


Verde River and Horseshoe Reservoir Fish Surveys

Final Report to Salt River Project – April 11, 2007

Collection Agreement between
Arizona Game and Fish Department
and Salt River Project

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Cover photos by Lorraine Avenetti (LA) and James Fulmer (JF): Verde River upstream of Horseshoe Reservoir during October 2006 (top left; by LA), seining the Verde River during October 2006 (top right, by JF), Horseshoe Reservoir at full pool in April 2005 looking towards the dam (bottom left; by LA), and setting a frame net in Horseshoe Reservoir during April 2005 (bottom right; by LA).

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Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

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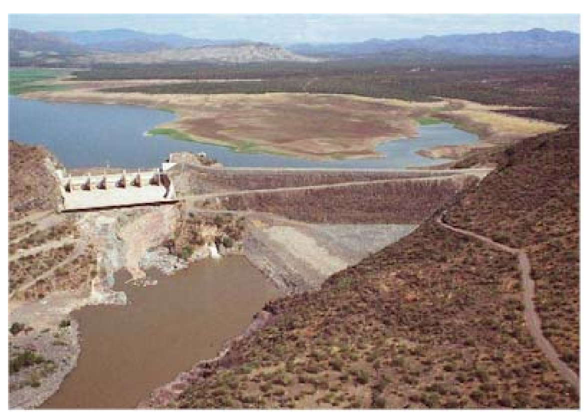
ABSTRACT

Horseshoe Reservoir is an irrigation storage reservoir on the Verde River operated by Salt River Project (SRP). To provide SRP with information to help decide which storage regime would best benefit native fish species, Arizona Game and Fish Department Research Branch conducted fish surveys in the lower Verde River immediately above Horseshoe Reservoir, and in Horseshoe Reservoir itself during 2005 when the reservoir filled, and during 2006, when the reservoir remained mostly at minimum pool to attempt to determine if species composition, relative abundance, and recruitment to age-1of nonnative fishes differed between the two years. The vast majority of the 9,864 fish captured during the study were nonnative (few of which were sport fish); only 14 native fish were captured, all within Horseshoe Reservoir. Common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) dominated (>87%) the catch in Horseshoe Reservoir during both years; sport fish were not common and typically were less than 10% of the catch. In Horseshoe Reservoir, electrofishing catch rates for common carp, goldfish, and all fish combined were greater in October 2006 than in October 2005. Electrofishing catch rates for all fish combined were also greater in March 2006 than they were in April 2005. Gill net catch rates for common carp, goldfish, and all fish combined did not differ between years for either spring or autumn comparisons. In the Verde River, common carp dominated the electrofishing catch and their catch rates did not differ between October 2005 and October 2006. Red shiner dominated the seining catch in the Verde River, and there were no significant differences in red shiner catch rates between October 2005 and 2006. Of large-bodied nonnative fish, only common carp and goldfish had detectable young-of-year cohorts (YOY), and the 2006 cohort was more abundant than the 2005 cohort. Ten razorback suckers and three Colorado pikeminnow were captured during the study, all within Horseshoe Reservoir. Based on locations of coded wire tags injected at the hatchery, razorback suckers had persisted in the river for 3-8 years after they were stocked, whereas Colorado pikeminnow only had only been in the river for 3-9 months. Seven razorback suckers were captured in a gill net set in the middle portion of the reservoir during April 2005. These seven fish were ripe and tuberculate, so there is a possibility they had or were getting ready to spawn. The current operating regime seems to be negatively impacting nonnative sport fish, but common carp and gold fish are thriving, and these two species may compete with and prey on early life stages of native fishes.

BACKGROUND

Horseshoe Dam was built during 1944-1946, creating Horseshoe Reservoir; Salt River Project Agricultural Improvement and Power District (SRP) operates the dam. Horseshoe Reservoir is an irrigation storage reservoir and annual fluctuations typically result in peak volumes during spring and minimum volumes in autumn and winter (Figure 1). In some past years with high precipitation (e.g., late 1980s and early 1990s), SRP voluntarily retained water in the reservoir during autumn and winter



Horseshoe Dam and Horseshoe Reservoir (top).

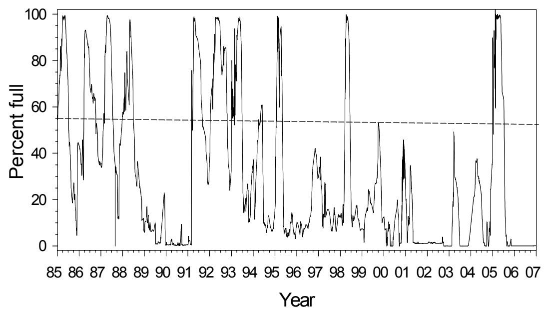
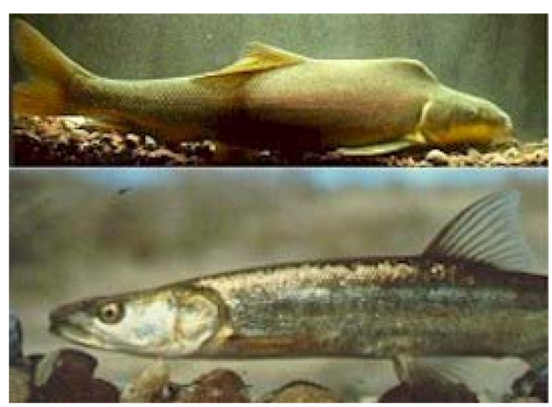


Figure 1. Percent fullness (% total possible acre-feet) of Horseshoe Reservoir by year, 1985-2006. The dashed line represents the 55% full level.

months to support a sport fishery. However, water operations since 1997 have focused on minimizing annual carryover storage to improve system efficiency (i.e., maximize available storage; Charles Ester, SRP Water Resource Operations Manager, personal communication). During dry years, Horseshoe Reservoir is dewatered in the summer, and hence does not foster an abundant sport fish population (Warnecke 1988).

The fish assemblage in Horseshoe Reservoir was dominated by nonnative fishes from the late 1980's (Warnecke 1988) through 2004 (Jim Warnecke, Fisheries Program Manager, Arizona Game and Fish Department, personal communication). Similarly, the Verde River immediately above the reservoir is dominated by nonnative fishes (Duffy 2004), but native fish abundance and richness increases upstream, until the reach above Sycamore Canyon Wilderness is dominated by native fishes (Rinne 2005). Two endangered native fishes, razorback sucker (*Xyrauchen texanus*) and Colorado pikeminnow (*Ptychocheilus lucius*), were stocked yearly, from 1981 through 2004, into the Verde River near Childs by Arizona Game and Fish Department (Hyatt 2004). Catch information indicates that neither of these species has established reproducing populations in the river (Hyatt 2004). Nonnative fishes, through predation and competition, pose one of the biggest threats to these endangered fish species, and to other native fishes. It is hypothesized that a change in the reservoir storage regime could disadvantage nonnative sport fish to the benefit of these native fishes. For example, the reservoir could be drained during the sport fish reproductive season, killing eggs, reducing rearing habitat, and making young fish more vulnerable to predation. Acquiring empirical data on species composition and recruitment to the nonnative fish populations during years with different reservoir storage regimes would provide information to help decide which storage regime would best benefit the native fish species. The objective of the Verde River-Horseshoe Reservoir Fish Sampling Project is to estimate species composition, relative abundance, and recruitment to age-1 of nonnative fishes in Horseshoe Reservoir and in the Verde River from Sheep Bridge to Horseshoe Reservoir during a year when Horseshoe Reservoir fills (2005) and a year when Horseshoe remains mostly empty (2006). A secondary objective is to determine percent of fish macrohabitat types (e.g., riffles, runs, pools), and substrate types (e.g., cobbles, gravels, sands) in the Verde River when Horseshoe Reservoir is at minimum pool. A tertiary objective is to estimate movements and growth of fish, by marking and recapturing them.



Razorback sucker (top) and Colorado pikeminnow (bottom).

METHODS

Standard fish sampling protocols developed by Arizona Game and Fish Department (AZGFD 2004) were used to survey fishes in Horseshoe Reservoir and the Verde River during the study period (2005-2006).

STUDY SITES

Horseshoe Reservoir

Horseshoe Reservoir was sampled at full pool (98-99% full) during April 2005, and near minimum pool (< 1%) during October 2005, March 2006, and October 2006. Because of the different surface areas during the time periods, it was necessary to use slightly different sampling methods as outlined in Arizona Game and Fish Department's standardized protocol (AZGFD 2004). Minimum pool and maximum pool Geographic Information Systems (GIS) covers were obtained from Salt River Project. The reservoir shoreline at each size was divided into 500 m segments (sites; Figures 2 and 3) using ArcGIS, resulting in 115 sites at full pool and 8 sites at minimum pool. The reservoir basin at full pool was divided into lower, middle, and upper portions to achieve an approximately equal number of 500-m sites in each portion (39, 38 and 38 sites in each respective portion; Figure 2). In each portion (hereafter referred to as a basin), sample sites were randomly chosen, such that each basin had: eight electrofishing sites, six gill-net sites, and three frame net sites. Alternative sites for all gear types were also randomly chosen, in case a site was deemed unacceptable (e.g., cliff face or too shallow to enter with a boat) upon arrival. At minimum pool, the entire reservoir was within the designated lower basin. Because there were only eight sites at minimum pool, the plan was to sample the entire shoreline by electrofishing, and set gill nets in each 500-m site if feasible.

Verde River

The Verde River, which was only sampled when the reservoir was at minimum pool, was divided into four reaches; the 'river' reach from Sheep Bridge downstream to where the reservoir began when at full-pool, and the three reaches that fell within the reservoir basins mentioned above which were submerged when the reservoir was full. The mean width of the river is approximately 15 m in the river reach, and was assumed to be similar in the lower reaches. Therefore, to have a high probability of collecting all fish species (Hughes et al. 2002), 100 times the mean width, or 1500 m (three 500-m sites) was sampled in each reach. The entire river from Sheep Bridge to Horseshoe Dam was divided into 500-m segments using National Geographic TOPO © software; beginning at Sheep Bridge, the river reach extended from Sheep Bridge downstream 4 km, the upper reach was from 4-8.5 km, the middle reach was from 8.5-14 km, and the lower reach was from 14–16.5 km (Figure 4). Three 500-m sample sites were randomly selected in each reach to be sampled by electrofishing, with a restriction that each was separated from the next downstream by 500 m; this restriction was not used in the lower reach because of the low number of available segments.

FISH SAMPLING

Horseshoe Reservoir

During April 2005, an anodized aluminum boat outfitted with a Smith-Root 5.0 GPP electrofishing unit and two cable-whisker cathode arrays suspended from booms off of the bow was used for electrofishing. A bow-mounted trolling motor was used to propel the boat during electrofishing. Electrofishing sites were marked during the day by hanging a 30-cm long PVC pipe, wrapped with highly-reflective white tape, on a branch of a tree or shrub at the north

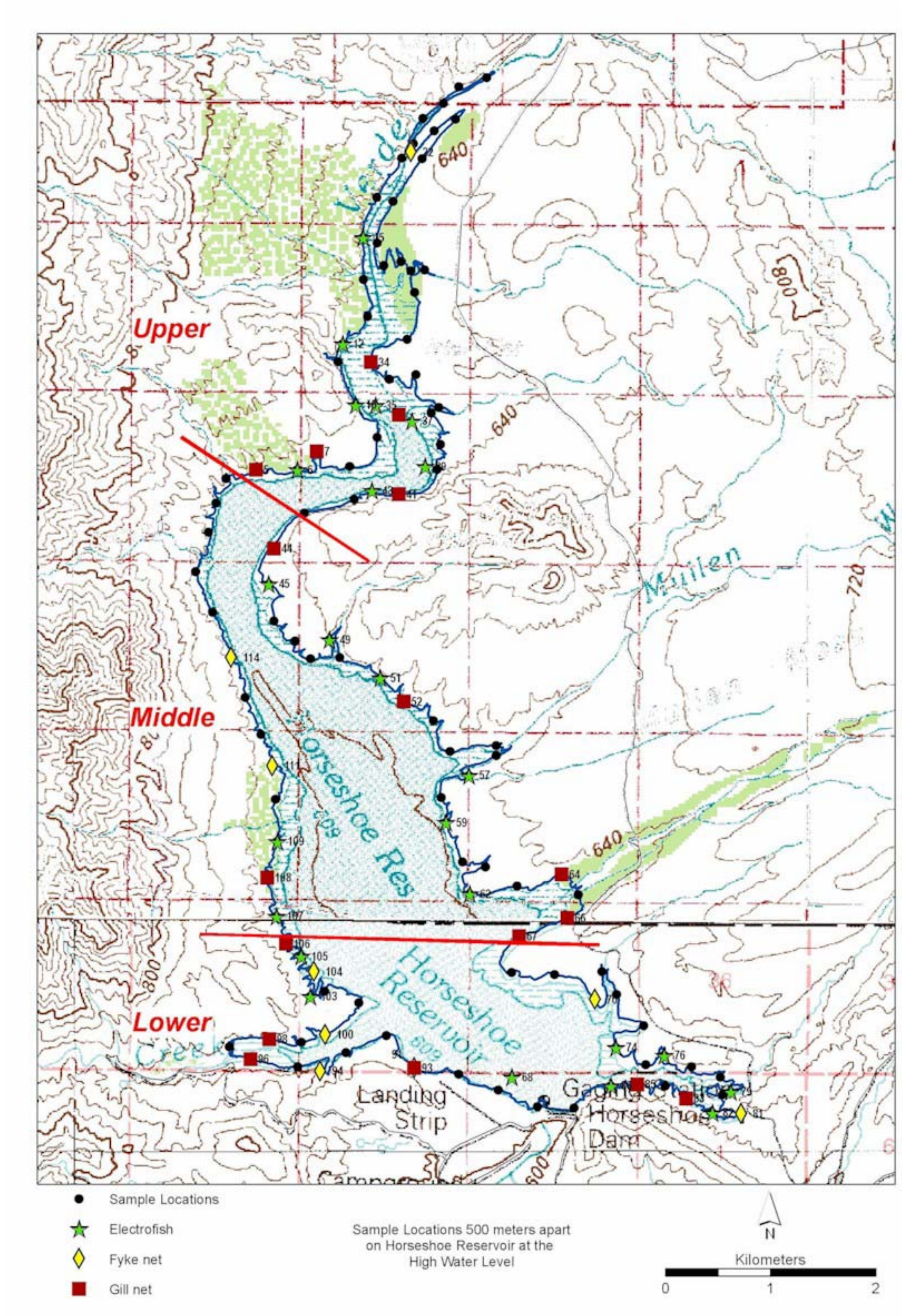


Figure 2. Map of Horseshoe Reservoir at full pool showing all potential sample sites (all symbols) in Lower, Middle, and Upper portions. Sites sampled in April 2005 are shown with unique symbols for each gear type.

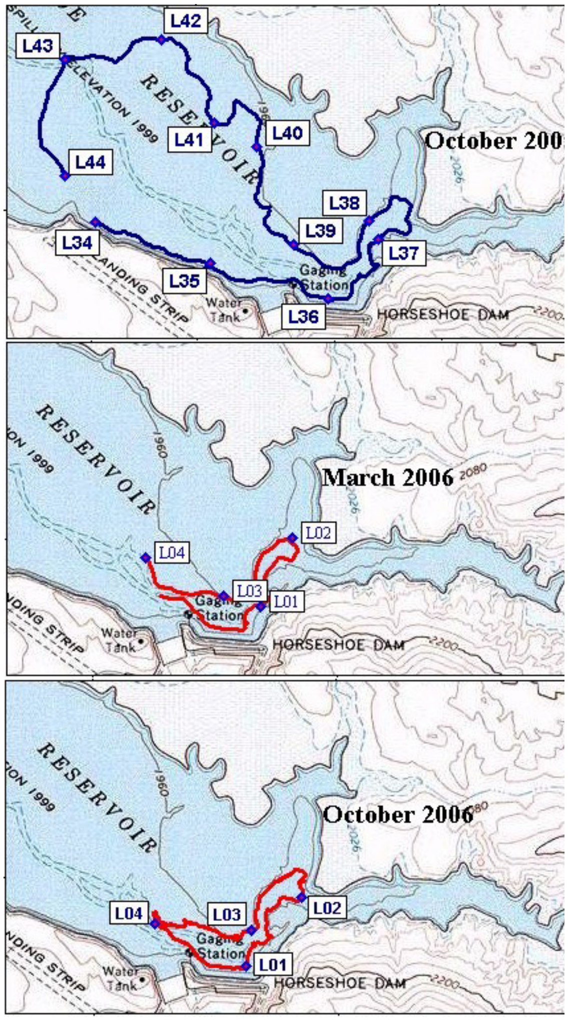


Figure 3. Maps showing the route taken when electrofishing Horseshoe Reservoir when it was near minimum pool October 2005, and March and October 2006; all within the Lower basin of the reservoir. Blue diamonds (L01, L02, etc.) refer to the end of sites sampled.

end of each site; markers were located at night with a spotlight. Eight sites were sampled per night April 4-6, 2005. Each site was shocked continuously for 900 seconds; duration was standardized, not distance (typically less than 500 m of shoreline was shocked). Output was kept between 7 and 8 Amps. Two people netted fish from the bow end of the boat (one of these people powered and steered the boat using an electronic trolling motor), and put captured fish into the live well. A third person processed fish (identified species, measured length (mm) and weight (g), injected fish >159 mm TL with spaghetti tags, and noted overall condition), and a forth person recorded data. Minimal size of fish to be tagged was increased from the proposed 150 mm TL to 160 mm because150 mm was deemed too small for our spaghetti tag needle without potentially causing significant injury to the fish.

During October 2005, March 2006, and October 2006, the lake was electrofished using a canoe outfitted with a Smith Root 2.5 GPP electrofishing unit, a 30 cm diameter spherical cathode suspended from a bow-mounted boom, and 12 x 334 cm anodized aluminum strips that were permanently affixed to each side of the canoe such that they would be mostly submerged when the canoe was loaded. A Smith-Root 2.5 GPP was used instead of a 5.0 GPP because the lake was accessed by floating into it from the Verde River after sampling the river, and the 2.5 GPP weighed 100 pounds less than the 5.0 GPP and thus allowed for more maneuverability in the Verde River. Output was kept between 4 and 8 Amps.

The reservoir was at different levels of fullness during the last three sampling trips, so the mapped sites were either on dry land or in the water. Therefore, the entire shoreline along the western, southern and eastern shores was sampled as planned, but the northern shoreline where the river enters was too shallow to access, so we shocked along the flooded tree-line (Figure 3). Each site was defined by the distance it took to shock continuously for 900 seconds.

Experimental gill nets (45.72 m long, 1.83 m tall, with 1.25 cm to 7.5 cm mesh) were set on the lake bottom, perpendicular to shore, with the small-mesh end anchored on or

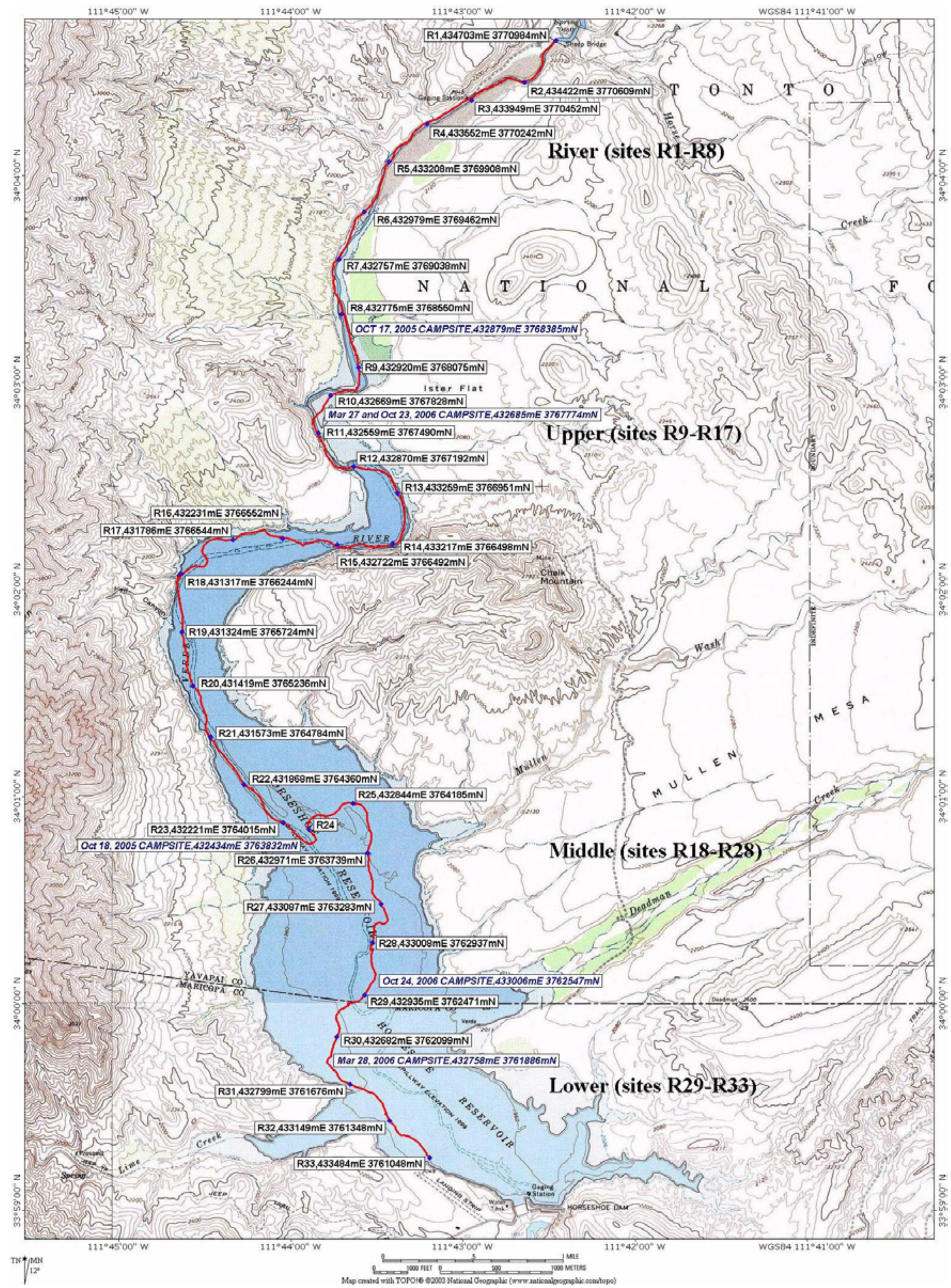


Figure 4. Map showing the Verde River course (red line) within Horseshoe Reservoir bed and all potential 500-m sample sites during October 2005, March 2006, and October 2006. Sites that were electrofished were chosen at random within each reach (River, Upper, Middle, and Lower).

near shore. Gill nets were set in the afternoon, and pulled the following day beginning in the morning. During April 2005, gill nets were set at 17 sites (six in the lower, six in the middle, and five in the upper basin), one less than planned. Six surface nets and two bottom 4-cm-mesh nets were inadvertently brought into the field on April 4, and so only three nets (the two bottom and one surface net) were set this first day. Seven bottom-set experimental gill nets were borrowed from the Region VI Arizona Game and Fish Department office, and set each of the subsequent days. During October 2005 and March and October 2006 the lake was very shallow (approximately 1.5 m maximum depth, but mostly <1 m deep). During October 2005 suitable sites to set nets in all of the 500-m shoreline sites could not be found, so only five experimental gill nets were set. During March and October 2006, we relaxed the restriction of only setting one net in each 500-m site so that eight nets could be set during each sampling trip. During each of the three later trips, nets were set in the afternoon (3-5 pm) and checked the following day (7am – 3 pm).

Frame nets (125 x 125 cm frames, 1 cm mesh) were used to sample fish in Horseshoe Reservoir during April 2005, but because so few fish were captured in them, they were deemed ineffective and so were not used during the remainder of the sampling trips. Frame nets were set on the bottom and perpendicular to the shore, with the middle divider being anchored near or on shore, and the wings being set at approximately 45 – 80 degree angles from the middle divider. Nets were set in the afternoon and pulled the following day, beginning in the morning. Three frame nets were set at nine sites (six in the lower, two in the middle, and one in the upper basin) during our sampling. Holes observed in the nets after the first and second sets were repaired with quick-ties to prevent fish escape.

Suitable shorelines were seined (2 x 9 m straight seine with 3-mm mesh) in Horseshoe Reservoir during March and October 2006 in an effort to capture smaller fish; smooth-bottom shorelines with shallow gradients were those deemed suitable.

All fish captured were identified to species, measured (mm TL), weighed (g), and if unmarked and ≥ 150 mm TL, marked with a spaghetti (Floy) tag injected into the muscle tissue below the dorsal fin, and released, except as noted below. In April 2005, due to a potential shortage of spaghetti tags, only largemouth bass and catfish captured in nets that were ≥ 150 mm TL were marked on April 5 and 6. On April 7, 2005, all fish captured in nets that were ≥ 150 mm TL were injected with spaghetti tags. During October 2006, we ran out of spaghetti tags during the final day of sampling Horseshoe Reservoir, so not all large fish were injected with spaghetti tags. During October 2006, fish marked with spaghetti tags were also marked by clipping the anal fin; this was implemented because Basavaraju et al. (1998) reported that floy-tag retention rates for common carp were extremely low and fin-spine clips were the best method of marking this species. Razorback suckers and Colorado pikeminnow were marked with PIT tags (125 kHz, 11.5 mm tags, injected into the abdominal cavity from the ventral body surface posterior to the pelvic fins) rather than spaghetti tags, and individuals were scanned for coded wire tags (these species are injected with coded wire tags at the hatchery before release into the river).

Verde River

We conducted a reconnaissance canoe trip in the Verde River from Sheep Bridge downstream and into Horseshoe Reservoir on October 12, 2005, and determined that the river would be best sampled using an electrofishing canoe, and that Horseshoe Reservoir was accessible via canoe. During the reconnaissance trip we flagged electrofishing sites (Figure 4) for the October 2005 sampling, although we subsequently found that we were able to adequately locate the sites with a GPS unit.

We surveyed fishes in the Verde River during October 17-19, 2005, March 27-29, 2006, and October 23-25, 2006. The canoe electrofisher was operated continuously throughout each targeted 500-m site, staying within the thalweg of shallow sites, otherwise alternating from side to side in pools and runs, but shocking the center of riffles. For safety, the electroshocker was not operated through riffles that were navigationally challenging.

A 2 x 9 m straight seine (3 mm mesh) was used to sample backwaters and sandy shorelines for small fish. Shoreline sites were seined in the downstream direction. Sites were opportunistically chosen, but were restricted to reaches that were not electrofished.

Experimental gill nets (45.72 m long, 1.83 m tall, with 1.25 cm to 7.5 cm mesh) were set in the river near our first camping site during March 2006 (one net set in site R9 and one in R10; Figure 4) and October 2006 (one set in site R9 and two in site R10); gill nets were not set during the first night of the October 2005 trip because we did not arrive at camp (within site R8) until dusk and it was storming. Nets were set with the small mesh end tied off on shore, and the other end extending out in approximately a straight line through the deepest part of the run or backwater. Gill nets were not set on the second night of each trip because the river was too shallow in the vicinity of the campsites.

Mini hoop nets (50 cm diameter, 1 m long, and 6 mm mesh) were set near our campsites in late afternoon on October 18, 2005 (three nets set in R23) and October 23, 2006 (four nets set in R9). The closed end of the hoop nets were tied off to shore, and the net was then stretched downstream so that the open end faced downstream; sticks were wedged between the hoops on each net to keep the net from collapsing. Hoop nets were checked the following morning.

Eleven minnow traps were set in the river near our campsites the nights of March 27, 2006 (set in site R9) and March 28, 2006 (set in site R30); traps were not set during the other two trips. Traps were baited with canned cat food, set under water near the shoreline, and secured to shore with twine. Traps were checked the morning after they were set.

All fish captured in the Verde River were processed in a similar fashion to those captured in Horseshoe Reservoir, but all fish ≥ 150 mm TL were marked with spaghetti tags. During all trips, all small-bodied fishes (e.g., red shiners and mosquito fish) were measured until the total number measured exceeded 100 individuals; thereafter individuals captured at the remaining sites were counted, but not weighed and measured.

VERDE RIVER FISH HABITAT

During the October 2005 reconnaissance trip, and during the March 2006 and October 2006 sampling trips, the length of each fish macro-habitat type (pool, glide, run, riffle, and cascade) in each 500-m site sampled for fish was visually estimated. For each fish macro-habitat unit, the dominant substrate was recorded (boulder, cobble, pebble, gravel, sand, and silt), and the percent of the stream surface that had overhanging vegetation was visually estimated. Based on these data, the percent of each fish macro-habitat type and substrate type within each site was calculated as 100 times the summed lengths of the specific macro-habitat type divided by 500 m. Mean percents for each fish macro-habitat type and substrate type, and mean percent overhanging vegetation coverage were calculated for each reach.

ANALYSIS

Percent composition of fish (100 times the number of individuals of a given species captured divided by total numbers of all individuals of all species captured) was calculated for each species using data from all gear types, and for each gear type.

Catch rates (catch-per-unit-effort) were calculated for each gear type. Electrofishing catch rate was calculated as 900 seconds (our standard electrofishing unit) times the number of fish captured divided by the seconds shocked at a site. Catch rates for gill nets, frame nets, hoop nets, and minnow traps were calculated as the number of fish captured divided by hours set (minutes were converted to decimal hours). Catch rates for seines were calculated as number of fish captured per square meter (length times width of area seined).

Catch rates were compared between spring periods and between autumn periods with ANOVA, rather than among all periods. The rationale for dividing the comparisons this way, rather than comparing among all four periods was as follows. Some goldfish were inadvertently identified as common carp during April 2005 (see results), therefore we could not accurately estimate carp or goldfish catch rates during April 2005; but catch rates of other species and total catch rates were accurate. Therefore we did not make comparisons of common carp and goldfish catch rates between April 2005 and March 2006. Secondly, we were more interested in comparing between years than between seasons within a year, because we expected greater catch rates during autumn when young-of year fish would be present than during spring sampling, which was done prior to the spawning season of most fish species. Comparisons of catch rates between periods were only done for the most abundant species and for all species combined.

Lengths of fish captured were examined to determine if young-of-year fish were present during the four sampling periods. Lengths of fish were partitioned into 10-mm classes for graphing purposes and to assess size structure of populations.

RESULTS

FISH SAMPLING

Nine thousand eight hundred and sixty four fish were captured during the study (Tables 1 and 2). Nearly all fish were non-native (99.86%); the only native fish captured during the study were 10 razorback suckers, 3 Colorado pikeminnow, and one Sonora sucker (*Catostomus insignis*). In Horseshoe Reservoir (Table 1), common carp (*Cyprinus carpio*) and goldfish (*Carassius auratus*) dominated (~ 85%) the catch; goldfish tended to dominate the electrofishing catch whereas carp tended to dominate the gill net catch. All other species were far less abundant and included largemouth bass (*Micropterus salmoides*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), yellow bullhead

Table 1. Percent composition of fish species captured in Horseshoe Reservoir by gear type during spring and autumn 2005 and 2006. Number of fish captured with each gear type during each period is given in parentheses.

Species		Apr05	Oct05	Mar06	Oct06	Total
Electrofishing						
Goldfish			72.4	59.9	57.0	37.5
Common carp		87.0[1]	27.6	39.5	28.5	53.6
Red shiner		2.6			6.1	2.5
Mosquitofish					7.5	1.8
Channel catfish				0.6	0.9	0.3
Green sunfish		5.2				2.1
Bluegill		0.3				0.1
Largemouth bass		4.9				2.0
	Number of fish	(345)	(145)	(167)	(214)	(871)
Gill net						
Goldfish		4.5	22.8	56.6	42.2	29.1
Common carp		86.1[1]	68.0	31.8	54.9	63.6
Channel catfish		5.0	5.7	5.1	0.4	3.4
Yellow bullhead			0.4		0.8	0.4
Green sunfish		0.7	0.4			0.3
Largemouth bass		1.7	0.9	3.0	0.6	1.3
Colorado pikeminnow					0.6	0.2
Flathead catfish		0.5	1.8	2.0		0.7
Unknown					0.2	0.1
Razorback sucker		1.7		1.0	0.2	0.7
Sonora sucker				0.5		0.1
	Number of fish	(424)	(228)	(198)	(490)	(1340)
Frame net						
Common carp		100.0				100.0
	Number of fish	(8)				(8)
Minnow trap						
Goldfish					11.1	6.3
Common carp				28.6	66.7	50.0
Mosquitofish					11.1	6.3
Bluegill				71.4		31.3
Flathead catfish					11.1	6.3
	Number of fish			(7)	(9)	(16)
Straight Seine						
Goldfish				31.8	6.3	8.8
Common carp				54.5	1.5	6.6
Red shiner				13.6	1.0	2.2
Mosquitofish					91.2	82.4
	Number of fish			(22)	(205)	(227)
All gear types						
Goldfish		2.4	42.1	55.6	37.4	30.0
Common carp		86.6	52.3	36.3	36.9	54.8
Red shiner		1.2		0.8	1.6	1.1
Mosquitofish					22.2	8.3
Channel catfish		2.7	3.5	2.8	0.4	2.0
Yellow bullhead			0.3		0.4	0.2
Flathead catfish		0.3	1.1	1.0	0.1	0.4
Green sunfish		2.7	0.3			0.9
Bluegill		0.1		1.3		0.2
Largemouth bass		3.1	0.5	1.5	0.3	1.4
Colorado pikeminnow					0.3	0.1
Unknown					0.1	0.0
Razorback sucker		0.9		0.5	0.1	0.4
Sonora sucker				0.3		0.0
	Number of fish	(777)	(373)	(394)	(918)	(2462)

[1]Some of these common carp were probably goldfish.

Table 2. Percent composition fish species captured in the Verde River, by gear type, during spring and autumn 2005 and 2006. Number of fish captured with each gear type and during each period is given in parentheses.

Species	Oct05	Mar06	Oct06	Total
Electrofishing				
Yellow bullhead	0.2			0.1
Goldfish	2.3	7.0	1.2	3.6
Common carp	96.1	91.6	87.2	92.2
Red shiner			6.5	1.7
Channel catfish	1.0	1.0	4.7	2.0
Smallmouth bass		0.5	0.3	0.2
Largemouth bass	0.4			0.2
Number of fish	(485)	(415)	(321)	(1221)
Straight Seine				
Goldfish	0.6		0.1	0.2
Common carp	0.9	1.1		0.5
Red shiner	92.1	98.4	80.6	87.1
Unknown shiner	2.6			0.7
Mosquitofish	3.1	0.5	19.3	11.3
Channel catfish	0.2			0.1
Smallmouth bass	0.1			0.0
Largemouth bass		0.1		0.0
Unknown poeceliid	0.4			0.1
Number of fish	(1748)	(1093)	(3294)	(6135)
Gill net				
Common carp		97.1	80.0	94.9
Largemouth bass		2.9		2.6
Flathead catfish			20.0	2.6
Number of fish		(34)	(5)	(39)
Mini hoop net				
Red shiner			100.0	100.0
Number of fish			(7)	(7)
Table Total				
Yellow bullhead	0.0			0.0
Goldfish	1.0	1.9	0.2	0.8
Common carp	21.6	27.6	7.8	16.1
Red shiner	72.1	69.7	74.0	72.5
Unknown shiner	2.0			0.6
Mosquitofish	2.4	0.3	17.5	9.4
Channel catfish	0.4	0.3	0.4	0.4
Smallmouth bass	0.0	0.1	0.0	0.1
Largemouth bass	0.1	0.1		0.1
Unknown poeceliid	0.3			0.1
Flathead catfish			0.0	0.0
Number of fish	(2233)	(1542)	(3627)	(7402)

(*Ameiurus natalis*), mosquitofish (*Gambusia affinis*), red shiner (*Cyprinella lutrensis*), razorback sucker, Colorado pikeminnow, and Sonora sucker.

The reported percent composition for common carp and goldfish in Horseshoe Reservoir during April 2005 may be slightly in error, because some goldfish may have been inadvertently identified as common carp during sampling April 5-6, 2005. Jim Warnecke, the Region VI Fisheries Program Manager, helped check nets on April 7, and identified goldfish in the catch, and fish were correctly identified to species for all nets processed that day. Goldfish captured on April 7, 2005 were primarily small (the largest was 234 mm TL) and comprised 9.1% of the catch (common carp were 77.4% of the catch). In addition, of the 99 common carp and goldfish captured that were less than 251 mm TL, 19 (19%) were goldfish. Therefore, it is possible that approximately 19% (71) of the 375 carp less than 250 mm TL captured by electrofishing, gill and frame netting the previous days were actually goldfish or goldfish-common carp hybrids.

Goldfish (top) and common carp (bottom) look similar.

In the Verde River (Table 2), red shiner comprised most (72.5%) of the catch overall, but common carp (16.1%) and mosquitofish (9.4%) were also common; other species were relatively rare, each comprising less than 1% of the catch (Table 2). The seine catch was dominated by red shiners (87%), but note that mosquitofish abundance increased dramatically in October 2006. Common carp dominated the electrofishing catch (> 87%) in all periods. No native species were captured in the Verde River.

Species catch rates differed between periods for some gear types. In Horseshoe Reservoir, electrofishing catch rates were dominated by common carp during April 2005 (but see explanation above), but by goldfish during the remaining three trips, whereas gill net catch rates were dominated by common carp during April and October 2005, and October 2006, but by goldfish during March 2006. Catch-per-unit-effort of all fish and for common carp in Horseshoe Reservoir during April 2005 did not differ among basins for electrofishing (ANOVA $p = 0.093$ and $p = 0.086$ respectively), nor for gill netting (ANOVA $p = 0.268$ and $p = 0.152$ respectively). Electrofishing catch rates for common carp, goldfish, and all fish were greater in October 2006 than in October 2005 (Table 3; F = 14.2, 8.4, and 18.6, p = 0.003, 0.013, and 0.001 respectively, df = 1, 12 in each comparison). Electrofishing catch rates for all fish were also greater in March 2006 than they were in April 2005. Gill net catch rates for common carp, goldfish, and all fish combined did not differ ($p>0.05$) between October 2005 and October 2006, nor did gill net catch rates for all fish differ between April 2005 and March 2006.

In the Verde River, common carp dominated the electrofishing catch (Table 4) in all reaches during all three trips; there were no

Table 3. Mean catch rates (numbers caught/effort) of fish species by gear type in three basins in Horseshoe Reservoir during spring and autumn 2005 and 2006. Standard error is given in parentheses, N = number of sample efforts. Effort was calculated as follows: electrofishing = seconds shocked/900; gill nets, hoop nets and minnow traps = hours net was set; seine = square meters seined (length x width). Superscript 'a' indicates significant ($P < 0.05$) ANOVA between October 2005 and 2006, superscript 'b' indicates significant ANOVA between April 2005 and March 2006.

	Apr05				Oct05	Mar06	Oct06
	Uppe	Middl	Lowe	Total	Lower	Lower	Lowe
Electrofishing	N=8	N=8	N=8	N=24	N=10	N=4	N=4
Goldfish					10.3 (3.89)	25.0 (8.11)	30.48 (4.83)[a]
Common carp	6.7 (2.19	20.3 (4.85	10.1 (5.09	12.4 (2.64)	4.0 (1.33)	16.5 (7.46)	15.24 (3.50)[a]
Red shiner	1.1 (0.99	0.0 (0.00	0.0 (0.00	0.4 (0.33)			3.24 (2.35)
Mosquitofish							4.00 (2.28)
Channel catfish						0.3 (0.25)	0.50 (0.29)
Green sunfish	0.2 (0.25	1.2 (0.45	0.7 (0.37	0.7 (0.22)			
Bluegill	0.0 (0.00	0.1 (0.12	0.0 (0.00	0.0 (0.04)			
Largemouth bass	0.9 (0.74	0.4 (0.18	0.9 (0.48	0.7 (0.29)			
Total	9.0 (3.26	22.1 (4.42	11.7 (4.81	14.3 (2.61)[b]	14.3 (3.87)	41.7 (14.46)	53.47 (11.11)[a]
Frame net	N=1	N=2	N=6	N=9			
Common carp	0.0 (0.00	0.2 (0.20	0.0 (0.00	0.0 (0.04)			
Total	0.0 (0.00	0.2 (0.20	0.0 (0.00	0.0 (0.04)			
Gill net	N=5	N=6	N=6	N=17	N=5	N=8	N=8
Yellow bullhead					0.0 (0.01)		0.0 0(.01)
Goldfish	0.1 (0.02	0.1 (0.08	0.0 (0.00	0.1 (0.03)	0.5 (0.19)	0.8 (0.07)	1.2 (0.22)
Sonora sucker						0.0 (0.01)	
Common carp	0.9 (0.26	1.7 (0.31	1.1 (0.24	1.3 (0.17)	1.5 (0.11)	0.4 (0.08)	1.6 (0.15)
Channel catfish	0.2 (0.07	0.1 (0.02	0.0 (0.01	0.1 (0.02)	0.1 (0.05)	0.1 (0.03)	0.0 (0.01)
Green sunfish	0.0 (0.00	0.0 (0.01	0.0 (0.01	0.0 (0.01)	0.0 (0.01)		
Largemouth bass	0.0 (0.00	0.0 (0.01	0.0 (0.04	0.0 (0.01)	0.0 (0.01)	0.0 (0.01)	0.0 (0.01)
Colorado							0.0 (0.01)
Flathead catfish	0.0 (0.01	0.0 (0.01	0.0 (0.00	0.0 (0.00)	0.0 (0.02)	0.0 (0.01)	
Razorback sucker	0.1 (0.08	0.0 (0.00	0.0 (0.00	0.0 (0.02)		0.0 (0.01)	0.0 (0.01)
Total	1.3 (0.39	1.9 (0.40	1.2 (0.27	1.5 (0.21)	2.2 (0.18)	1.4 (0.15)	2.9 (0.29)
Minnow trap						N=22	N=10
Goldfish							0.0 (0.01)
Common carp						0.0 (0.01)	0.0 (0.02)
Mosquitofish							0.0 (0.01)
Bluegill						0.0 (0.01)	
Flathead catfish							0.0 (0.01)
Total						0.0 (0.01)	0.0 (0.02)
Straight Seine						N=12	N=12
Goldfish						0.0 (0.01)	0.1 (0.02)
Common carp						0.1 (0.03)	0.0 (0.02)
Red shiner						0.0 (0.01)	0.0 (0.01)
Mosquitofish							0.9 (0.31)
Total						0.1 (0.05)	1.0 (0.31)

Table 4. Mean catch rates (numbers caught/effort) of fishes by reach in the Verde River during three time periods. Standard error is given in parentheses; N = number of sample efforts. No fish were captured in minnow traps set during March 2006 (11 sets in upper and lower reaches) so data are not shown. Effort was calculated as follows: electrofishing = seconds shocked/900; gill nets and hoop nets = hours set; seine = square meters seined (length x width).

Gear Type	Reach	Species	Oct05	Mar06	Oct06
Electrofishing	River		N=3	N=3	N=3
		Goldfish	0.5 (.54)	0.0 (.00)	0.0 (.00)
		Common carp	49.2 (6.92)	44.4 (12.44)	11.1 (9.29)
		Red shiner	0.0 (.00)	0.0 (.00)	8.8 (6.64)
		Channel catfish	0.0 (.00)	0.6 (.64)	3.1 (1.02)
		Smallmouth bass	0.0 (.00)	0.7 (.36)	0.0 (.00)
		TOTAL	49.8 (7.28)	45.8 (13.22)	23.1 (9.60)
	Upper		N=3	N=3	N=3
		Yellow Bullhead	0.6 (.62)	0.0 (.00)	0.0 (.00)
		Goldfish	3.4 (2.50)	2.0 (1.23)	0.0 (.00)
		Common carp	73.0 (34.86)	72.6 (18.27)	73.3 (40.03)
		Red shiner	0.0 (.00)	0.0 (.00)	0.6 (.56)
		Channel catfish	0.4 (.42)	0.6 (.60)	1.8 (.98)
		Smallmouth bass	0.0 (.00)	0.0 (.00)	0.7 (.73)
		Largemouth bass	0.8 (.79)	0.0 (.00)	0.0 (.00)
		TOTAL	78.2 (37.47)	75.3 (17.11)	76.4 (38.45)
	Middle		N=3	N=3	N=3
		Goldfish	0.0 (.00)	4.0 (3.10)	0.7 (.67)
		Common carp	55.5 (20.45)	30.1 (5.60)	44.1 (13.94)
		Channel catfish	0.6 (.65)	0.7 (.71)	2.6 (1.32)
		TOTAL	56.2 (20.75)	34.8 (8.16)	47.4 (12.18)
	Lower		N=3	N=3	N=3
		Goldfish	1.0 (.50)	9.6 (4.94)	1.4 (1.44)
		Common carp	57.7 (8.38)	49.9 (16.51)	41.2 (19.78)
		Channel catfish	1.7 (1.03)	0.0 (.00)	1.6 (1.00)
		TOTAL	60.4 (7.92)	59.5 (21.27)	44.3 (18.48)
	TOTAL		N=12	N=12	N=12
		Yellow Bullhead	0.2 (.15)	0.0 (.00)	0.0 (.00)
		Goldfish	1.2 (.68)	3.9 (1.67)	0.5 (.38)
		Common carp	58.9 (9.30)	49.2 (7.58)	42.4 (12.14)
		Red shiner	0.0 (.00)	0.0 (.00)	2.3 (1.82)
		Channel catfish	0.7 (.33)	0.5 (.26)	2.3 (.50)
		Smallmouth bass	0.0 (.00)	0.2 (.12)	0.2 (.18)
		Largemouth bass	0.2 (.20)	0.0 (.00)	0.0 (.00)
		TOTAL	61.1 (9.94)	53.8 (8.11)	47.8 (11.25)
Straight Seine	River		N=3	N=4	N=6
		Goldfish	0.0 (.01)	0.0 (.00)	0.0 (.00)

Table 4. continued…

Gear Type	Reach	Species	Oct05	Mar06	Oct06
		Common carp	0.0 (.01)	0.1 (.08)	0.0 (.00)
		Red shiner	2.8 (2.64)	12.7 (9.66)	5.1 (1.84)
		Unknown shiner	0.0 (.02)	0.0 (.00)	0.0 (.00)
		Mosquito fish	0.2 (.16)	0.3 (.25)	0.3 (.25)
		Channel catfish	0.0 (.01)	0.0 (.00)	0.0 (.00)
		Smallmouth bass	0.0 (.00)	0.0 (.00)	0.0 (.00)
		Unknown poeceliid	0.0 (.00)	0.0 (.00)	0.0 (.00)
		TOTAL	3.1 (2.83)	13.0 (10.00)	5.5 (1.74)
	Upper		N=2	N=3	N=4
		Common carp	0.0 (.02)	0.0 (.02)	0.0 (.00)
		Red shiner	4.9 (3.73)	9.8 (4.38)	7.6 (3.88)
		Unknown shiner	0.1 (.05)	0.0 (.00)	0.0 (.00)
		Mosquito fish	0.1 (.05)	0.0 (.01)	2.9 (2.67)
		Largemouth bass	0.0 (.00)	0.0 (.00)	0.0 (.00)
		TOTAL	5.1 (3.82)	9.8 (4.36)	10.5 (6.42)
	Middle		N=2	N=5	N=2
		Goldfish	0.0 (.01)	0.0 (.00)	0.0 (.00)
		Common carp	0.0 (.01)	0.1 (.13)	0.0 (.00)
		Red shiner	0.1 (.11)	3.5 (2.64)	2.4 (2.31)
		Mosquito fish	0.0 (.00)	0.0 (.00)	0.2 (.19)
		Channel catfish	0.0 (.01)	0.0 (.00)	0.0 (.00)
		TOTAL	0.2 (.09)	3.6 (2.78)	2.6 (2.50)
	Lower		N=1	N=3	N=3
		Goldfish	0.0 (.)	0.0 (.00)	0.1 (.04)
		Common carp	0.0 (.)	0.0 (.01)	0.0 (.00)
		Red shiner	0.0 (.)	0.0 (.01)	1.9 (.99)
		Mosquito fish	0.0 (.)	0.0 (.00)	0.0 (.04)
		Channel catfish	0.0 (.)	0.0 (.00)	0.0 (.00)
		TOTAL	0.1 (.)	0.0 (.01)	1.9 (1.01)
	TOTAL		N=8	N=15	N=15
		Goldfish	0.0 (.00)	0.0 (.00)	0.0 (.01)
		Common carp	0.0 (.01)	0.1 (.05)	0.0 (.00)
		Red shiner	2.3 (1.33)	6.5 (2.87)	4.8 (1.32)
		Unknown shiner	0.0 (.02)	0.0 (.00)	0.0 (.00)
		Mosquito fish	0.1 (.06)	0.1 (.07)	0.9 (.72)
		Channel catfish	0.0 (.00)	0.0 (.00)	0.0 (.00)
		Smallmouth bass	0.0 (.00)	0.0 (.00)	0.0 (.00)
		Largemouth bass	0.0 (.00)	0.0 (.00)	0.0 (.00)
		Unknown poeceliid	0.0 (.00)	0.0 (.00)	0.0 (.00)
		TOTAL	2.5 (1.39)	6.7 (2.96)	5.7 (1.90)

Table 4. continued…

Gear Type	Reach	Species	Oct05	Mar06	Oct06
Gill net	Upper			N=2	N=3
		Common carp		1.1 (.38)	0.1 (.08)
		Largemouth bass		0.0 (.03)	0.0 (.00)
		Flathead catfish		0.0 (.00)	0.0 (.02)
		TOTAL		1.1 (.35)	0.1 (.07)
Mini hoop net	Upper				N=4
		Red shiner			0.1 (.11)
		TOTAL			0.1 (.11)

significant differences in catch rates among reaches during any of the three periods. Common carp and goldfish electrofishing catch rates did not differ between October 2005 and October 2006, but channel catfish catch rates were greater in October 2006 than they were during October 2005 (df = 1 and 22, F = 7.29, *p*= 0.013). Red shiner dominated the seining catch in the Verde River, and there were no significant differences in catch rates among reaches for any of the three sampling periods. Catch rates for red shiner, mosquitofish, and goldfish did not differ (*p*>0.05) between October 2005 and October 2006. No fish were captured in the three mini hoop nets set on October 18, 2005 and checked the following day, but this was likely due to the fact that the river rose and fell overnight due to rains on October 17 and 18; all of the nets were collapsed in the morning, or had mouths out of the water. No fish were captured in any of the 22 minnow trap sets. However, 14 crayfish, *Orconectes spp*., were captured in seven of the minnow traps.

For species with detectable a young-of-year cohorts (YOY), the 2006 cohort was more abundant than the 2005 cohort (Figure 5). Based on length frequency distributions, we categorized common carp, goldfish, green sunfish, bluegill, largemouth bass, smallmouth bass, flathead catfish and channel catfish ≤ 100 mm TL during October as YOY fish. Because fish growth is slow during winter temperatures, and spawning of these species typically does not occur until spring, we categorized fish ≤ 60 mm TL of these species captured during April 2005 or March 2006 as YOY. As such, only 24 of the 677 (3.5%) common carp captured during October 2005 were YOY (2 of 195 in Horseshoe Reservoir and 22 of 482 in the Verde River), compared to 100 of 623 (16.1%) captured during October 2006 (100 of 339 captured in Horseshoe Reservoir and 0 of 284 captured in the Verde River). No common carp ≤ 60 mm TL were captured during April 2005 or March 2006, but 5 of 568 (0.9%) common carp captured during March 2006 were between 88 and 100 mm TL (88, 90, 93, 93 and 100 mm TL, all five captured in Horseshoe Reservoir).

A similar pattern was evident for goldfish: the 2006 YOY cohort was more abundant than the 2005 YOY cohort. Ten of the 179 (5.6%) goldfish captured during October 2005 were YOY (6 of 157 in Horseshoe Reservoir and 4 of 22 in the Verde River), compared to 144 of 350 (41.1%) captured during October 2006 (140 of 343 in Horseshoe Reservoir and 4 of 7 in the Verde River). No YOY goldfish YOY were captured during April 2005 or March 2006; however 2 of the 248 (0.8%) goldfish captured (both in Horseshoe Reservoir)

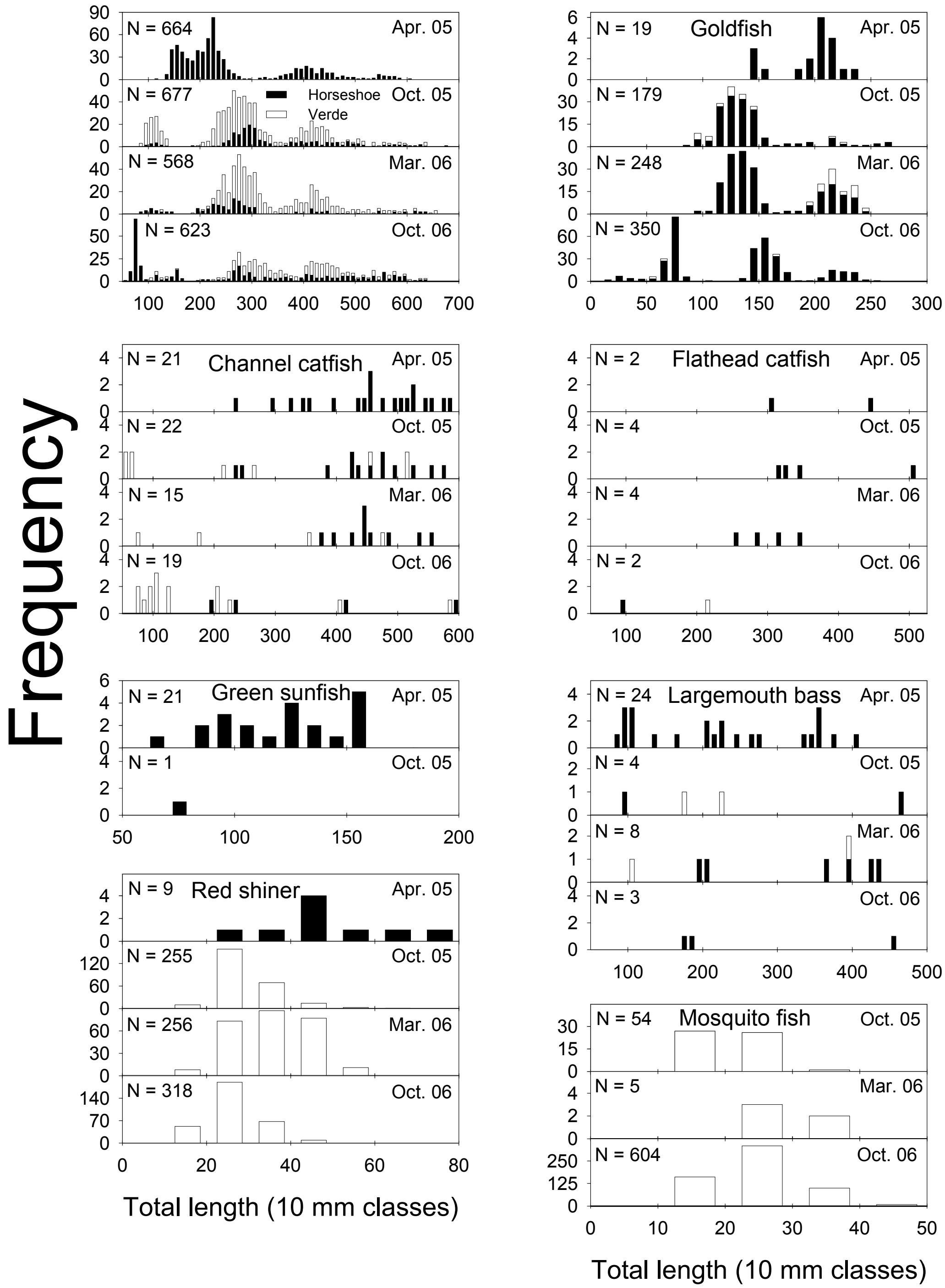


Figure 5. Length frequencies of fish species captured by netting and electrofishing in Horseshoe Reservoir during April 2005, and in Horseshoe Reservoir (solid bars) and the Verde River (open bars) during October 2005, March 2006, and October 2006. During April 2005, approximately 19% of the common carp less than 250 mm could be goldfish.

during March 2006 were ≤ 100 mm TL (92 and 98 mm TL).

Less can be said about YOY recruitment of other species because so few fish were captured, although all of the channel catfish ≤ 100 mm TL were captured in the Verde River: four in October 2005, one in March 2006 (72 mm TL, so considered an age-1), and five in October 2006. Only 1 (92 mm TL) of 12 flathead catfish captured was YOY, and it was captured in Horseshoe Reservoir during October 2006. Only one largemouth bass YOY was captured, and it was caught in Horseshoe Reservoir during October 2005 (100 mm TL); the 4 small individuals (90, 100, 100, 100 mm TL) captured in April 2005 were considered age-1. All green sunfish were captured in Horseshoe Reservoir, only one of which was considered a YOY (74 mm TL, during October 2005). All bluegill were captured in Horseshoe Reservoir during April 2005 (1 fish) and March 2006 (5 fish), but none were considered YOY.

Most red shiner and mosquito fish were captured in the Verde River, and length (Figure 5) typically was only measured for these species at one site in the Verde River because they were so abundant; these small-bodied fish were not the main targets of the study. However, the tremendous numbers of individuals captured (Tables 2 and 3), as well as the length frequencies observed in the Verde River, indicates that recruitment of these two species is occurring, particularly in the Verde River, and catch rates were greater in October 2006 than October 2005 suggesting that more recruitment occurred during 2006 than during 2005.

Common carp and goldfish were the only species with sufficient numbers of individuals captured to say anything accurate about population size structure (Figure 5). Multiple size classes of common carp and goldfish were captured, indicating healthy populations in Horseshoe Reservoir.

We marked 2,561 fish during the study: 378 during April 2005, 623 during October 2005, 681 in March 2006, and 879 during October 2006 (Table 5). Only three fish were recaptured during the study (all three were common carp marked with spaghetti tags, and all were recaptured during the same trip that they were marked in), so we can say little about movement or growth of marked fish. In addition, none of the fish we marked were captured in the Verde River between Childs and Sheep Bridge during the June 2006 survey conducted by Arizona Game and Fish Departments Region 6 Office (Jim Warnecke, Region 6 Fisheries Program Manager, personal communication). We also cannot accurately estimate growth of YOY to age 1 based on length frequencies from October 2005 and March 2006, because so few YOY fish were produced in 2005.

Ten razorback suckers and three Colorado pikeminnow were captured during the study, all within Horseshoe Reservoir (Table 6). Based on locations of coded wire tags, razorback suckers had been in the river for 3-8 years after they were stocked, whereas

Seven razorback suckers were captured in one gill net during April 2005.

Table 5. Numbers of individuals of each species marked and subsequently recaptured in the Verde River and Horseshoe Reservoir during the study.

Period	Mark type	Species	Marked	Recaptured
Apr 05	Spaghetti	Common carp	340	
		Channel catfish	20	
		Green sunfish	2	
		Largemouth bass	14	
		Flathead catfish	2	
Oct 05	Spaghetti	Yellow bullhead	2	
		Goldfish	32	
		Common carp	569	1
		Channel catfish	14	
		Largemouth bass	2	
		Flathead catfish	4	
Mar 06	Spaghetti	Goldfish	113	
		Sonora sucker	1	
		Common carp	544	1
		Channel catfish	12	
		Largemouth bass	5	
		Flathead catfish	4	
	PIT	Razorback sucker	2	
Oct 06	Spaghetti	Yellow bullhead	2	
		Goldfish	9	
		Common carp	43	
		Channel catfish	4	
		Smallmouth bass	1	
		Flathead catfish	1	
	Spaghetti +anal fin clip	Goldfish	113	
		Common carp	404	1
		Channel catfish	6	
		Largemouth bass	1	
	Anal fin clip	Yellow bullhead	2	
		Goldfish	160	
		Common carp	131	
		Channel catfish	1	
		Largemouth bass	1	
Table Total			2561	3

Colorado pikeminnow only had only been in the river for 3-9 months. Seven razorback suckers were captured in a gill net set in the middle portion of the reservoir during April 2005. The gill net was set in 2.4-2.7 m deep water in a flooded portion of the Verde River arm of Horseshoe Reservoir at UTM easting 432834, northing 3767500 (site 34; Figure 2). The net was set on April 6, 2005 at 17:10 pm and pulled on April 7, 2005 at

Table 6. Information about razorback suckers and Colorado pikeminnow captured in gill nets in Horseshoe Reservoir, Arizona during 2005 and 2006. Fish were tagged with coded-wire tags (CWT) at the hatchery before being stocked into the Verde River.

Date Captured	Species	Length	Weight	Sex	Condition	Body area tagged	CWT--date and geographic location
Apr. 2005	Razorback sucker	490	1370	M	Ripe, tuberculate	unknown	unknown
Apr. 2005	Razorback sucker	426	650	M	Ripe, tuberculate	unknown	unknown
Apr. 2005	Razorback sucker	478	1130	M	Ripe, tuberculate	unknown	unknown
Apr. 2005	Razorback sucker	432	830	M	Ripe ,tuberculate	unknown	unknown
Apr. 2005	Razorback sucker	465	990	M	Ripe, tuberculate	unknown	unknown
Apr. 2005	Razorback sucker	391	570	M	Ripe, tuberculate	unknown	unknown
Apr. 2005	Razorback sucker	406	660	M	Ripe, tuberculate	unknown	unknown
Mar. 2006	Razorback sucker	451	790	U	Not tuberculate	right cheek	Feb. or Mar. 2003 at Beasley Flats; Sep. or Oct. 2002 at Childs
Mar. 2006	Razorback sucker	494	1140	U	Not tuberculate	between pectoral fins	Jan.30, 2003 at Childs
Mar. 2006	Colorado pikeminnow	405	--	U	Dead on shore	Right cheek	Apr. 19, 2005 at Beasley Flats
Oct. 2006	Razorback sucker	445	730	U	Not tuberculate	left caudal	Nov 25, 1998 at Childs; Jan. or Feb. 2004 at Beasley Flats
Oct. 2006	Colorado pikeminnow	434	440	U	---	none detected	Probably Aug 2, 2006 at Camp Verde
Oct. 2006	Colorado pikeminnow	401	380	U	---	none detected	Probably Aug 2, 2006 at Camp Verde
Oct. 2006	Colorado pikeminnow	390	310	U	---	none detected	Probably Aug 2, 2006 at Camp Verde

10:45 am. Unfortunately, the crew did not have either a coded wire tag wand or a PIT tag scanner with them, and thus it is unknown which year these fish were stocked. However, given the size of the fish, they were probably stocked in winter 2004, or earlier. The fish were ripe and tuberculate, so there is a possibility they had or were getting ready to spawn. Surface water temperature when the nets were pulled was 19˚C on April 7 and averaged 18.1˚C during April 5-7.

Two razorback suckers were captured in a gill net set in Horseshoe Reservoir on March 30, 2006. The gill net was set on the bottom in 0.5-1.0 m deep water in the cove to the northeast of the dam; gill net coordinates were UTM easting 434778, northing 3760800. Neither of the fish was tuberculate, and sex was not determined. A Colorado pikeminnow was found dead on shore near the gill net that the razorback suckers were captured in. The pikeminnow appeared to have been killed by a bird of prey; half of its side was eaten away, but it was still relatively fresh (coloration was still present as was muscle).

One razorback sucker and three Colorado pikeminnow were captured in Horseshoe Reservoir on October 25, 2006. The fish were captured in the same cove, northeast of the dam, where these species were captured in March 2006. The sex of these fish was not determined. Each fish was captured in a separate gill net, the razorback sucker at UTM easting 434701 and easting 3760892, and the Colorado pikeminnow at: UTMs easting 434704 and northing 3760936, easting 434696 and northing 3760847, easting 434577 and northing 3760673.

VERDE RIVER FISH HABITAT

In the River and Upper reaches of the study area, all four fish macro-habitat types were represented, and it was only in these two reaches that pools (backwater pools) were found (Figure 6). The Middle and Lower reaches were dominated by runs and glides. Substrate types corresponded to habitat types, in that coarse substrates tended to be

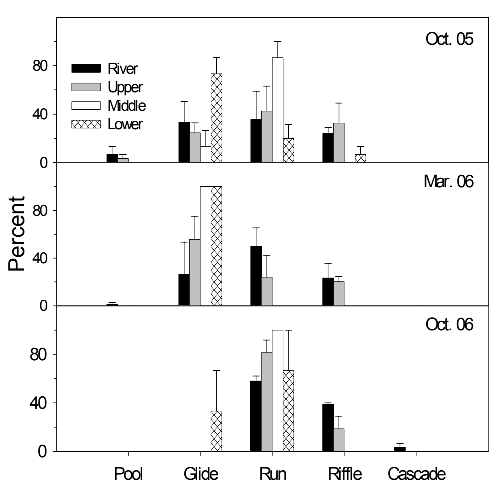


Figure 6. Percent composition (means with standard error; N = 3 for each reach and period) of fish habitat types in the four reaches of the Verde River sampled during 2005 and 2006. The River reach extended from Sheep Bridge downstream 4 km, the Upper reach was from 4 to 8.5 km, the Middle reach was from 8.5 to 14 km, and the Lower reach was from 14 to 16.5 km.

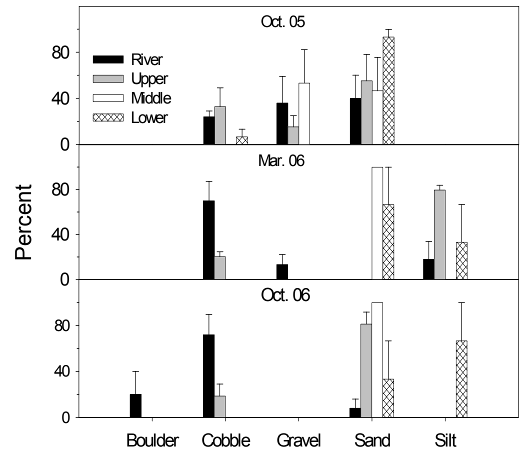


Figure 7. Percent composition (means with standard errors; N = 3 for each reach) of dominant substrate types in the four reaches of the Verde River sampled during 2005 and 2006. The River reach extended from Sheep Bridge downstream 4 km, the Upper reach was from 4 to 8.5 km, the Middle reach was from 8.5 to14 km, and the Lower reach was from 14 to16.5 km.

found mostly in the River and Upper reaches and fine substrates were mostly found in the Middle and Lower reaches (Figure 7). Tree and riparian vegetation lined the River, Upper, and Middle reaches, but then thinned out to where the Lower reach had approximately 1% overhanging vegetation (Figure 8; October 2005 not shown because data were not collected in all reaches). Some emergent aquatic vegetation (cattails and bulrush) was observed in the River and Upper reaches. During October 2006, we noted that the aquatic plant *Ludwigia peploides,* floating water primrose, was widespread along the shore and almost completely covered the largest backwater (located in the upper reach).

DISCUSSION

Characteristics of the fish community in Horseshoe Reservoir differed between the two years of study, as did the volume of the reservoir; high flows in the Verde River during winter 2004-2005 resulted in a full

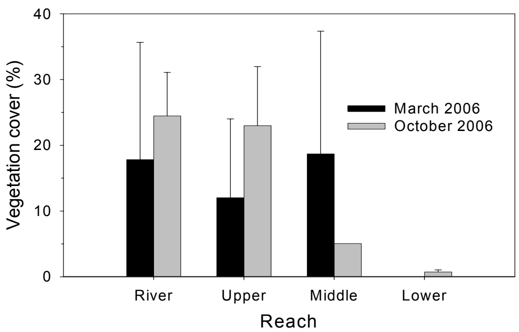


Figure 8. Percent of river covered by overhanging vegetation (means with standard errors; N = 3 for each reach) in the four reaches of the Verde River sampled during March and October 2006. The River reach extended from Sheep Bridge downstream 4 km, the Upper reach was from 4 to 8.5 km, the Middle reach was from 8.5 to 14 km, and the Lower reach was from 14 to 16.5 km.

reservoir mid-February through mid-May 2005, but then water was released until it reached minimum pool in late August 2005, and it remained near minimum pool (never exceeding 3.5% full) for the remainder of the study. Catch rates of common carp and goldfish, the two most common species in Horseshoe Reservoir, were greater in 2006 than they were in 2005. In addition, more YOY carp and goldfish were produced in 2006 than in 2005, as indicated by the abundance of small fish captured in October of those years.

Common carp and goldfish dominated the fish assemblage in Horseshoe Reservoir during this study. Comparison of gill net data from the current study with data from 1994 – 2004 (obtained from Jim Warnecke, Arizona Game and Fish Department Region VI Fisheries Program Manager), indicates that sport fish, such as largemouth bass, channel catfish, flathead catfish, and black crappie (*Pomoxis nigromaculatus*) used to dominate the catch in the mid 1990s, but then beginning in 1999, common carp began and continue to dominate the catch (Table 7). A somewhat similar pattern is evident in electrofishing data from 1987 – 2006; largemouth bass dominated in 1987 (Warnecke 1988) and 1994, but then common carp dominated in 1999 and were the second most dominant species, after goldfish, in October 2005 and 2006 (Table 8). Catch rates of fish (without regard to species) appear to be similar in the present study with past surveys, although data were not available for all years. For instance, gill net CPUE for all fish during 2005 and 2006 in Horseshoe Reservoir was within the range of mean CPUE for previous years' surveys [3.402±1.589 fish/hr for 3 nets in 1998 (data obtained from Jim Warnecke, AGFD Region VI), and 0.765±0.737 fish/hr for 5 nets in 2004 (Weedman 2004); *note Weedman did not calculate mean CPUE but it can be calculated from data presented in table 2 of his report*]. Electrofishing CPUE may be similar to previous years, but few sites were sampled in previous years and effort was not always recorded; mean CPUE was 3.84 fish/hr for three of the sites sampled in 1998.

The low recapture rate of marked fish was interesting, and could indicate large population size, high mortality, high emigration, or high tag loss. No marked sport fish were recaptured, but few were marked. Catch rate information suggests these species were rare, so it is unlikely that they had large populations. Floy tags are commonly used to mark these species throughout the world, and tag retention is typically high. Mortality and emigration may be the most likely reasons for low recapture rates of these species. More goldfish were marked than the sport fish, but still, only 145 were marked by the end of the third trip, the preponderance of which were marked in Horseshoe Reservoir. Catch rate information during the second through fourth sampling events indicate that there is a tremendous population of goldfish in Horseshoe Reservoir, so this is likely the

Table 7. Percent composition of fish species captured in gill nets 1994-2006 in Horseshoe Reservoir. Data from 1994-2004 were obtained from Jim Warnecke, Arizona Game and Fish Department, Regional VI Fisheries Program Manager.

	Year							
Species	1994	1996	1997	1998	1999	2004	Oct-05	Oct-06
Common carp	20.7	5.2		22.1	63.9	71.4	68.0	54.9
Goldfish				7.7	6.8		22.8	42.2
Colorado pikeminnow		6.3						0.6
Razorback sucker								0.2
Threadfin shad				0.2				
Channel catfish	5.9	9.5		4.0	4.4	12.9	5.7	0.4
Flathead catfish	10.5	7.6	18.2	6.0	0.5		2.2	
Largemouth bass	40.1	5.4	14.5	7.5	8.3	15.7	0.9	0.6
Yellow bullhead								0.8
Smallmouth bass	0.3							
Black crappie	21.3	56.4	67.3	50.0	13.7			
Green sunfish	0.3			0.2	1.5		0.4	
Redear sunfish				0.7				
Bluegill		6.5		1.5	1.0			
Walleye	0.9	3.0						
Total fish	324	367	165	452	205	70	228	490

Table 8. Percent composition of fish species captured by electrofishing in Horseshoe Reservoir, 1987-2005. Data for 1987 was taken from Warnecke (1988). Data from 1994-1999 were obtained from Jim Warnecke, Arizona Game and Fish Department, Regional VI Fisheries Program Manager.

	Year					
Species	1987	1994	1998	1999	Oct-05	Oct-06
Common carp	10.7	5.2	9.2	48.1	27.6	31.6
Goldfish	0.1		2.6		72.4	63.2
Red shiner		0.3		20.4		1.6
Golden shiner	1.5					
Threadfin shad	1.0	0.5	72.6			
Channel catfish	0.1		0.5			1.0
Flathead catfish				7.4		
Largemouth bass	64.5	42.1	5.8	11.1		
Smallmouth bass	1.5	15.2	0.3	5.6		
Black crappie	3.4	0.5	1.3			
Green sunfish			6.8	5.6		
Bluegill	17.0	36.1	0.8	1.9		
Mosquitofish						2.6
Total fish	786	382	380	54	145	214

best explanation why none of the marked individuals were recaptured. Most marked fish in the study were common carp. Based on catch rate data, there is a very large population of common carp in the system. Nonetheless, we expected to recapture more individuals, given that 1,453 common carp were marked with floy tags during the first three trips. Mortality is probably not the best explanation of low recapture rates of common carp, because they are extremely hardy and long-lived fish, and Basavaraju et al. (1998) reported no mortality of floy-tagged carp in their study evaluating marking techniques. Downstream emigration rates are unknown because the river was not sampled downstream of Horseshoe Reservoir. We did not capture any common carp upstream in the river that were marked in the reservoir, nor were any recaptured in the reach from Childs to Sheep bridge during a June 2006 fish survey (Jim Warnecke, Region VI Fisheries Program Manager, personal communication), so upstream emigration out of the study area may be low. However, emigration could have been undetected because tag loss was high. Tag loss is the most likely explanation for the low recapture rates of common carp. Basavaraju et al. (1998) reported 0 to 10% floy-tag retention rates in common carp. Scars were observed in the general tagging location on a few carp captured in our study, possibly resulting from lost tags. Basavaraju et al. (1998) recommended fin clips to mark common carp, as this method had the highest retention rate of 10 methods tested. Common carp were fin clipped during the final sampling trip in our study, immediately after reading the Basavaraju et al. (1998) article. Hopefully, some of these fish will be recaptured during future monitoring.

Length frequencies of common carp in the Verde River during October 2005 show an increase in the proportion of young-of-year from the reservoir pool upstream to Sheep Bridge (Robinson 2006), but this pattern was not seen during the two subsequent trips in 2006. It could be that small fish migrate upstream, but then we should have observed the same pattern on all trips. Another explanation for the distribution of small fish in the system might be the presence of spawning habitat. Common carp spawn in submerged vegetation in shallow areas of lakes and streams during spring to early summer. During October 2005 (and the two trips in 2006), more cattails and bulrush, as well as terrestrial vegetation was observed in the upper reaches than in the lower reaches of the Verde River. Therefore, more spawning habitat should have been available in the upper reaches of the full reservoir during April 2005; the submerged vegetation in the middle and lower reaches would have been too deep. During 2006, when the reservoir remained mostly at minimum pool, we observed relatively little submerged vegetation in the river, but submerged vegetation was observed in the reservoir. Recruitment of YOY carp and goldfish was greater in 2006 than in 2005, possibly because the reservoir remained relatively stable, near minimum pool, and spawning substrate and rearing habitat for these species were available.

Dead vegetation in Horseshoe Lake bottom at minimum pool might serve as spawning habitat for common carp and goldfish.

The yearly fluctuation of surface levels of Horseshoe Reservoir likely favors species such as common carp and goldfish, which spawn during spring over submerged vegetation and are habitat and diet generalists. During the drought years from 1996 through 2004 the reservoir remained less than 30% full for at least 70% of each year, and only exceeded 55% during 1998 (Figure 1), which allowed trees and other vegetation to became established in the lake bed. Most runoff in the Verde River Basin occurs during late-winter and spring, and is hence when Horseshoe Reservoir reaches its peak elevation, submerging established terrestrial vegetation, and providing ideal spawning and rearing habitat for common carp and goldfish. It is likely that reproductive success of species that inhabit and spawn in both lentic and lotic environments (e.g., common carp, smallmouth bass, flathead catfish, channel catfish, mosquitofish) are less impacted by fluctuating reservoir levels, because when the reservoir levels drop, they can still spawn in the stream.

Most fish species should benefit from high springtime lake levels, but rather than retaining water in Horseshoe Reservoir for long periods, water is released quickly after it comes into the reservoir. During years when reservoir levels drastically decrease during the spring-early summer (e.g., 1993, 1995, 1998, 2001, 2003, and 2005) fish recruitment is likely to be poor, because nests, eggs, and young-of-year habitat become desiccated after reservoir levels drop. During 2005, reservoir levels remained relatively high between March and May (stayed above 97% full March 1st though May 15th) possibly facilitating spawning and larval survival. However, the reservoir then decreased to 64% by the end of June, and 12% by the end of July, possibly negatively impacting larval survival by decreasing habitat and making them more vulnerable to predation. The fact that we did not detect large age-0 size classes of any fish species in October 2005 supports this hypothesis. High flows in December 2004-March 2005 might have flushed some fish into the reservoir, and indeed the highest numbers of largemouth bass, green sunfish, and channel catfish captured in Horseshoe Reservoir were during April 2005. Even so, numbers of sport fish captured in April 2005 were low, so another explanation for the poor 2005-year class could be because few adults were present.

Sport fish do not appear to be very abundant, or to have healthy populations (based on size structures) in Horseshoe Reservoir. Although a number of factors may be responsible, lack of spawning habitat when the reservoir is near minimum pool, and quickly dropping reservoir levels during spring seem most likely to affect sport fish populations in Horseshoe Reservoir. Most of the sport fish species that occur in Horseshoe Reservoir spawn in the spring and build and guard nests with eggs and larvae; e.g., largemouth bass, smallmouth bass, green sunfish, bluegill, channel catfish, and flathead catfish. Substrate in Horseshoe Reservoir is dominated by fines (silt and clay; personal observation) near the dam, which is where the entire reservoir is located during minimum pool. Silt substrates are anoxic and are easily moved by currents so any eggs laid could be quickly covered and die because of oxygen depletion.

Suitable spawning substrate (gravel) for native fishes such as desert sucker (*Catostomus clarki*), Sonora sucker, and roundtail chub (*Gila robusta*; Minckley 1973) was available in the upper two reaches of the Verde River studied; however, pool habitat which adults prefer

(Rinne 1992), was minimal in these reaches and nonexistent in the lower two reaches. When Horseshoe Reservoir fills into the upper basin, razorback sucker spawning substrate (gravels) would be available in the upper and middle basins and rearing habitat would be available in the flooded vegetation (Modde et al. 2001). The capture of seven ripe and tuberculate male razorback suckers in one net in the upper reservoir basin, suggests that these fish were a spawning aggregation. In Lake Mead, Albrecht and Holden (*In press*) hypothesize that the stable but small razorback sucker population is a result of long-term and short-term fluctuations in lake level. The long-term fluctuations allow terrestrial vegetation to establish, which floods when the reservoir levels rise and provide increased protective cover for larval and juvenile razorback suckers. However, reservoir levels in Horseshoe Reservoir are highly unstable during the spring, so even when vegetation does get flooded, water is released quickly, so that habitat becomes desiccated. In addition, razorback suckers in Horseshoe Reservoir and the Verde River immediately upstream face threats from nonnative predatory fish; razorbacks can carry out their life history in ponds in the absence of predators (Mueller 1995). Although predatory sport fish are relatively rare, common carp may be a large impediment to the establishment of razorback sucker in the lower Verde River and Horseshoe Reservoir because of their great abundance, occupation of similar habitat, a generalist diet which likely overlaps with razorback suckers, and they are known to consume small fish and fish eggs, and so likely consume early-life-stage razorback suckers. Red shiner, a lotic species which is abundant throughout the Verde River (Rinne 2005), are also known to prey on larval fishes (Ruppert et al. 1993) and are thus another threat to razorback suckers and other native fishes. Mosquitofish, which can inhabit both lentic and lotic environments, pose a similar threat (Courtenay and Meffe 1989).

Over 22,000 razorback suckers greater than 300 mm TL were stocked into the Verde River near Childs from 1991 through 2003, because it was hoped that fish this size would be less vulnerable to predation, but there is no evidence that the species has established a self-sustaining population (Hyatt 2004). Lack of success has been attributed to unsuitable habitat and presence of nonnative-fish predators and competitors. A different strategy may be necessary to attain the goal of establishing a self-sustaining population. It may be possible to establish razorback suckers in Horseshoe Reservoir and the Verde River immediately upstream by managing reservoir water levels and stocking fish into the reservoir. During years when winter-spring runoff fills the reservoir, water levels could be kept relatively constant through spring, and razorback suckers (various age classes) could be stocked into the reservoir. If stocked early enough, adults could spawn in the flooded reservoir, and yearlings and sub-adults would have plenty of habitat with low densities of sport fish in which to grow. When reservoir levels are dropped, these fish would face increased threats from nonnative predatory and competitory fish. However, if fish can grow large enough (e.g., > 300 mm TL), they may at least be able to avoid predation.

Gear Assessment

Use of multiple gear types is critical to assess the species assemblage in Horseshoe Reservoir. The 13 species captured in the reservoir were either captured in gill nets or by electrofishing; eight of the species were captured using electrofishing and ten of the species were captured using gill netting. Yellow bullhead, flathead catfish, Colorado pikeminnow, Sonora sucker, and razorback sucker were captured in gill nets but not by electrofishing, whereas red shiner, mosquitofish and bluegill were captured by electrofishing and not in gill nets. No additional fish species were captured in the other gears used (seines, trap nets, minnow traps).

Electrofishing and gill nets were the most effective gears used to capture fish in Horseshoe Reservoir; fish were captured at all but one of the 24 electrofishing sites in April 2005, and at all sites in the three subsequent sampling events. Fish were captured in every gill net set. Fish were captured in 15 of 24 seine hauls and 10 of 32 minnow trap sets. For frame nets, fish were only captured in one of nine sets. The low capture of fish in frame nets is likely due to a combination of factors: 1) few small fish were in the lake at the time of the survey, as evidenced by the catch from the other gear types and observations, 2) we only had three available nets, all of which were in only moderate condition, 3) most of the randomly chosen sites had slopes that were too steep for effective net sets, and 4) nets were not baited. If frame nets are to be used in the future, at least eight (to match the number of gill net sets) should be set and baited per night.

In the Verde River, nine fish species were captured, eight either by electrofishing or seining; mosquitofish were only captured by seining, whereas all species captured by electrofishing were also captured by seining. One species, flathead catfish, was captured by gill netting, but not by electrofishing or seining. Mini hoop nets were not that effective at capturing fish; a few red shiners were captured in one of four nets set in October 2006, and no fish were captured in the three nets set in October 2005, but that may have been due to the rise and fall of the river during the night that they were set. Minnow traps also were not effective in the Verde River; of 28 minnow trap sets (baited with canned cat food), no fish were captured.

Use of multiple gear types was also critical to assess the size structure of fishes. Small fish were captured by electrofishing; total length of fish ranged from 25-599 mm with 4.9% of fish being less than 100 mm TL. The experimental gill nets we used, with a minimum mesh size of 1.25 cm, are of course biased against capture of small fish with girths less than 1.25 cm, but they still were effective at capturing small fish; length of fish ranged from 58 – 680 mm with 11.7% being less than 100 mm TL. Seining was very effective for capturing small fish; of 1,627 fish that were measured for length, total lengths ranged from 12 through 425 mm, and 96.7% were less than 100 mm TL. Based on the above data, it is recommended that boat or canoe-mounted electrofishers, experimental gill nets, and seines be used to capture fish in Horseshoe Reservoir and the Verde River immediately upstream during any future efforts to monitor the fish assemblage.

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