. Snorkeling. |
| 6-9 October 2008 | Collected water physico-chemistry data and deployed remote PIT scanner units. Photopoint documentation of pond vegetation. |
| 20-24 October 2008 | Conducted yearly sampling of all ponds. Deployed remote PIT scanner units. Deployed trammel and gill nets and set hoop nets and minnow traps in all ponds with native fish. |
| 3-6 November 2008 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed trammel nets. |
| 17-20 November 2008 | Deployed remote PIT scanner units. Deployed trammel nets and hoop nets. |
| 9-12 December 2008 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed hoop nets. Assisted with stocking razorback sucker in Pond 2. |
| 13-16 January 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed trammel and gill nets and set hoop nets and minnow traps in all ponds with native fish. - |
| 26-29 January 2009 | Deployed remote PIT scanner units. Deployed trammel and gill nets and - set hoop nets and minnow traps in all ponds with native fish. - Photopoint documentation of pond vegetation. Deployed artificial habitat. Assisted with stocking of razorback sucker in Pond 6. |
| 9-12 February 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Snorkeled. Spot-lighted for larvae. |

| | |
|---|---|
| 22-26 February 2009 | Deployed remote PIT scanner units. Deployed hoop nets. Snorkeled. Spot-lighted for larvae. |
| 10-13 March 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Spot-lighted for larvae. Deployed artificial habitat. |
| 30-2 March/April 2009 | Deployed remote PIT scanner units. Deployed hoop nets. Spot-lighted for larvae. |
| 13-16 April 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed hoop nets. Spot-lighted for larvae. |
| 27-30 April 2009 | Deployed remote PIT scanner units. Deployed hoop nets. Photopoint documentation of pond vegetation. Assisted in Pond 1 renovation. |
| 11-14 May 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. |
| 25-28 May 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed minnow traps |
| 8-9 June 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed minnow traps. |
| 22-25 June 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed minnow traps. Snorkeled transects. |
| 7-10 July 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Assisted in Pond 1 renovation. |
| 20-24 July 2009 | Collected water physico-chemistry data and deployed remote PIT scanner units. Deployed gill nets and minnow traps. |

Table 2. Contact numbers, scanning effort and contacts per effort (CPE) for PIT tagged razorback sucker stocked into Imperial Ponds in SY 2009. Stocked razorback sucker 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 3 and 5 were not stocked with razorback sucker.

| | | **Pond** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **1** | | **2** | | **4** | | **6** | |
| **Year** | **Month** | **FDX** | **HDX** | **FDX** | **HDX** | **FDX** | **HDX** | **FDX** | **HDX** |
| 2008 | July | - | - | - | - | 14 | - | - | - |
| | August | - | - | - | - | 57 | - | - | - |
| | September | 24 | - | - | - | - | - | - | - |
| | October | 30 | - | - | - | 88 | - | - | - |
| | November | 9 | - | - | - | - | - | - | - |
| | December | - | - | 67 | 243 | - | - | - | - |
| 2009 | January | - | - | 3 | 32 | 227 | - | 29 | 82 |
| | February | - | - | 102 | 534 | 158 | - | - | - |
| | March | - | - | - | - | 157 | - | 51 | 180 |
| | April | - | - | 21 | 508 | - | - | 46 | 247 |
| | May | - | - | 24 | 259 | 62 | - | - | - |
| | June | - | - | - | - | 140 | - | 74 | 276 |
| | July | - | - | 12 | 168 | 40 | - | 15 | 39 |
| Interim Monitoring | | | | 197 | 4,256 | 566 | - | 1,677 | 7,695 |
| Totals | | **63** | - | **426** | **6,000** | **1,509** | - | **1,892** | **8,519** |
| Scanning effort (hours) | | 635.2 | | 2,632.6 | | 2,696.6 | | 2,921.9 | |
| CPE (contacts per hour) | | **0.10** | - | **0.16** | **2.28** | **0.56** | - | **0.65** | **2.92** |

Table 3. Native fish stocking records and population (top) and survival (bottom) estimates for FY 2009 at Imperial Ponds, Imperial NWR. No population estimates were calculated for July, August, and November, 2008 due to a lack of recapture data.

| | | | 2008 | | | | | 2009 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pond** | **Species** | **No. Stocked (Date)** | **September** | **October** | **December** | **January** | **February** | **March** | **April** | **May** | **June** |
| 1 | razorback sucker | 305 (November 2007) | 17 | 26 | | | | | | | |
| 2 | razorback sucker | 59 (December 2008) | | | 59 | | 52 | 52 | 51 | 50 | |
| 2 | bonytail | 800 (December 2007) | 45 | | | | | | | | |
| 4 | razorback sucker | 272 (November 2007) | 156 | 178 | | 148 | 156 | | 128 | 141 | 121 |
| 6 | razorback sucker | 198 (January 2009) | | | | | 106 | 59 | 75 | 66 | 68 |

| | | | 2008 | | | | | 2009 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pond** | **Species** | **No. Stocked (Date)** | **September** | **October** | **December** | **January** | **February** | **March** | **April** | **May** | **June** |
| 1 | razorback sucker | 305 (November 2007) | 5.6% | 8.5% | | | | | | | |
| 2 | razorback sucker | 59 (December 2008) | | | 100.0% | | 88.1% | 88.1% | 86.4% | 84.7% | |
| 2 | bonytail | 800 (December 2007) | 5.6% | | | | | | | | |
| 4 | razorback sucker | 272 (November 2007) | 57.4% | 65.4% | | 54.4% | 57.4% | | 47.1% | 51.8% | 44.5% |
| 6 | razorback sucker | 198 (January 2009) | | | | | 53.5% | 29.8% | 37.9% | 33.3% | 34.3% |

Table 4. Numbers of razorback sucker contacted in one to four habitats within a 24 hour period during standardized PIT scanning at Imperial Ponds. Data were for any given 24 hours of scanning; thus multiple counts of the same fish are possible if the same fish was contacted on multiple days.

| | **Habitats** | | | | |
|---|---|---|---|---|---|
| **Pond** | **1** | **2** | **3** | **4** | **Sums** |
| **2** | 254 | 109 | 31 | 1 | 395 |
| **4** | 202 | 28 | 3 | 0 | 233 |
| **6** | 197 | 75 | 30 | 3 | 305 |
| **Totals** | 653 | 212 | 64 | 4 | 933 |

Table 5. Sampling effort per pond in net-hours during autumn sampling, Oct 20-24 at Imperial Ponds. No sampling was conducted in ponds 5 & 6, which were without native fish.

| Pond | Hoopnet | Gillnet | Trammel | Minnow Trap | Total - |
|---|---|---|---|---|---|
| 1 | 1,182.2 | 0.0 | 60.4 | 594.0 | 1,836.5 |
| 2 | 543.4 | 10.1 | 0.0 | 430.3 | 983.8 |
| 3 | 321.5 | 3.8 | 4.9 | 578.1 | 908.2 |
| 4 | 836.3 | 5.3 | 27.9 | 0.0 | 869.5 |
| Total | 2,948.4 | 81.7 | 93.1 | 1,602.4 | 4,598.1 - |

Table 6. Individual species captured during autumn sampling, Oct 20-24, at Imperial Ponds. A dash indicates a lack of effort for the given pond and method.

| Species | Hoopnet | Gillnet | Trammel | Minnow Trap | Total |
|---|---|---|---|---|---|
| Pond 1 | | | | | |
| Bluegill | 522 | - | 7 | 73 | 602 |
| Common carp | 51 | - | 64 | 0 | 115 |
| Mosquitofish | 0 | - | 0 | 120 | 120 |
| Razorback sucker | 0 | - | 1 | 0 | 1 |
| Threadfin shad | 0 | - | 65 | 0 | 65 |
| Warmouth | 147 | - | 8 | 0 | 155 |
| Total | 720 | - | 145 | 193 | 1,058 |
| Pond 2 | | | | | |
| Bluegill | 144 | 2 | - | 28 | 174 |
| Bonytail | 6 | 58 | - | 1 | 65 |
| Mosquitofish | 0 | 0 | - | 36 | 36 |
| Threadfin shad | 0 | 3 | - | 0 | 3 |
| Warmouth | 6 | 0 | - | 1 | 7 |
| Total | 156 | 63 | - | 66 | 285 |
| Pond 3 | | | | | |
| Common carp | 16 | 9 | 0 | 11 | 36 |
| Threadfin shad | 0 | 3 | 0 | 0 | 3 |
| Mosquitofish | 0 | 0 | 0 | 6 | 6 |
| Sunfish (juveniles) | 0 | 0 | 0 | 9 | 9 |
| Warmouth | 260 | 0 | 0 | 37 | 297 |
| Total | 277 | 14 | 0 | 72 | 363 |
| Pond 4 | | | | | |
| Bluegill | 130 | 0 | 6 | - | 136 |
| Razorback sucker | 0 | 0 | 7 | - | 7 |
| Redear sunfish | 1 | 0 | 0 | - | 1 |
| Sunfish (juveniles) | 58 | 0 | 3 | - | 61 |
| Threadfin shad | 0 | 16 | 94 | - | 110 |
| Warmouth | 93 | 0 | 18 | - | 111 |
| Total | 282 | 16 | 128 | - | 426 |

Table 7. Secchi depth in meters (top) and staff gauge elevation in feet (bottom) for SY 2009 at Imperial Ponds. Asterisk indicates that the Secchi disk was visible from the bottom of the pond. Two readings per month were taken during summer months, and these are differentiated by T1 for the first trip during the month and T2 for the second. A dash indicates no readings were taken for the given pond and month.

| Secchi Depth | Pond 1 | Pond 2 | Pond 3 | Pond 4 | Pond 5 | Pond 6 |
|---|---|---|---|---|---|---|
| July 2008 | 2.1 | 3.0* | 2 | 2 | 2.5* | 3.1 |
| August 2008 T1 | 2.1 | 3.7* | 2.2 | 2.1 | 2.8 | 2.8 |
| August 2008 T2 | 1.9 | 3.6* | 2.6 | 2.1 | 1.7 | 2.5 |
| September 2008 T1 | 2.05 | 2.7 | 3 | 2.33 | 2.08 | 2.48 |
| September 2008 T2 | 2.21 | 3.17* | 2.87* | 2.08 | 1.69 | 1.94 |
| October 2008 | 2.18 | 3.10* | 2.59 | 1.64 | 2.42 | 1.82 |
| November 2008 | 1.92 | 2.47* | 2.33 | 0.9 | 1.3 | 2.31 |
| December 2008 | 2.89* | 3.10* | 1.4 | 0.74 | 1.17 | 2.5 |
| January 2009 | 2.12* | 2.75* | 1.1 | 0.94 | 1.13 | 2.19* |
| March 2009 | - | 2.73* | 0.85 | 0.82 | 1.71 | 2.89* |
| April 2009 | - | 2.50* | 1.59 | 0.73 | 2.2 | 1.85 |
| May 2009 T1 | - | 1.81 | 1.52 | 1.24 | 2.2 | 1.94 |
| May 2009 T2 | - | 2.07 | 1.24 | 1.48 | 1.71 | 2.27 |
| June 2009 T1 | - | 2.29* | 1.37 | 2.49 | 1.4 | 1.94 |
| June 2009 T2 | - | 2.21* | 1.49 | 2.03 | 1.55 | 2.88* |
| July 2009 T1 | - | 2.98* | 1.1 | 1.27 | 1.14 | 2.27 |
| July 2009 T2 | - | 2.81* | 1.02 | 2.65* | 1.01 | 2.13 |

| Staff Gauge | Pond 1 | Pond 2 | Pond 3 | Pond 4 | Pond 5 | Pond 6 |
|---|---|---|---|---|---|---|
| July 2008 T1 | 187.5 | 186.2 | 185.7 | 187.1 | 184.0 | 185.3 |
| July 2008 T2 | 187.5 | 187.4 | 186.0 | 186.5 | 185.2 | 187.5 |
| August 2008 T1 | 187.5 | 187.5 | 186.1 | 186.5 | 184.3 | 187.5 |
| August 2008 T2 | 187.1 | 187.2 | 186.2 | 186.6 | 184.7 | 187.5 |
| September 2008 T1 | 186.5 | 186.3 | 185.8 | 185.9 | 184.4 | 185.4 |
| September 2008 T2 | 186.1 | 185.8 | 185.4 | 185.7 | 184.8 | 184.7 |
| October 2008 | 185.9 | 185.8 | 185.9 | 186.3 | 184.6 | 184.7 |
| November 2008 | 186.5 | 186.5 | 186.3 | 186.6 | 184.6 | 184.8 |
| December 2008 | 184.9 | 185.9 | 184.6 | 184.0 | 183.9 | 183.8 |
| January 2009 | 184.6 | 184.7 | 184.0 | 184.2 | 183.2 | 183.0 |
| March 2009 | - | 184.6 | 185.2 | 185.3 | 183.9 | 185.9 |
| April 2009 | - | 184.1 | 186.1 | 185.9 | 184.3 | 185.5 |
| May 2009 T1 | - | 183.8 | 186.0 | 186.5 | 184.6 | 185.4 |
| May 2009 T2 | - | 183.4 | 186.0 | 186.7 | 184.5 | 185.0 |
| June 2009 T1 | - | 183.1 | 186.0 | 184.5 | 186.7 | 184.8 |
| June 2009 T2 | - | 182.9 | 185.5 | - | 184.2 | 185.1 |
| July 2009 T1 | - | 185.8 | 185.0 | 184.0 | 185.6 | 184.4 |
| July 2009 T2 | - | 185.3 | 185.0 | 186.5 | 183.9 | 184.4 |

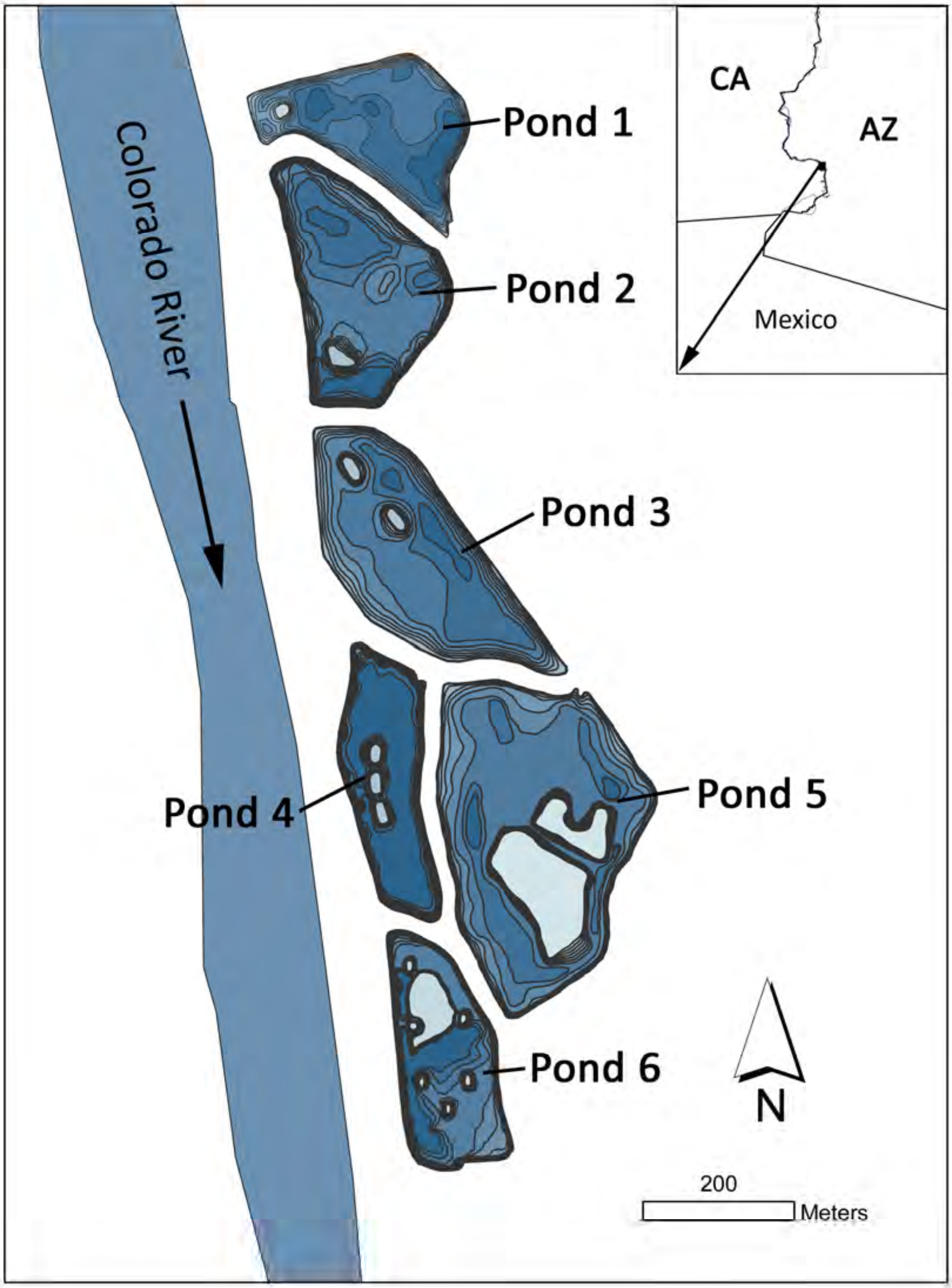


Figure 1. Bathymetric map of the six Imperial Ponds located at Imperial NWR, AZ, and area map (inset). Contour lines represent a change in elevation (pond depth) of one foot.

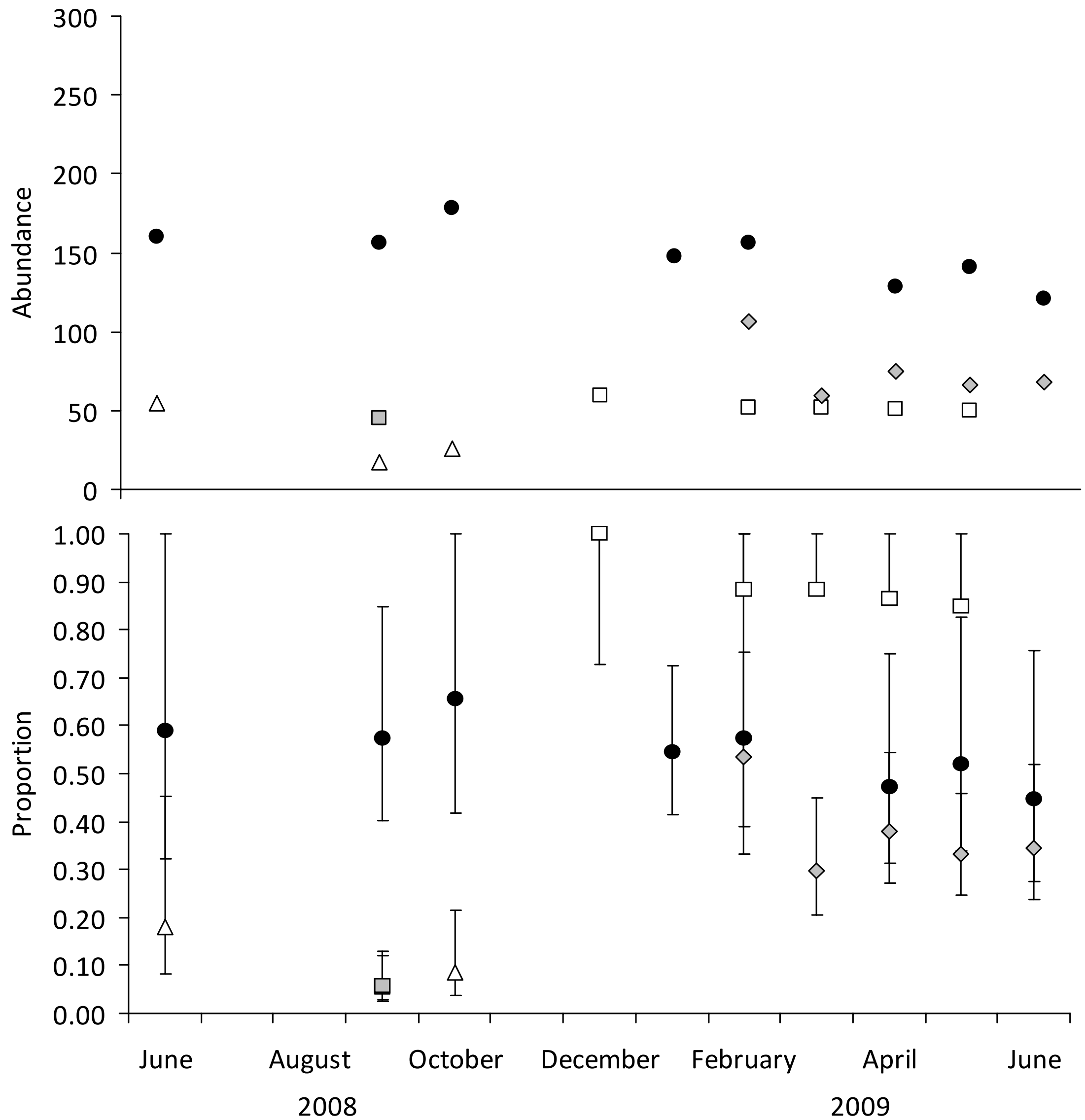


Figure 2. Population (top) and survival (bottom) estimates for razorback sucker in Pond 1 (open triangles), Pond 2 (open squares), Pond 4 (black circles), and Pond 6 (grey diamonds), and bonytail in Pond 2 (grey squares) based on PIT scanning mark-recapture data from routine monitoring at Imperial Ponds. Error bars are 95% confidence intervals.


Figure 3. PIT scanner locations for standardized PIT scanner deployments were randomly placed among four habitats from February to July 2009 in Pond 2. Habitats were rip-rap shore (checker pattern), mud shore (dotted pattern), hummock (vegetation pattern and green area), and open water (grey area). Boat ramps were scanned as well (lined area). Colored circles represent scanner deployment locations for the months of February (orange), March (green), April (blue), May (violet), June (yellow), and July (red). Scanning was not conducted every month in every pond.


Figure 4. PIT scanner locations for standardized PIT scanner deployments were randomly placed among four habitats from February to July 2009 in Pond 4. Habitat pattern and deployment location (circle) color coding is the same as for Figure 3.

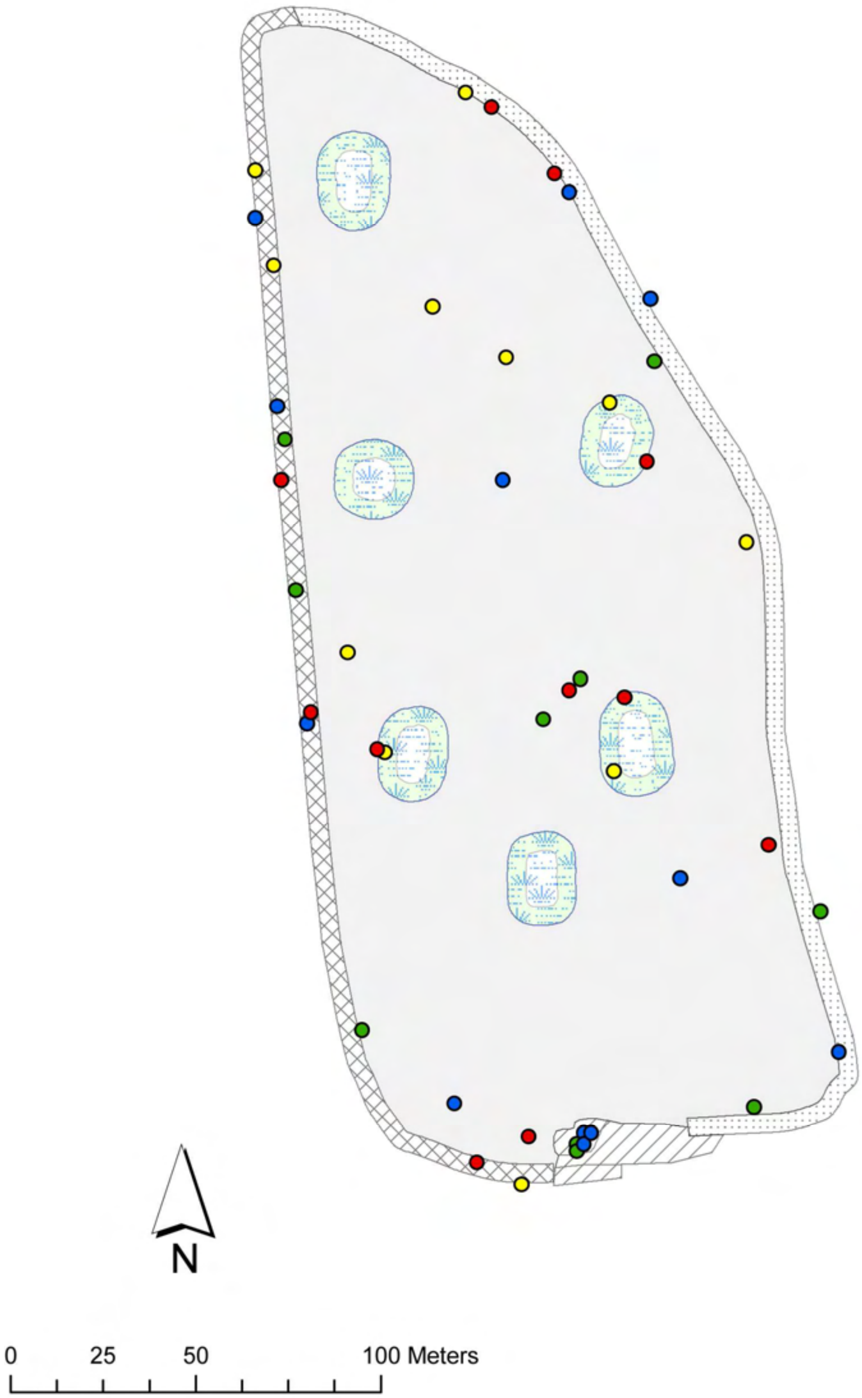


Figure 5. PIT scanner locations for standardized PIT scanner deployments were randomly placed among four habitats from February to July 2009 in Pond 6. Habitat pattern and deployment location (circle) color coding is the same as for Figure 3.

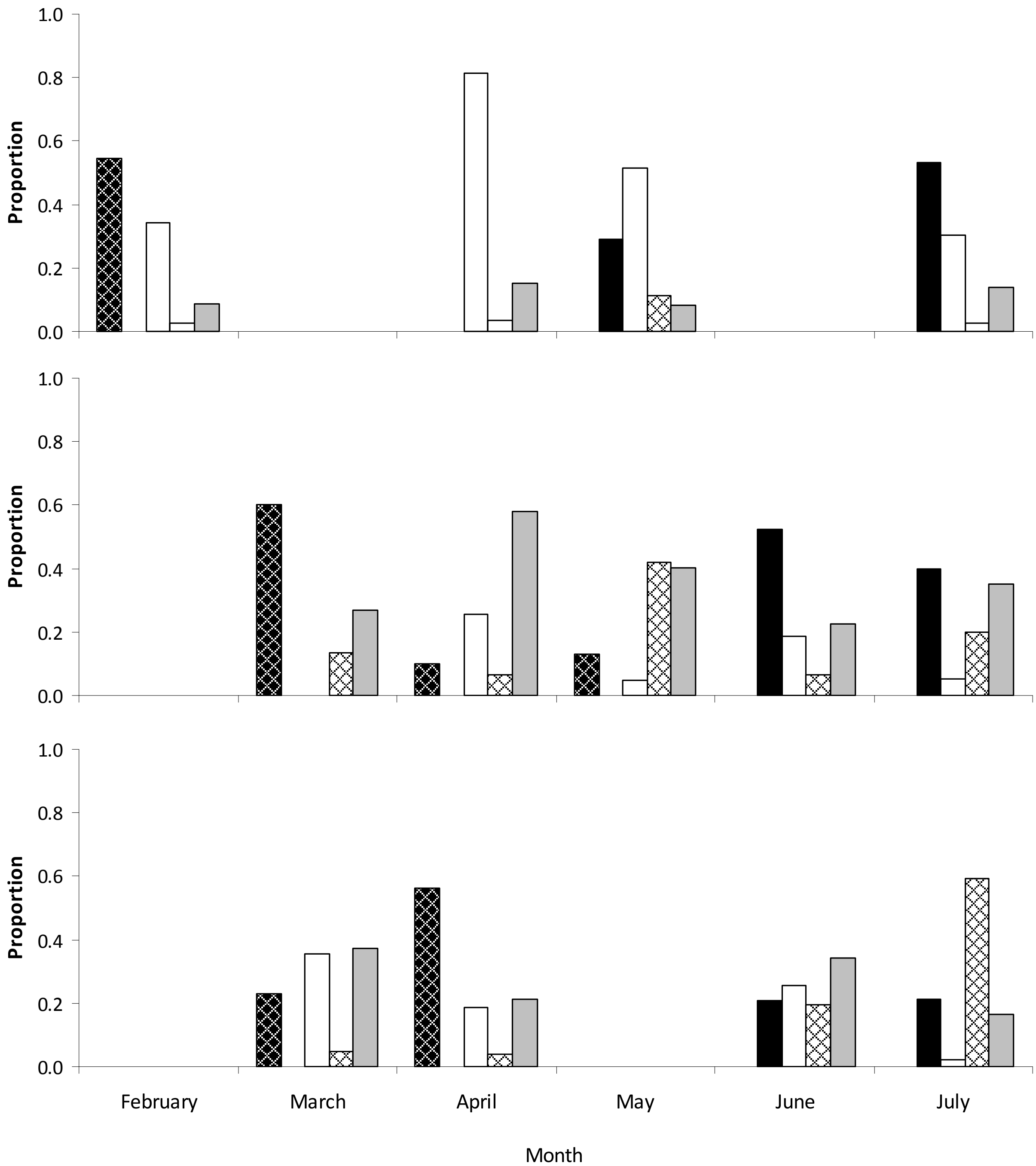


Figure 6. Monthly PIT scanner contacts of razorback sucker from standardized habitat use sampling for ponds 2 (top), 4 (middle), and 6 (bottom) of Imperial Ponds from February to July 2009 among four habitat types and the boat ramp; (black), mud shore (white), open water (white diamonds), rip-rap shore (grey), and boat ramp (black diamonds). Boat ramps were scanned between February and May. A complete absence of contacts in any given month denotes a lack of scanning and not a lack of contacts.

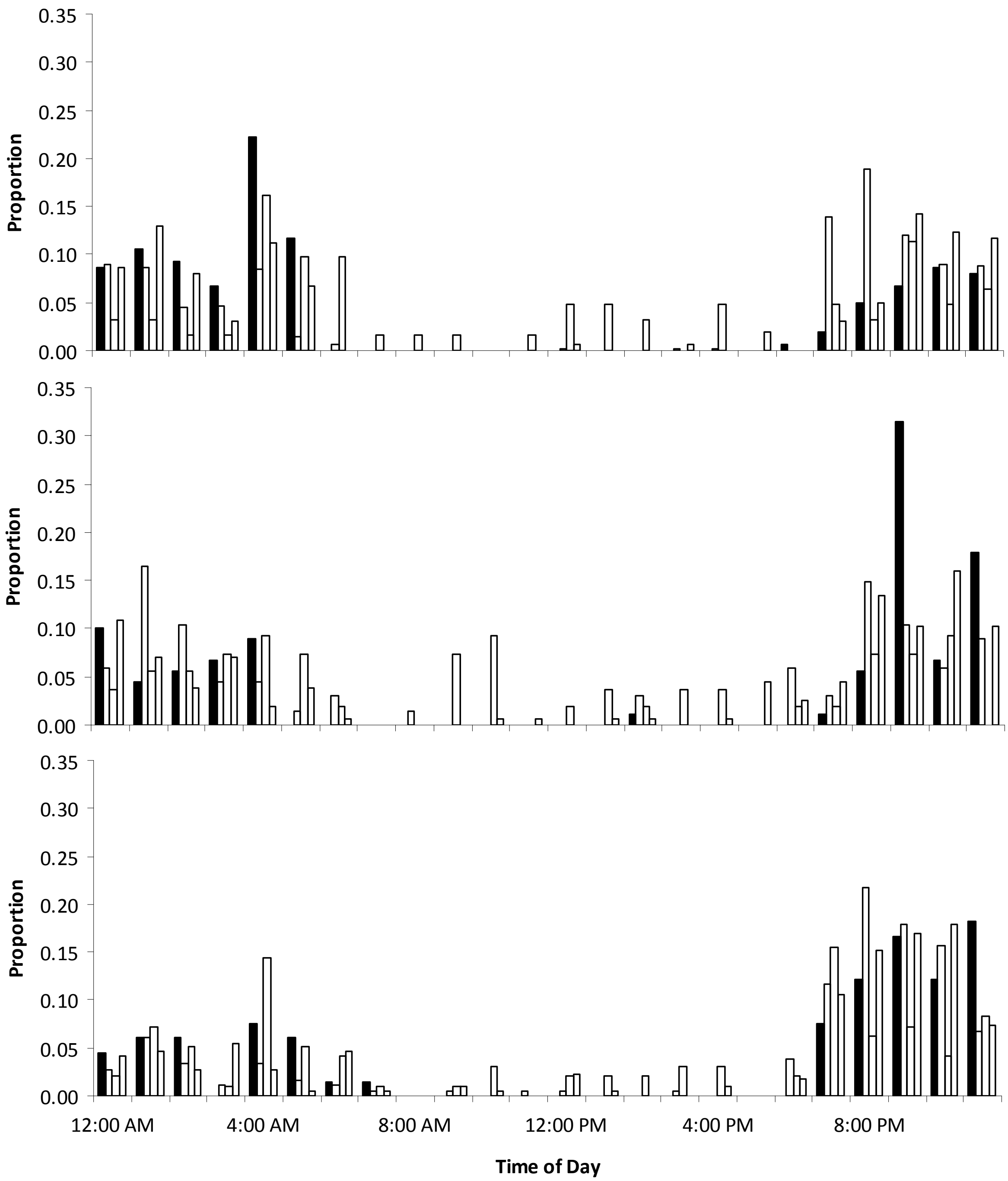


Figure 7. Hourly PIT scanner contacts of razorback sucker from standardized habitat use sampling for ponds 2 (top) with 1,131 total scans, 4 (middle) with 366 total scans, and 6 (bottom) with 560 total scans among four habitat types in Imperial Ponds; hummock (black), mud shore (white), open water (white diamonds), and rip-rap shore (grey). Scanners were deployed from February 2009 through July 2009.

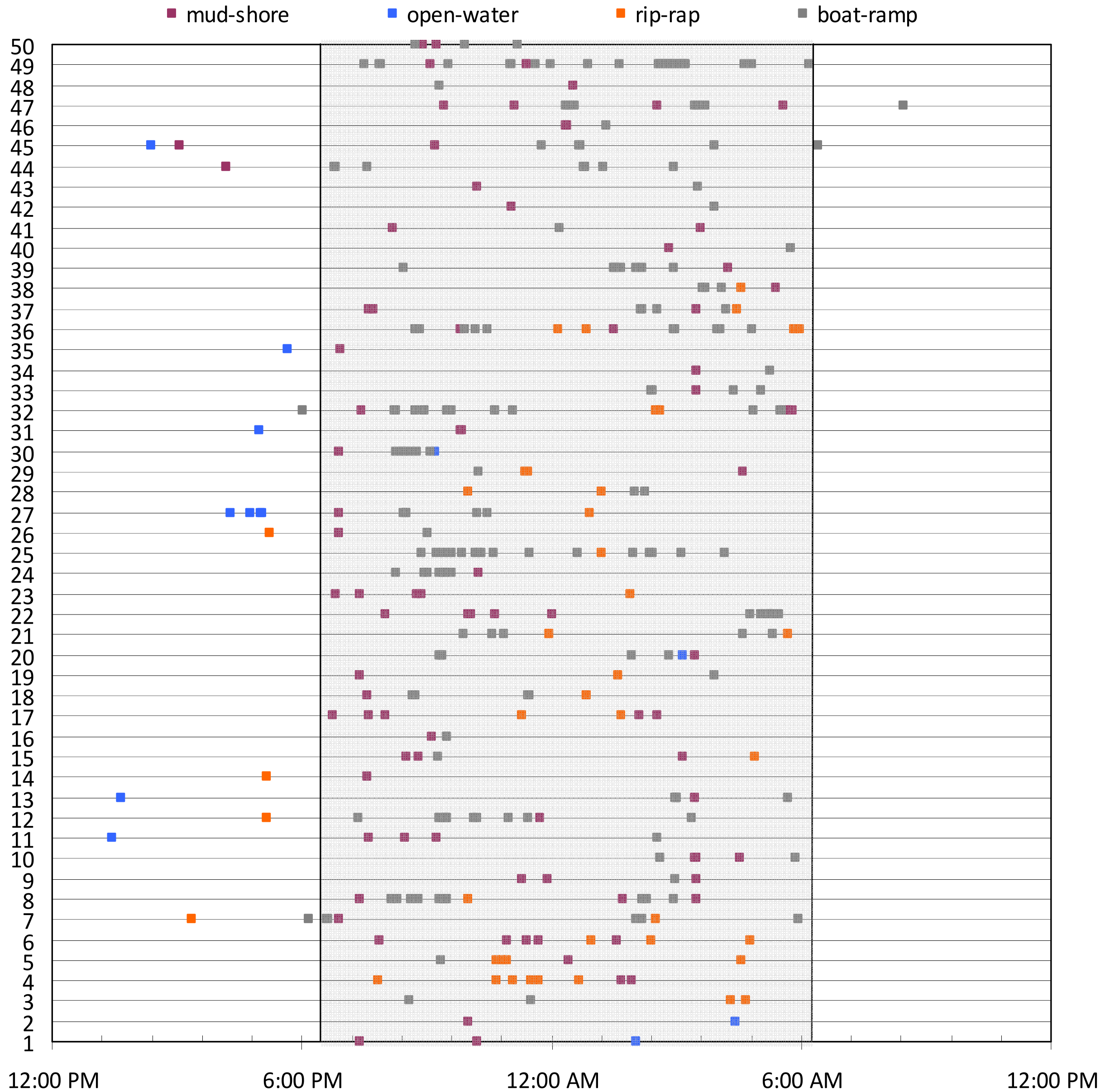


Figure 8. Multiple habitat PIT scanner contacts for February 2009 in Pond 2. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

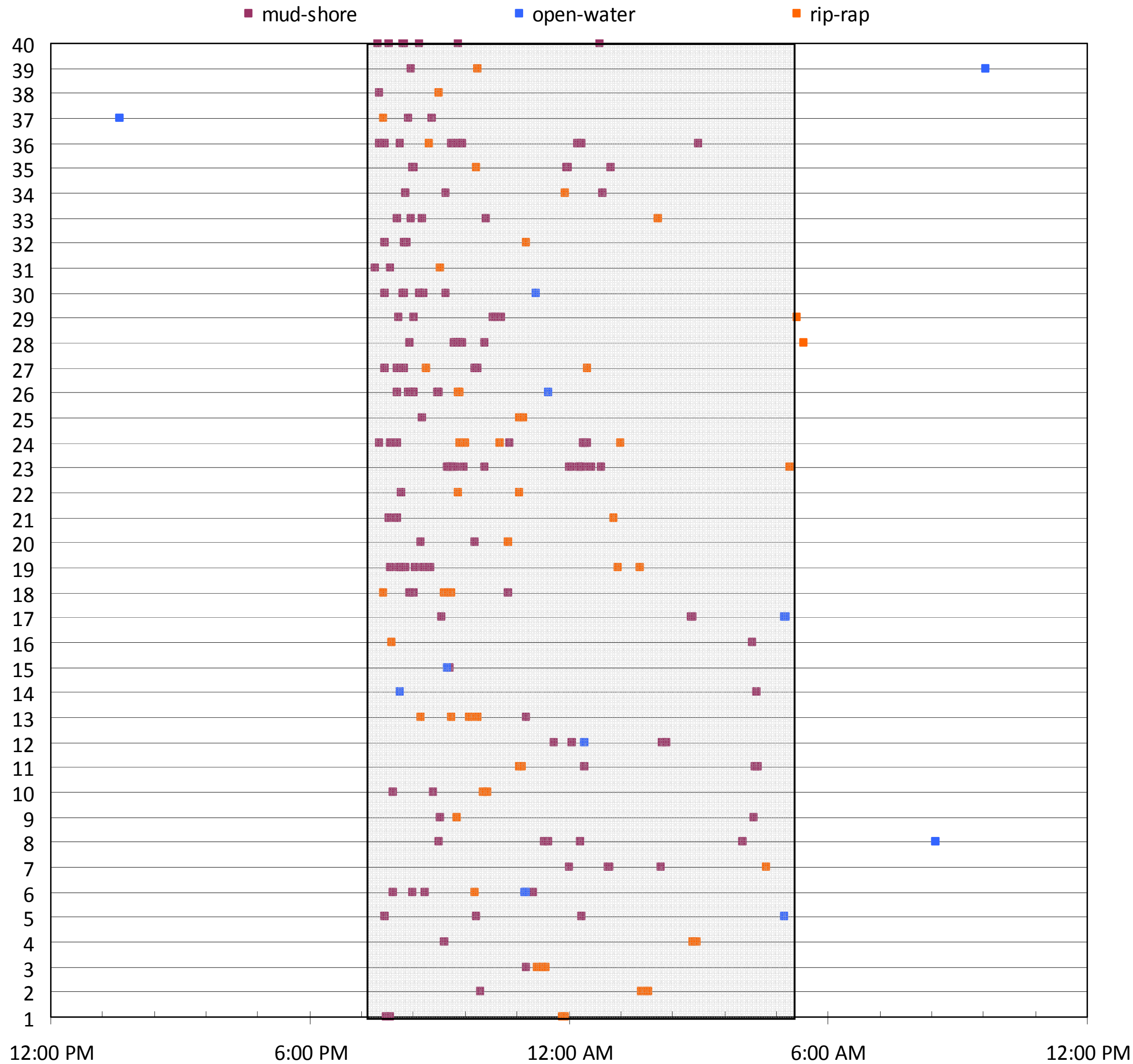


Figure 9. Multiple habitat PIT scanner contacts for April 2009 in Pond 2. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

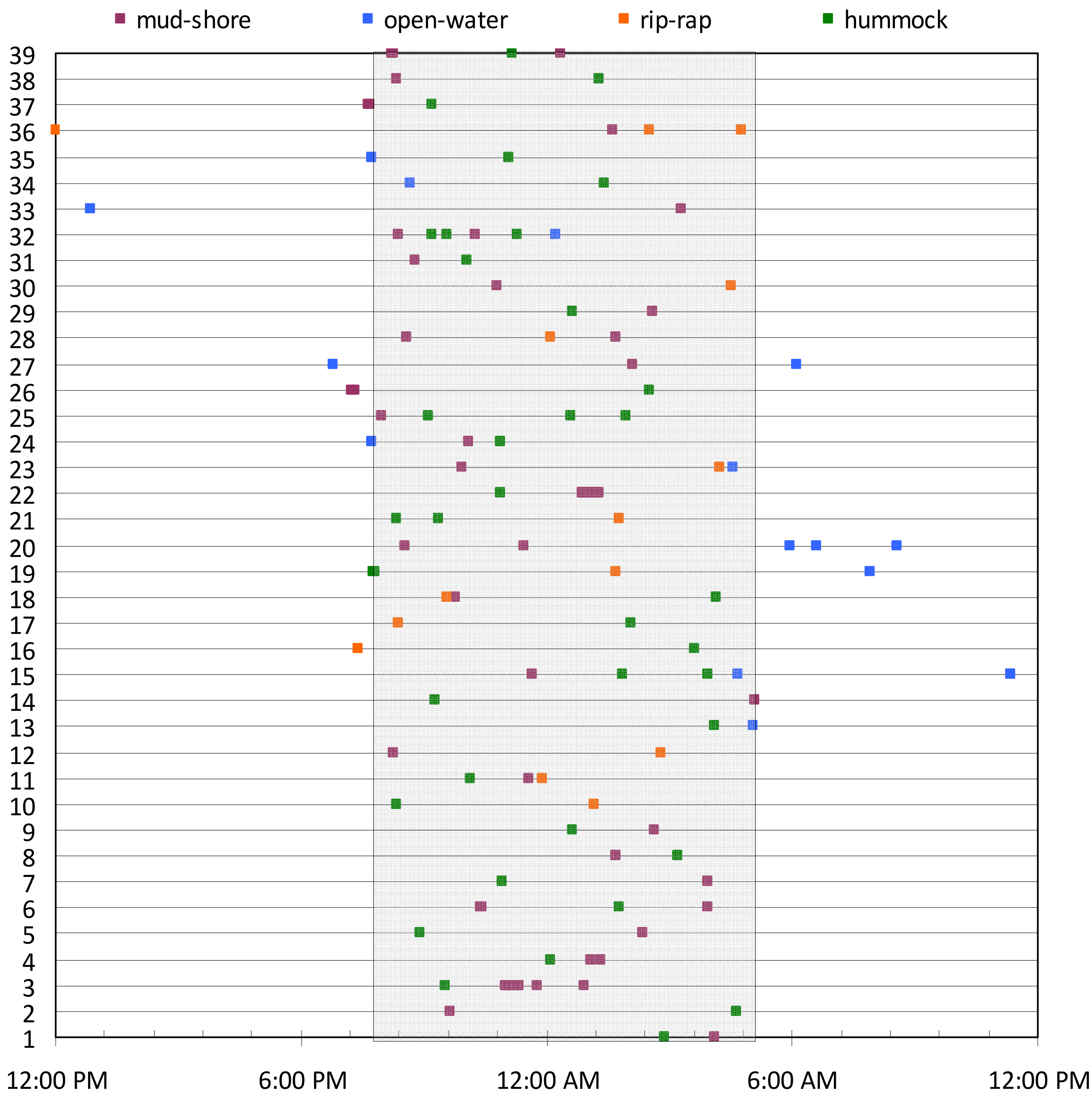


Figure 10. Multiple habitat PIT scanner contacts for May 2009 in Pond 2. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

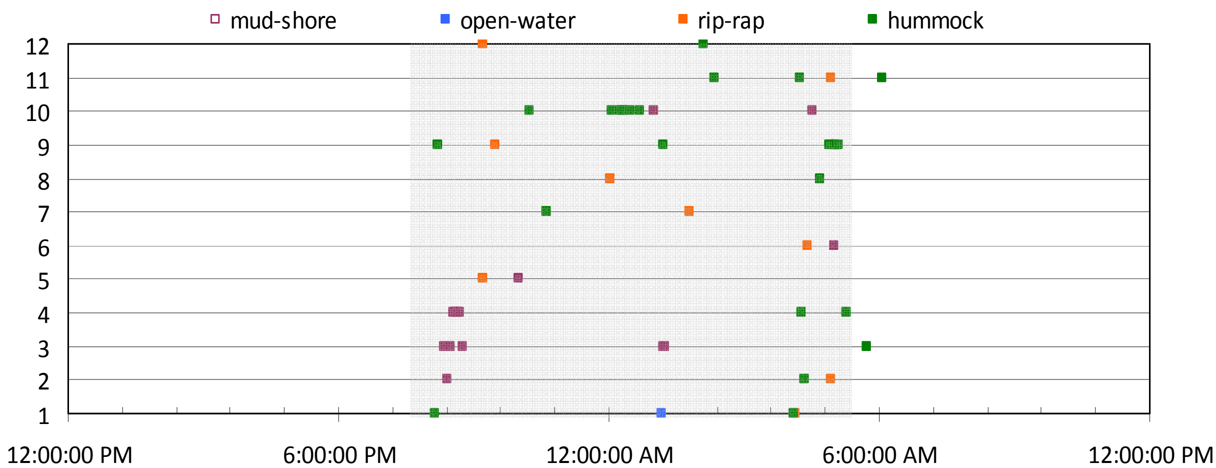


Figure 11. Multiple habitat PIT scanner contacts for July 2009 in Pond 2. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

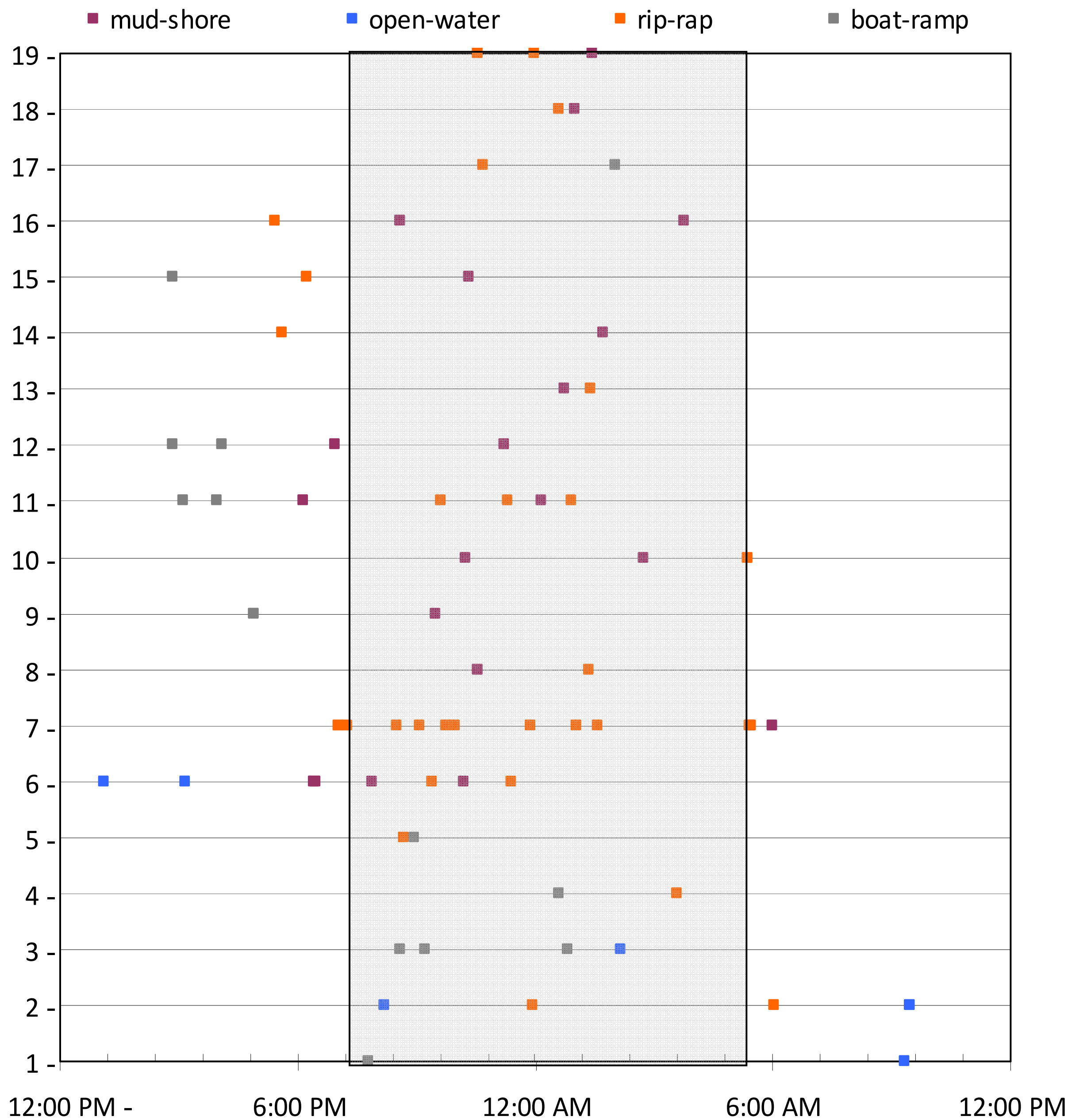


Figure 12. Multiple habitat PIT scanner contacts for April 2009 in Pond 4. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

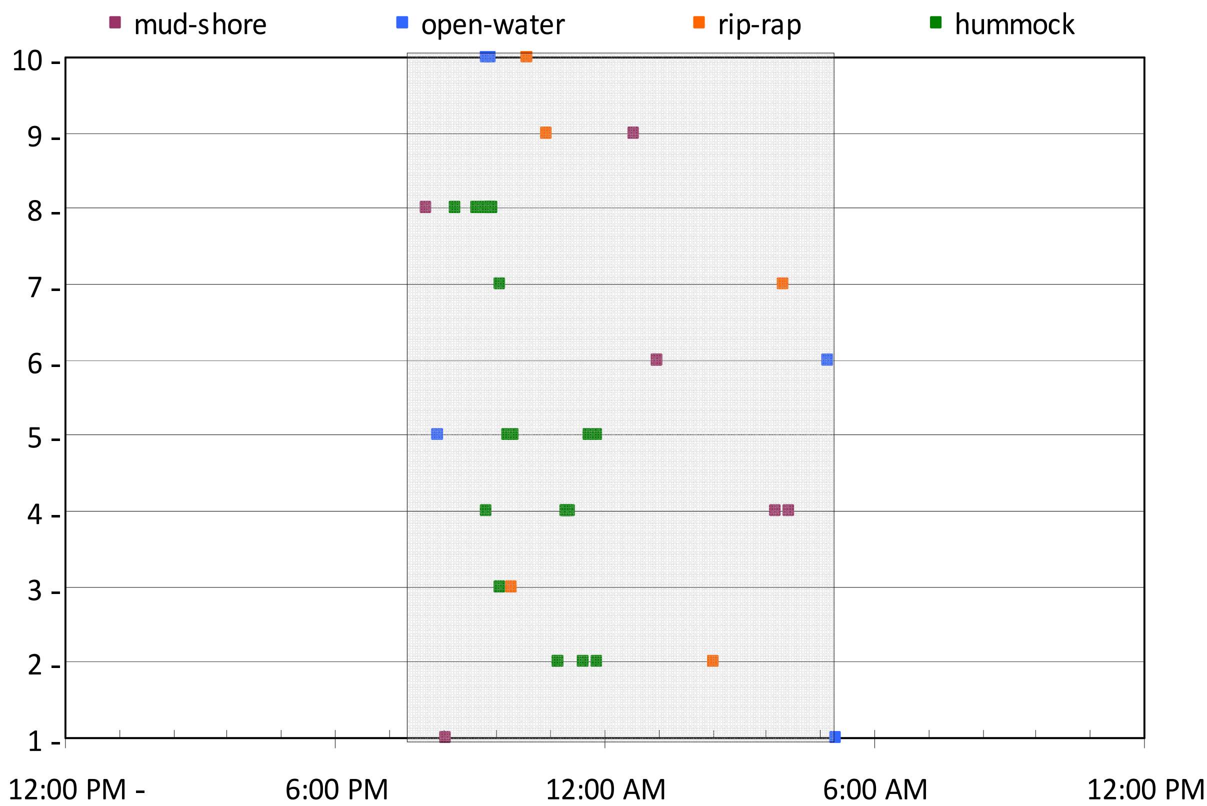


Figure 13. Multiple habitat PIT scanner contacts for June 2009 in Pond 4. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

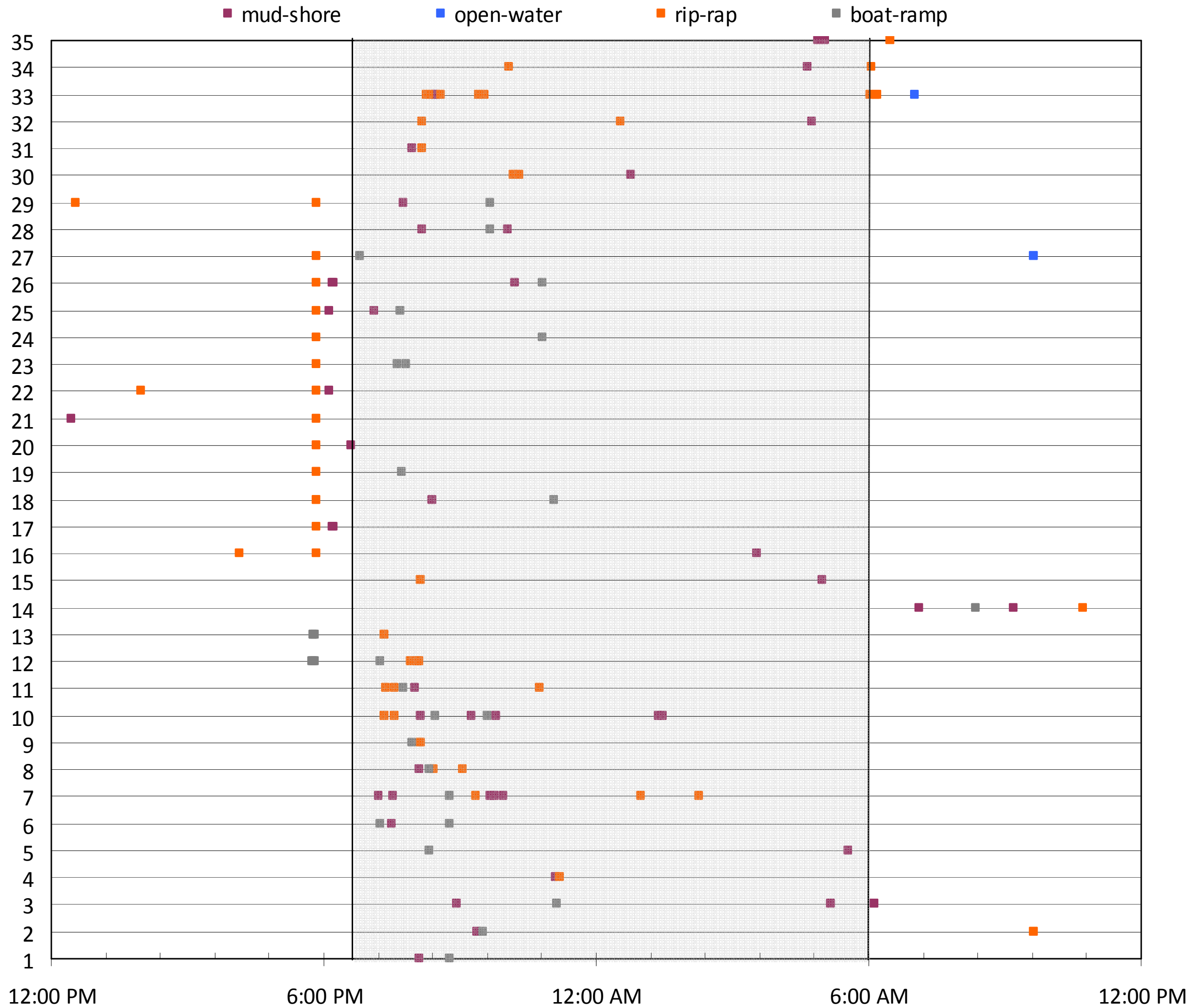


Figure 14. Multiple habitat PIT scanner contacts for March 2009 in Pond 6. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

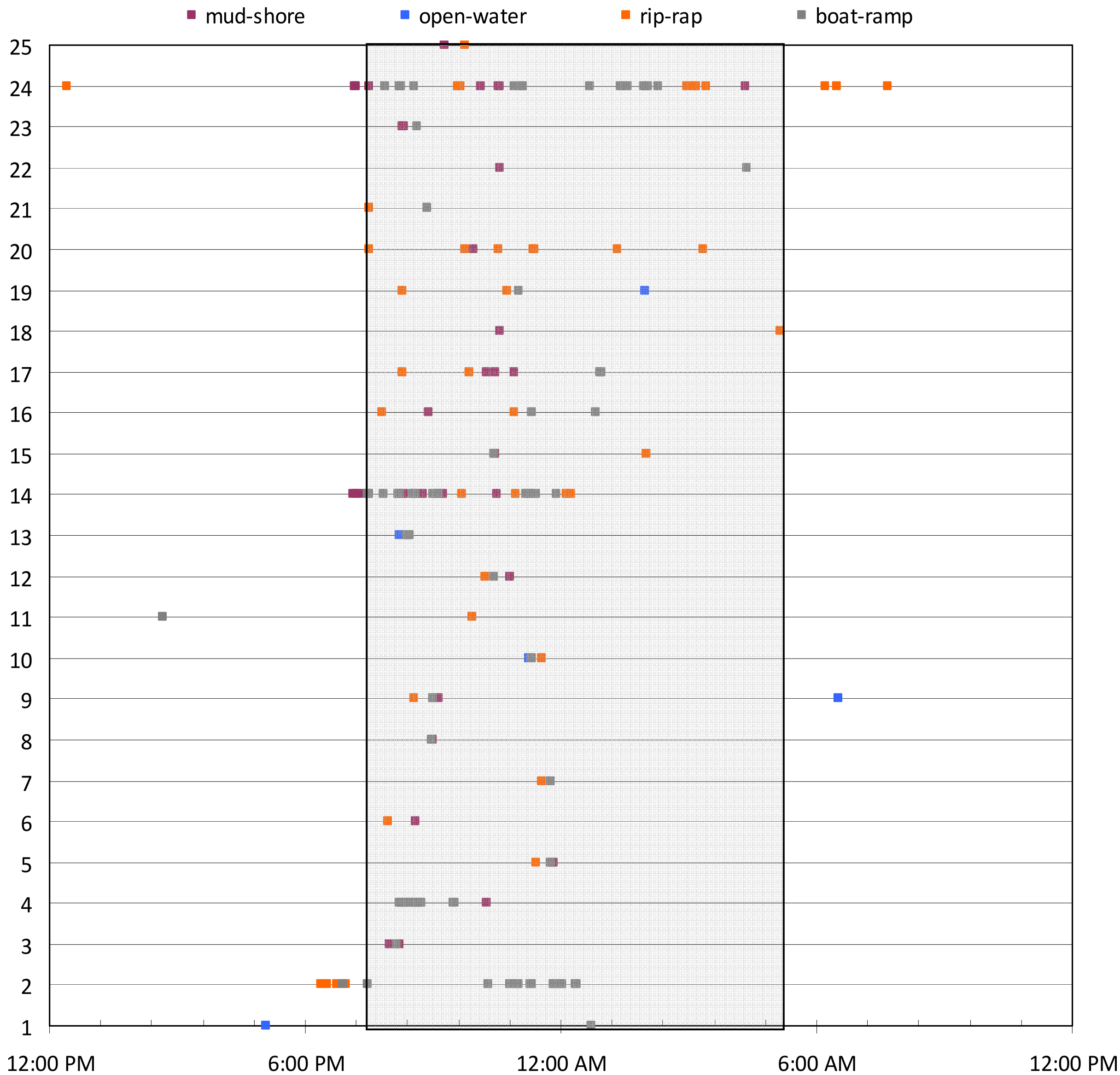


Figure 15. Multiple habitat PIT scanner contacts for April 2009 in Pond 6. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

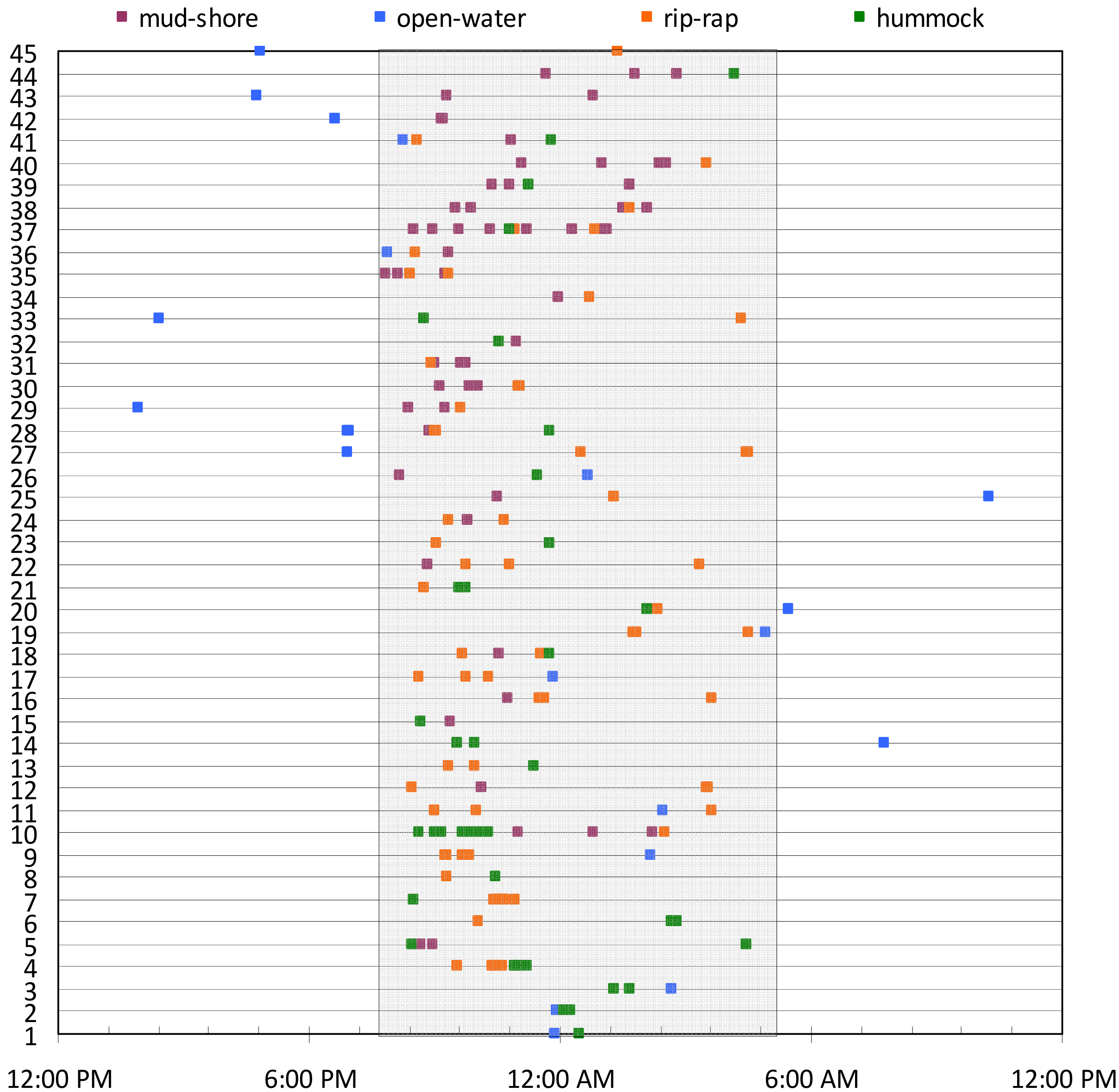


Figure 16. Multiple habitat PIT scanner contacts for June 2009 in Pond 6. The vertical axis represents a single razorback sucker for a 24 hour period, but multiple lines could represent the same fish on different days. Contacts are colored coded by habitat (see legend at top of figure), and the time period between sunset and sunrise is shaded.

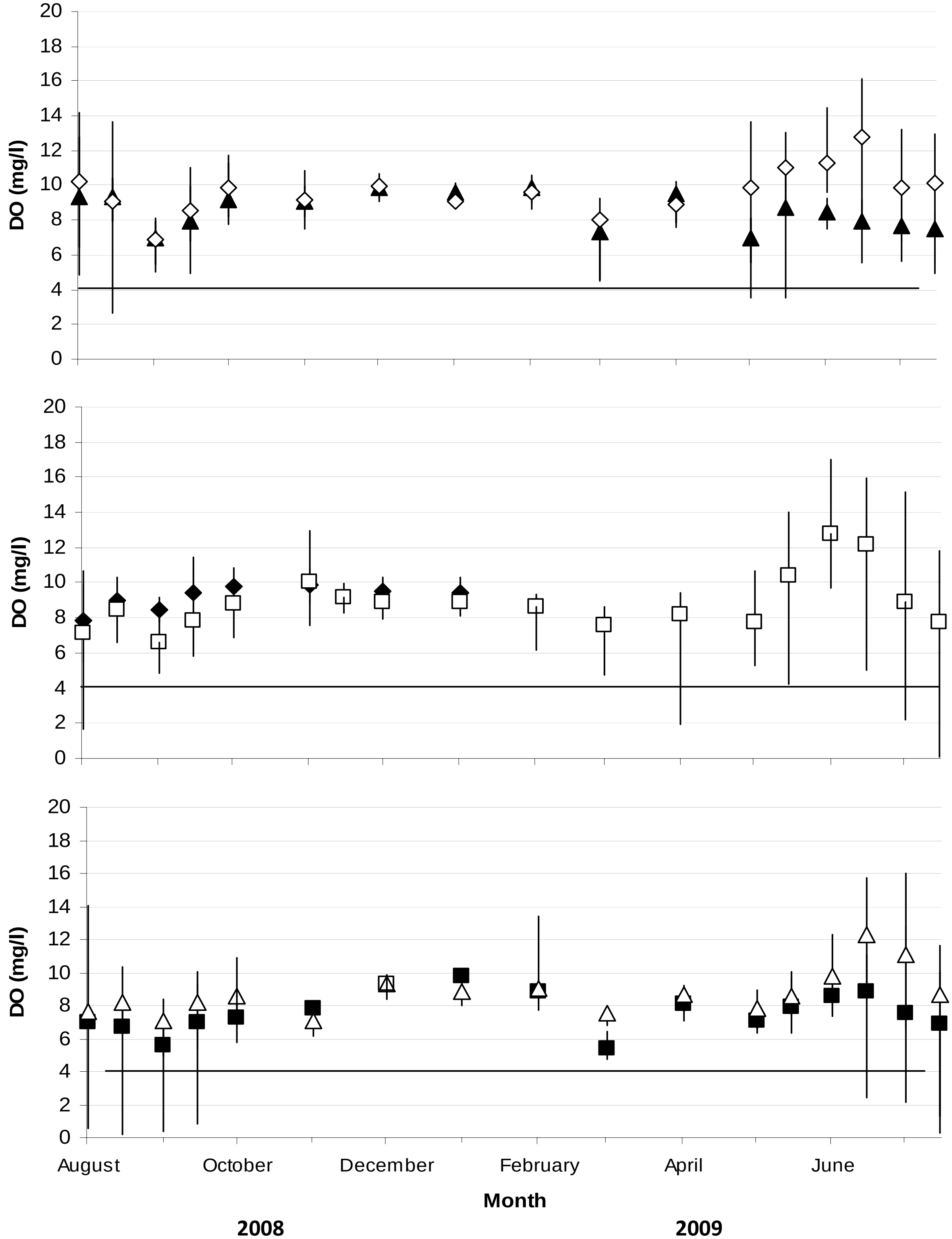


Figure 17. Mean dissolved oxygen (DO) and range (line projections) as measured during routine monitoring for ponds 1 (black diamond), 2 (white square), 3 (black triangle), 4 (white diamond), 5 (black square), and 6 (white triangle). The black horizontal line indicates the threshold value of 4 mg/L.

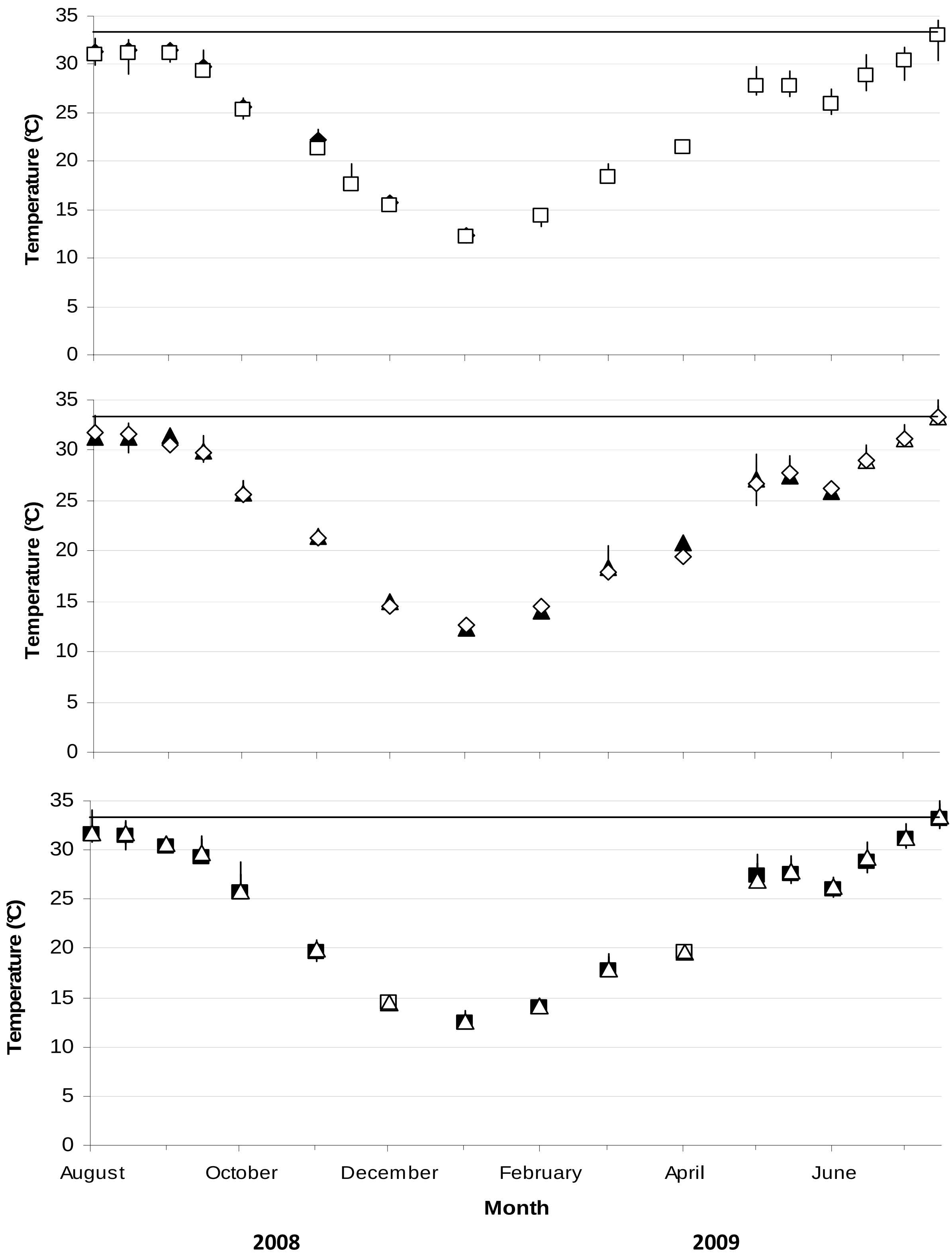


Figure 18. Mean temperature and range (line projections) for ponds 1, 2, 3, 4, 5, and 6. Pond symbols are the same as for Figure 17. The black horizontal line indicates the threshold value (33.3° C).

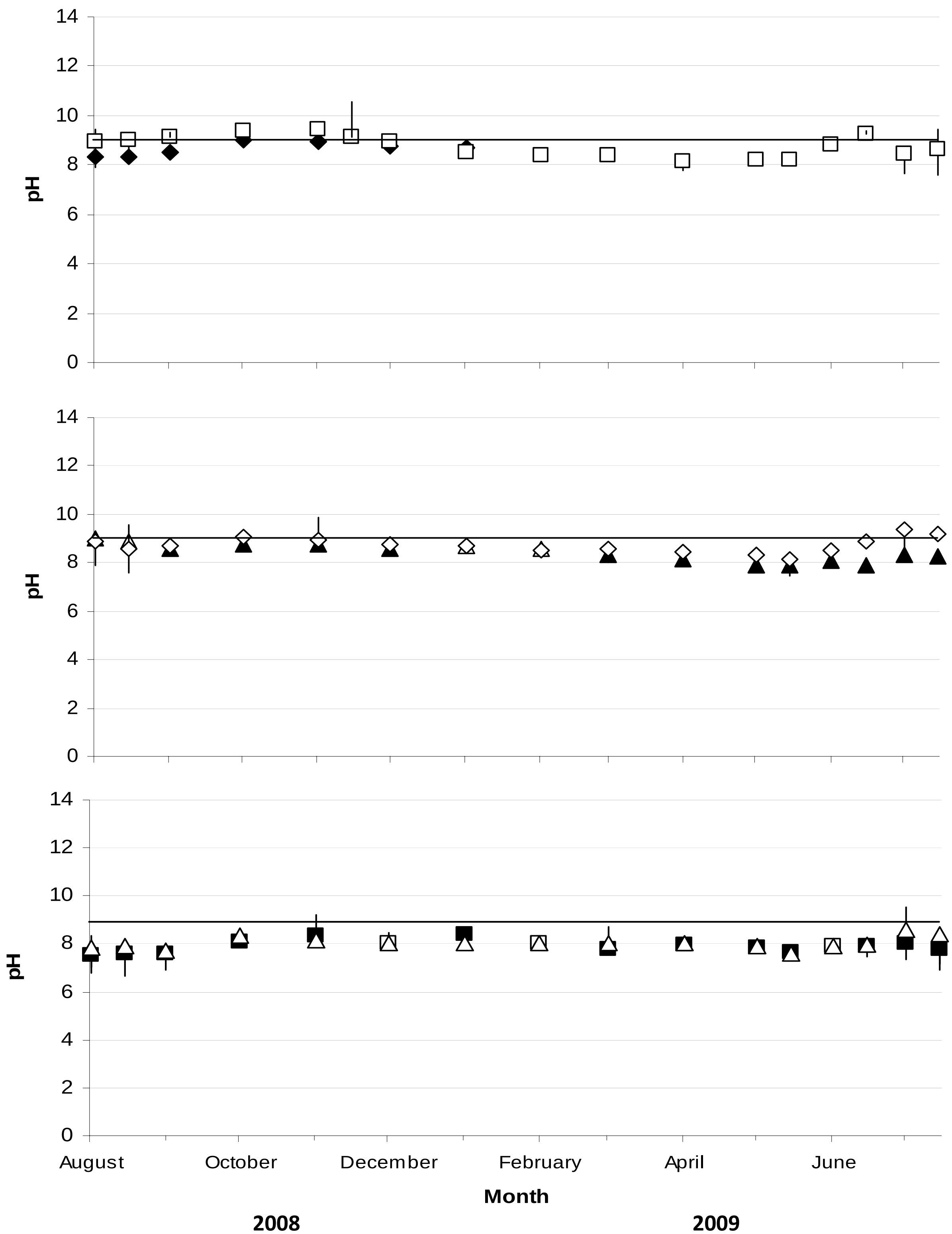


Figure 19. Mean pH and range (line projections) for ponds 1, 2, 3, 4, 5, and 6. Pond symbols are the same as for Figure 17. No pH data were collected during the second trip in September 2008 due to a broken probe. The black horizontal line indicates the threshold value of 9.0. All values less than 6 or greater than 12 were excluded because they were likely due to erroneous readings.

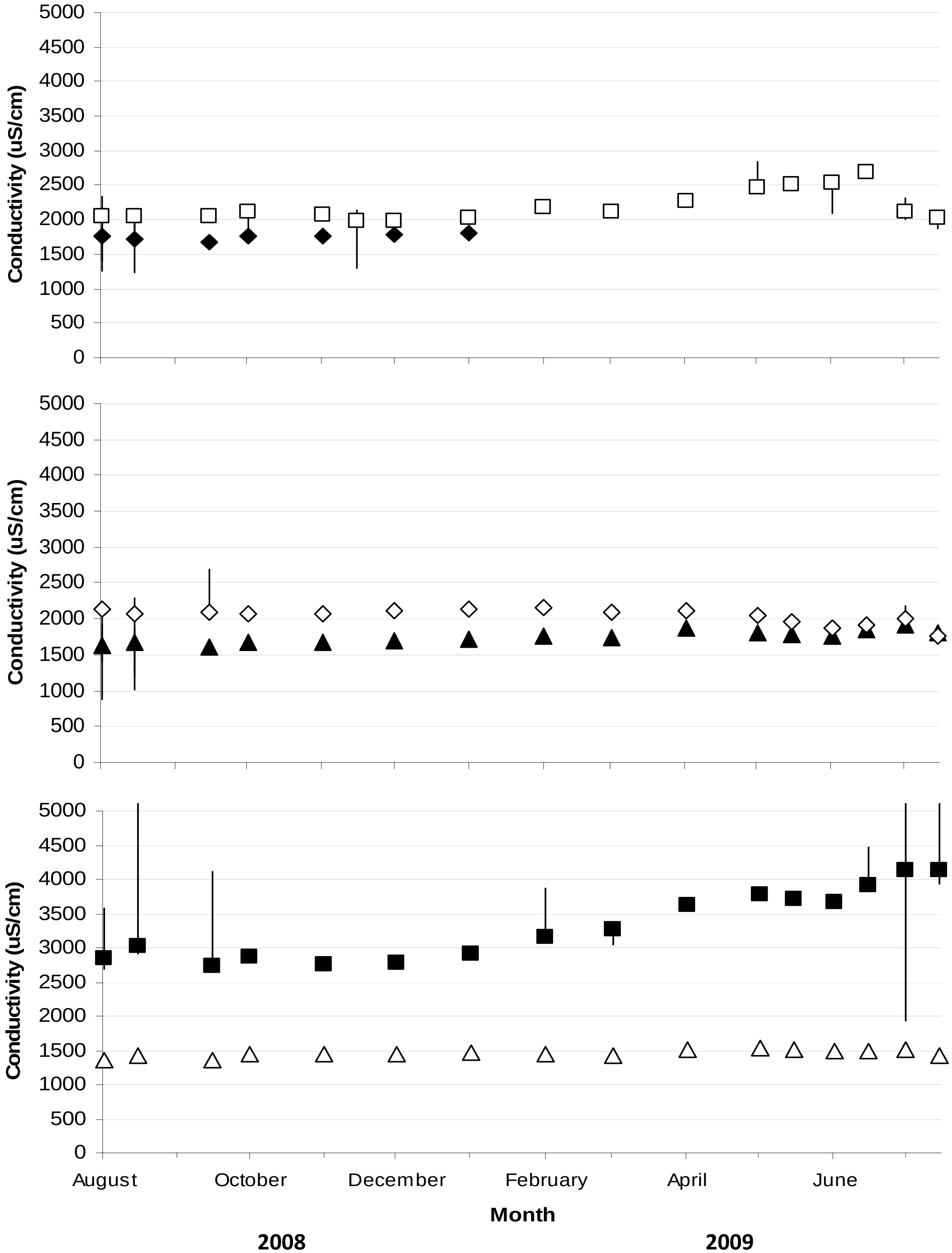


Figure 20. Mean conductivity and range (line projections) for ponds 1, 2, 3, 4, 5, and 6. Pond symbols are the same as for Figure 17. No readings were taken during the first trip in September 2008 because of problems with the probe. No threshold value for conductivity has been established.

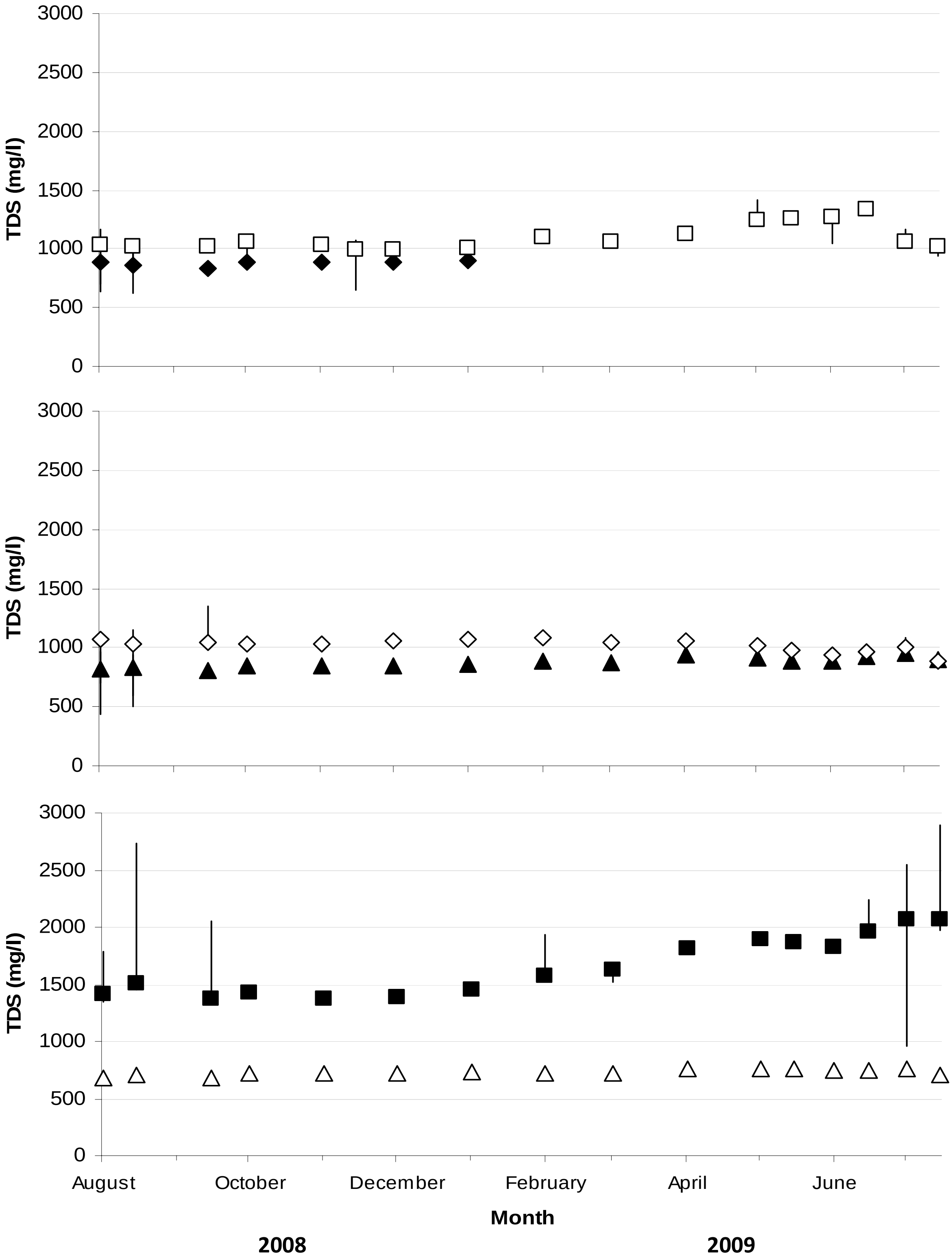


Figure 21. Mean total dissolved solids (TDS) and range (line projections) for ponds 1, 2, 3, 4, 5, and 6. Pond symbols are the same as for Figure 17. No readings were taken during the first trip in September 2008 because of problems with the probe. No threshold value for total dissolved solids has been established.

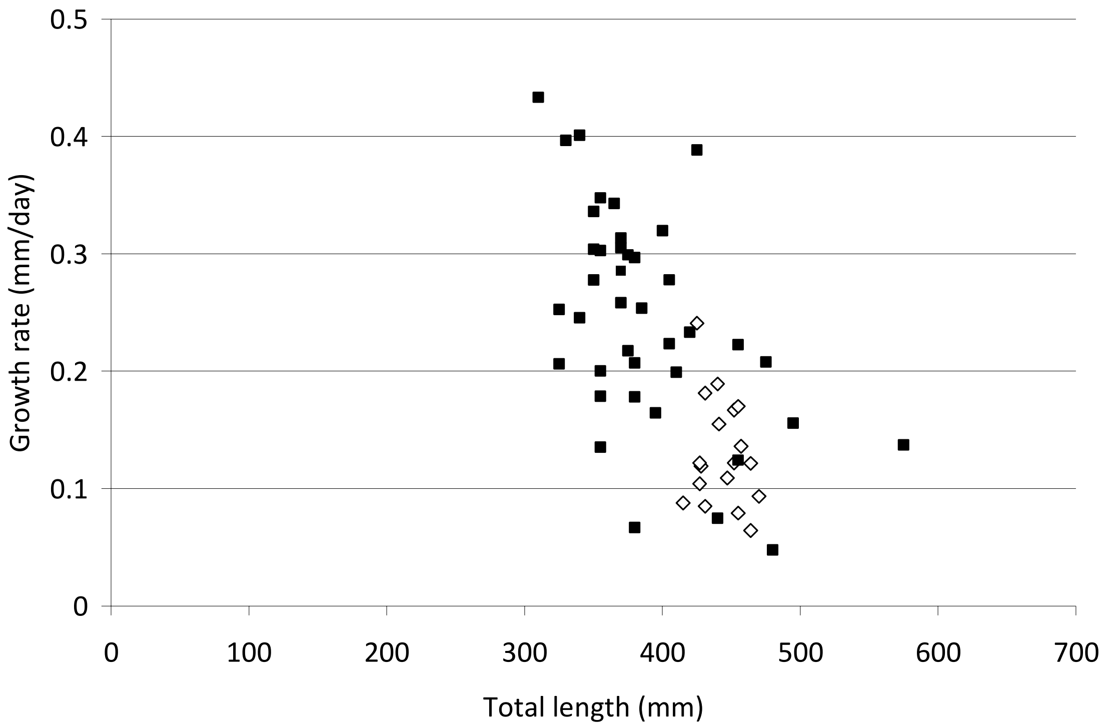


Figure 22. For a given size at release (x-axis), growth rates of razorback sucker stocked into Imperial ponds (white diamonds) were similar to growth rates for repatriate razorback sucker stocked into Lake Mohave (black squares). Growth data from Lake Mohave was restricted to post-release fish that were captured between 150 and 500 days after release, a similar time frame compared to razorback sucker captured in Imperial Ponds.