LONG-TERM MONITORING OF FISH ASSEMBLAGES IN THE GILA RIVER DRAINAGE, NEW MEXICO

1988 – 2005

SUBMITTED TO
U.S. FISH AND WILDLIFE SERVICE
AND
U.S. BUREAU OF RECLAMATION

SUBMITTED BY
YVETTE M. PAROZ AND DAVID L. PROPST
CONSERVATION SERVICES DIVISION
NEW MEXICO DEPARTMENT OF GAME AND FISH
AND
JEROME A. STEFFERUD
U.S. FOREST SERVICE - RETIRED

APRIL 24, 2006

EXECUTIVE SUMMARY

Monitoring of Gila-San Francisco Drainage warmwater fish assemblages was conducted annually (October and November) at six permanent sites in the Gila River drainage and two in the San Francisco River drainage. Included were one site each on the East, Middle, and West forks of the Gila River, mainstem Gila River near Riverside, near Middle Box mouth, and in Lower Box (Fisherman's Point), San Francisco River near Glenwood, and Tularosa River near Eagle Peak Road. Sampling was initiated at five sites in 1988, one in 1989, and two sites were added in 1997. This report covers results through 2005. The overarching objective of this effort was to document long-term population trends of native and nonnative fish species at sites that collectively were representative of lotic habitats in the drainage.

Eight native and fifteen nonnative fish species were collected among the study sites. Abundance of native fishes declined at most sites over the study period, but most noticeably over past 6 years. Abundance of nonnative fishes did not appreciably increase at any location, except on Middle Fork Gila River. Only one specimen of roundtail chub was collected, from Gila River-Riverside site, in the course of the study. Spikedace and loach minnow densities decreased at each of the Gila forks sites; neither has been collected at Middle Fork site since 1998, or the East Fork site since 2000. Loach minnow densities also decreased at the Tularosa site. However, loach minnow was regularly collected at the San Francisco River and Gila River-Riverside sites. Spikedace densities generally declined at all sites of collection. Headwater chub abundance

decreased at the East and Middle Gila River forks sites, but showed a slight increase at the West Fork Gila River site. Abundance of other native species generally decreased or was stable. The only significant abundance increase was by longfin dace at Gila River--Riverside. For the past several years, nonnative species numerically dominated the Middle Fork, Middle Box, and Fisherman's Point Gila River sites. No native species has been collected at Fisherman's Point since 2002.

The highest percentage of native fishes was found in run and riffle habitats, while nonnative fishes were collected most often in backwater and shore run habitats. Headwater chub occupied slower, deeper habitats with finer substrate than desert sucker and Sonora sucker. Loach minnow was collected where larger substrate and faster water velocities were present. Longfin dace and spikedace were found in similar water velocities, but substrate sizes were finer in habitats occupied by longfin dace. Speckled dace was found in habitats intermediate in velocity and substrate size compared to that occupied by loach minnow, spikedace, and longfin dace.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Historically, the Gila River drainage in New Mexico supported a native fish fauna comprised of eleven species, and perhaps thirteen. Neither Colorado pikeminnow *Ptychocheilus lucius* nor razorback sucker *Xyrauchen texanus* was documented by specimens, as native to the basin in New Mexico, but each was historically present downstream in Arizona portions of the Gila River and likely entered New Mexico at least seasonally. Gila topminnow *Poeciliopsis occidentalis*, historically present in San Francisco River near Pleasanton, was extirpated during the 1950s, but was repatriated to New Mexico in 2005. The remaining ten species persist, albeit most in greatly reduced abundance and range, in the Gila River drainage in New Mexico.

Taxonomy of the suite of chub species (*Gila* sp.) found in the Gila River drainage has undergone revision since sampling was initiated at these sites (Minckley and DeMarais 2000, Nelson et al. 2004). For congruity of this study and the state recovery plan (Carman 2006), chubs collected in the forks of the Gila River were classified as headwater chub *Gila nigra* and those downstream of confluence of forks as roundtail chub *Gila robusta*. Only one chub specimen was collected at mainstem Gila River sites (Riverside site 1991). The only known population of Gila chub *Gila intermedia* in New Mexico exists in Turkey Creek.

Five extant Gila River basin fishes, Gila trout *Oncorhynchus gilae*, Gila chub *Gila intermedia,* spikedace *Meda fulgida*, loach minnow *Tiaroga cobitis*, and Gila topminnow are federally protected as threatened or endangered species and the U.S. Fish and Wildlife Service has been petitioned to list roundtail chub *Gila robusta* and headwater chub *Gila nigra* as endangered or threatened. Each federally listed and petitioned species, except headwater chub, is listed as threatened or endangered by the State of New Mexico. Headwater chub has been recommended for state listing as endangered. Four species, longfin dace *Agosia chrysogaster*, speckled dace *Rhinichthys osculus*, desert sucker *Catostomus (Pantosteus) clarki*, and Sonora sucker *Catostomus insignis*, are widespread in the basin in New Mexico.

Several nonnative warmwater fishes have been introduced to the Gila River basin. Nonnative sport fishes found in warmwater streams include channel catfish *Ictalurus punctatus*, flathead catfish *Pylodictus olivaris*, and smallmouth bass *Micropterus dolomieui*. Red shiner *Cyprinella lutrensis*, fathead minnow *Pimephales promelas*, western mosquitofish *Gambusia affinis* are generally distributed; other nonnative fishes (e.g., black bullhead *Ameiurus melas*, yellow bullhead *A. natalis*, and green sunfish *Lepomis cyanellus)* occur irregularly across the drainage.

To document status, trends, and investigate the dynamics of warmwater stream fish assemblages in southwest New Mexico, annual monitoring occurred at six permanent sites in the Gila River drainage and two sites in the San Francisco River drainage. Collectively, these sites supported all extant native Gila basin fishes, except Gila trout, Gila chub, and Gila topminnow.

The described field work and corresponding annual reports were funded through federal Sport Fish Restoration Grant FW-17. This long term compilation and analysis of the eighteen year data set was made possible from funding through the U.S. Bureau of Reclamation. This document is a compilation of data collected annually at each site. General patterns and trends in fish assemblages at each permanent site are presented. Additionally, summary information on habitat associations of common species is presented.

STUDY AREA

Sample sites were selected to include the range of warmwater lotic habitats in the Gila-San Francisco River drainage in New Mexico, to collectively include all extant native warmwater fish species, and finally, to be reasonably accessible (Figure 1). Four native fishes (longfin dace, loach minnow, desert sucker, and Sonora sucker) were present at all sites. Seven native fishes (longfin dace, headwater chub, spikedace, speckled dace, loach minnow, desert sucker, and Sonora sucker) occupied each of the three Gila River fork sites (Figures 2-5). Collectively, mainstem Gila River sites supported longfin dace, roundtail chub, spikedace, loach minnow, desert sucker, and Sonora sucker.

Sampling has occurred annually at the Middle and East forks sites since 1988, except 1996 when the East Fork site was not sampled. Annual sampling began at the West Fork site in 1989. Sampling at the Riverside site began in 1988 and in 1997 at the lower Gila River sites, Middle Box and Fisherman's Point (Figures 6-9). Sampling was initiated on the Tularosa River-Eagle Peak Road and San Francisco River-Glenwood sites in 1988 (Figures 10-12). The San

Francisco River and mainstem Gila River sites were not sampled in 2000 because of high flows.

In size (drainage area, channel dimensions, and discharge volume), the streams at each site ranged from small (Tularosa River) to comparatively large (Gila River at Riverside, Middle Box, and Fisherman's Point). The Gila forks and San Francisco River at Glenwood sites were on intermediate-sized streams. Channel gradients at all sites were low, typically, 0.5%.

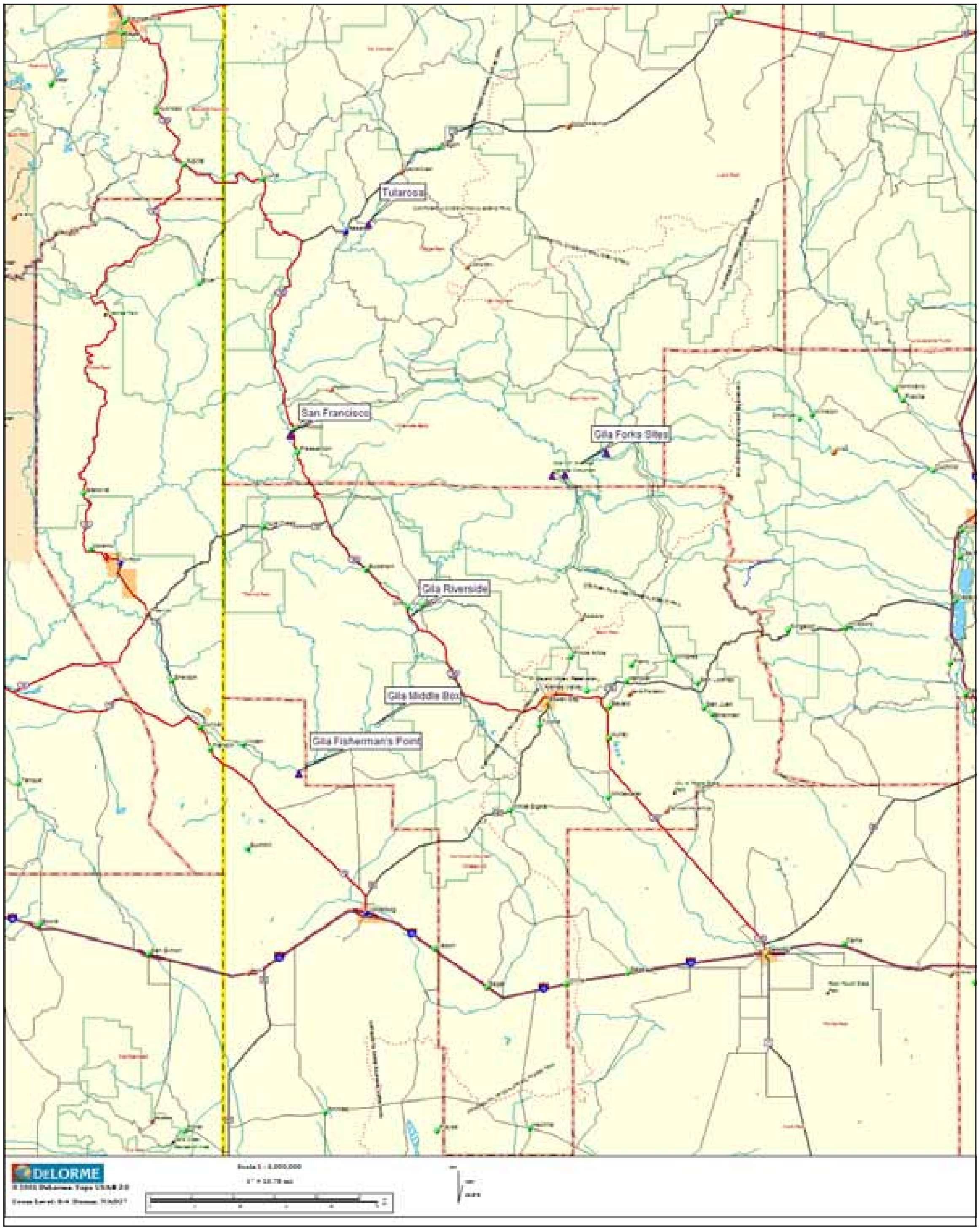


Figure 1. Approximate locations of permanent sites in the Gila and San Francisco Drainage in southwestern New Mexico.

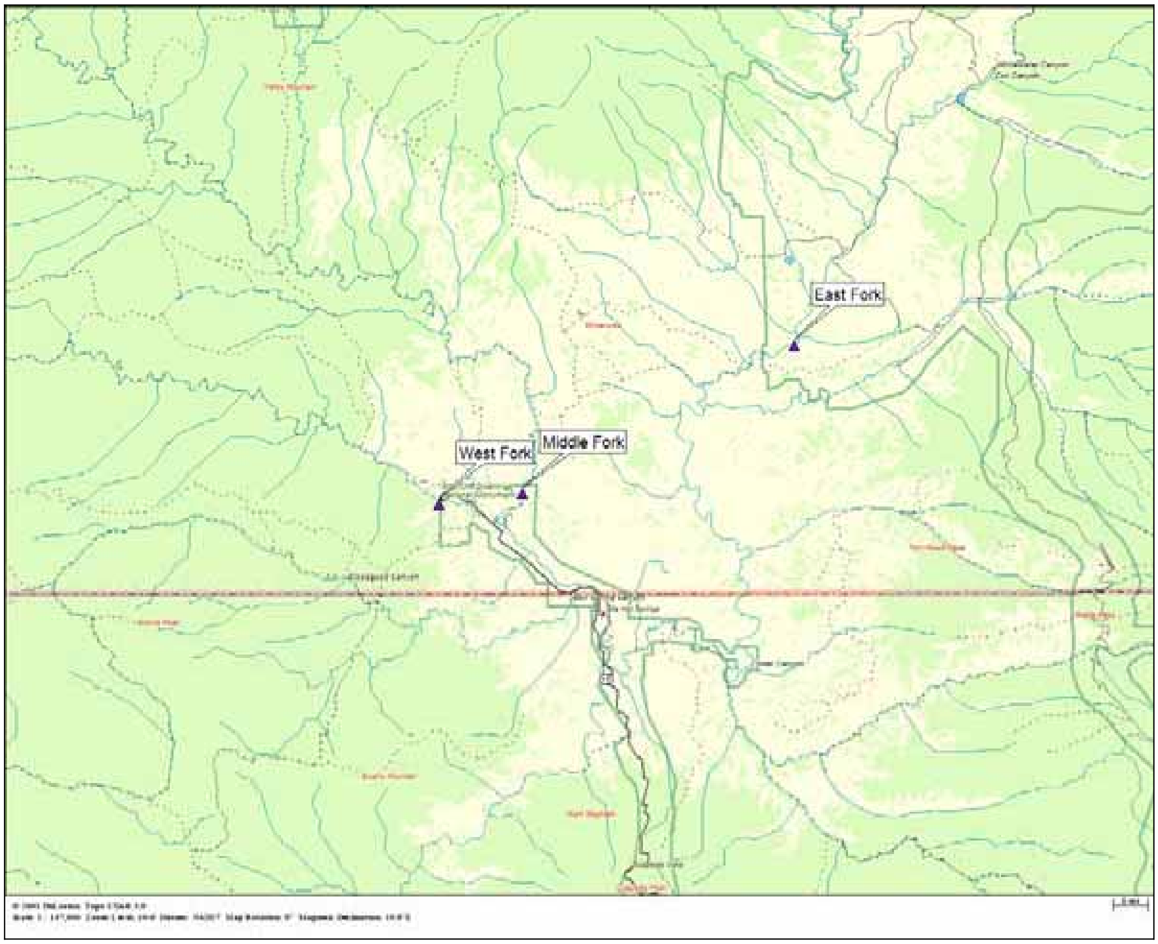


Figure 2. Approximate location of Gila River West, Middle, and East forks study sites.

East Fork Gila River

From 1988 through 1995, the East Fork Gila River site was located about 1.5 km downstream of the confluence of Beaver and Taylor creeks. In 1996, the site was re-located about 4 km downstream. No meaningful differences were discerned between the sites. At both locations, the stream meandered across a largely un-shaded valley. Wetted channel width was about 4 m, riffle and run depths were 0.2 to 0.4 m, and deeper pool depths were 1.0 to 1.5 m. Sand and gravel-bottomed runs were the most common habitat, but short riffles and pools associated with uprooted trees and large boulders were also comparatively common (Figure 3). Dispersed livestock grazing was the primary land use in vicinity of site.


Figure 3. East Fork Gila, lower end of permanent site.

Middle Fork Gila River--Trailhead

For most of its course, the Middle Fork Gila River is canyon-bound. At the study site near its confluence with West Fork Gila River, the canyon was broader and the stream was partially shaded by willow and cottonwood. Wetted channel width ranged from 8 to 15 m and water depths over 2 m were common in pools associated with large boulders. Riffle and run habitats were common. Site length was 235 m. Land use in vicinity of the site was limited to wilderness-associated recreational activities. Before 1998, horses used by the U. S. Forest Service grazed along the site. Riparian vegetation recolonized the streambanks after grazing ceased (Figure 4).


Middle Fork Gila River, Point 4 - 2005

Middle Fork Gila River, Point 4 - 1997


Middle Fork Gila River, Point 3 - 2004

Middle Fork Gila River, Point 3 - 1998


Middle Fork Gila River, Point 2 - 2004

Middle Fork Gila River, Point 2 - 1997

Figure 4. Views of Middle Fork Gila River permanent study site, Catron County, New Mexico.

West Fork Gila River

The West Fork Gila River site, about 1 km upstream of its confluence with Middle Fork Gila River, was in the shadow of a high (50 m) cliff. Stream width varied from 4 to 10 m and depths ranged between 0.2 and 0.4 m in most habitats; a moderately large pool between 1 and 2 m deep was within the site. Habitats ranged from rapid-velocity riffles to eddy pools associated with large boulders, but most of the site was low-velocity run. Cobble and gravel were the main substrata in all habitats, except low velocity pools where sand was predominant. Willow *Salix sp.*, box elder *Acer negundo*, and narrowleaf cottonwood *Populus augustifolia* bordered the stream within the site which was 215 m in length (Figure 5). Recreational activities associated with wilderness and Gila Cliff Dwellings National Monument were the primary land uses in vicinity of the site. Forest fires occurred in much of the upper watershed of this site during the sampling period and floods carrying large quantities of ash, sediment and burned debris were common during 2001 through 2004. During the period of sampling, the stream channel gradually moved away from the base of the cliff of the west side towards the east.

West Fork Gila River, Point 3 – 2005

West Fork Gila River, Point 3 – 1996

Figure 5. Views of West Fork Gila River permanent study site, Catron County, New Mexico.

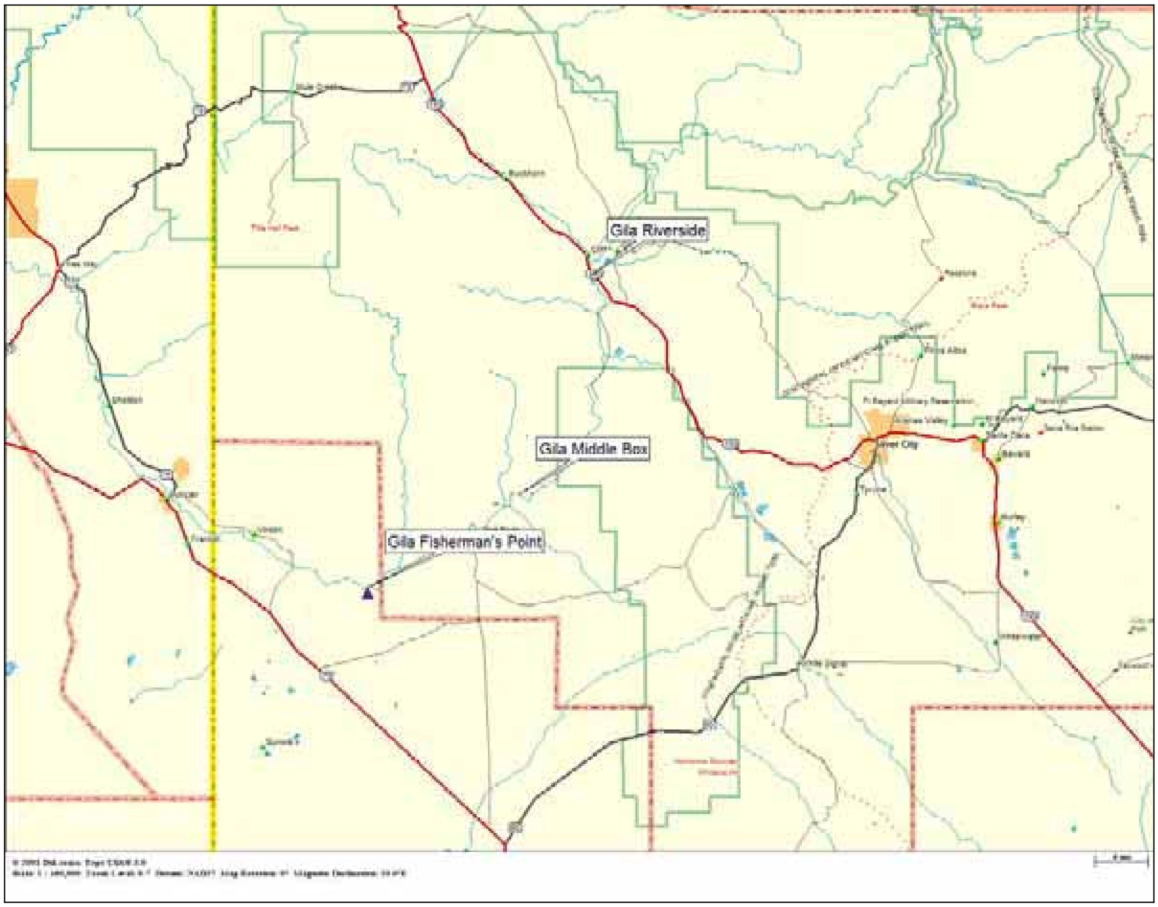


Figure 6. Approximate locations of Gila River mainstem permanent study sites.

Gila River--Riverside

The Riverside site was located on the mainstem Gila River in low-relief Cliff-Gila Valley where the river meanders through irrigated and fallow floodplain. Cottonwood and seep willow *Baccharis salicifolia* edged banks through much of the valley. Habitat in the broad (20 to 40 m) river consisted mainly of shallow, sand-bottomed runs, but backwaters and embayments associated with sand/gravel bars were moderately common. Riffle habitat occurred mainly in channel constrictions and few pools were present. The study site was 190 m long. Cattle grazing, recreational angling, and waterplay were the major uses at the site. During the study period, the channel meandered back and forth across the floodplain, sometimes on an annual basis (Figure 7).


Gila River--Riverside, Point 2 - 2005


Gila River--Riverside, Point 2 - 2004


Gila River--Riverside, Point 1 - 2005


Gila River--Riverside, Point 1 - 1999

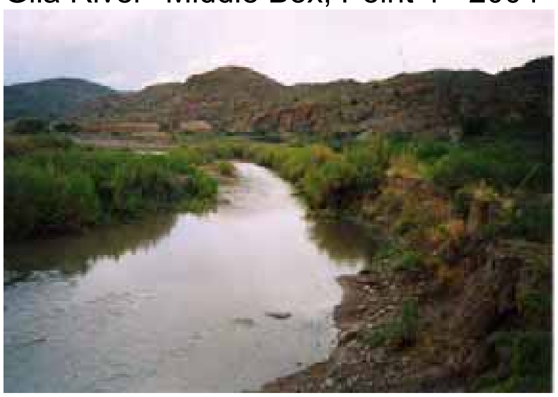
Figure 7. Views of Gila River—Riverside permanent study site, Grant County, New Mexico.

Gila River--Middle Box

The Middle Box site was located just downstream of the exit of the Gila River from the Burro Mountains. At the site, wetted channel width varied from 10 to 30 m. Broad, shallow, sand-bottomed runs were the predominant habitat. Cobbled riffle habitat was limited. Seep willow was the main riparian vegetation (Figure 8). Mineral extraction and dispersed livestock grazing were the primary land uses in vicinity of the site.

Gila River--Middle Box, Point 4 - 2004

Gila River--Middle Box, Point 4 - 1999



Gila River--Middle Box, Point 1 – 2005

Gila River--Middle Box, Point 1 - 1999

Figure 8. Views of Gila River—Middle Box permanent site, Grant County, New Mexico.

Gila River--Fisherman's Point

The most downstream Gila River site, Fisherman's Point, was in a canyon-bound reach. Dense stands of coyote willow *S. exigua* and seep willow with scattered cottonwood and Arizona sycamore *Platanus wrightii* bordered the river within the site (Figure 10). Habitat consisted almost entirely of moderately-deep runs. Limited amounts of low-velocity habitat occurred along shorelines and in association with root wads. With exception of short riffles having gravel and cobble, sand was the only substrate. Domestic livestock have been excluded from the river in the vicinity of the site since 1997. During the sampling period (post 1997) vegetation has increased on the streambanks.

Gila River--Fisherman's Point
Point 2 - 2005

Gila River—Fisherman's Point,
Point 2 - 2002

Gila River--Fisherman's Point, Point 4 – 2001

Figure 9. Views of Gila River—Fisherman's Point permanent study site, Hidalgo County, New Mexico.

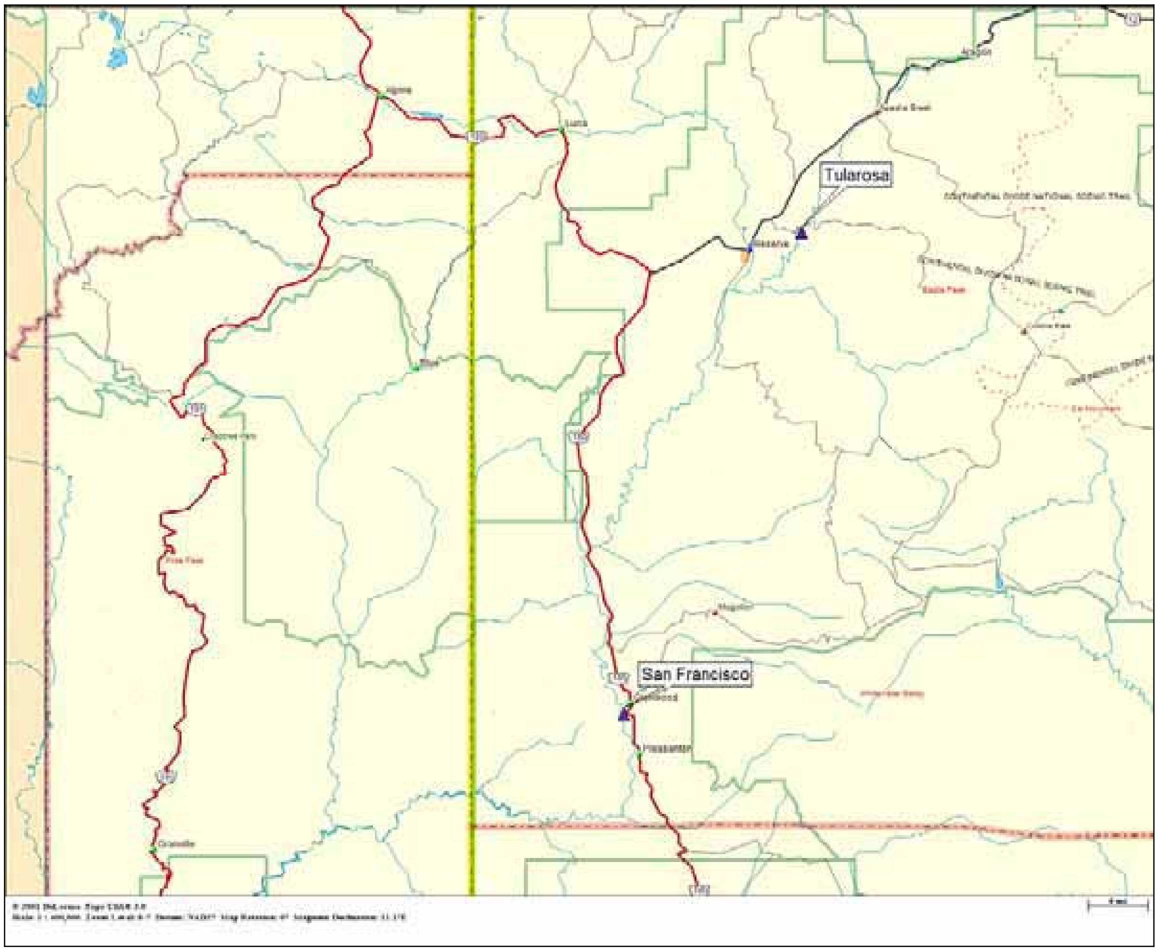


Figure 10. Approximate location of San Francisco River drainage permanent study sites.

Tularosa River

At this site, the Tularosa River meandered through a broad valley. Wetted channel width rarely exceeded 2 m and depths were typically less than 0.5 m. Habitat consisted mainly of shallow, cobbled riffles, long moderate-velocity cobble- and sand-bottomed runs, and scattered graveled pools associated with root wads and boulders. Site length was 165 m. Stream banks were vegetated with grasses, sedges and other grass-like plants; woody riparian vegetation was sparse (Figure 11). Dispersed livestock and wild elk grazing was the primary land use in the watershed near the site.

Tularosa River, Point 3 - 2005

Tularosa River, Point 3 - 1999

Tularosa River, Point 1 - 2004

Tularosa River, Point 1 -1997

Figure 11. Views of Tularosa River-Eagle Peak Road permanent study site, Catron County, New Mexico.

San Francisco River

Upstream of the permanent site, the San Francisco River flowed through pastureland, irrigated fields, and several small settlements. Within the immediate vicinity of site, however, the river was canyon-bound with dense stands of coyote willow, seep willow, Gooding willow *S. gooddingii,* and cottonwood edging the river. Long, low velocity runs and pools were separated by moderately-steep gradient riffles (Figure 12). Stream width varied from 4 to 12 m and depths exceeded 2 m in pools associated with cliffs. Site length was 125 m.

San Francisco River, Point 6 - 2005

San Francisco River, Point 6 - 2001

San Francisco River, Point 3 - 2003

Figure 12. Views of San Francisco River-Glenwood permanent study site, Catron County, New Mexico.

METHODS

Sampling normally occurred each year at each site in October. The East Fork Gila River site was sampled in early November in several years. At each site, sampling for fish in each individual mesohabitat (Table 1) occurred in rough proportion to its availability within a site. The particular method used to obtain specimens depended upon mesohabitat being sampled. Broad shallow runs, and similar mesohabitats with smooth substrates, were sampled with drag seines (normally 3.0 x 1.2 m, 3.2 mm mesh). A battery-powered backpack electrofisher was used to stun fishes in cobble-bottomed runs, debris pools, and similar mesohabitats, and specimens were then collected with dip nets. A seine and backpack electrofisher were used in tandem to collect fishes from rapid-velocity habitats (e.g., riffles and chutes). All specimens collected from each mesohabitat were identified, enumerated, measured (±1 mm total and standard lengths and ±1 g mass, if total length >75 mm), and released (except nonnative fishes) Nonnative fishes were disposed of or preserved in 10% formalin and transported to the laboratory. Retained specimens were accessioned to University of New Mexico Museum of Southwestern Biology. If the electrofisher was used, elapsed electrofishing time for mesohabitat sampled was recorded. The portion of area sampled of each mesohabitat (regardless of collection method) was demarked with surveyor flags to aid in measurement of area sampled. Fish density was calculated as number of fish captured per square meter sampled.

Following specimen collection a single measurement of length, and several width, depth, and water velocity measurements were obtained within the sampled area of each sampled mesohabitat. For analysis, these measurements were averaged for each mesohabitat. Substrate composition was characterized visually at several locations within sampled portion of each mesohabitat. For analyses, values were assigned to the primary substrate type (silt=1, sand=2, gravel=3, cobble=4, boulder/bedrock=5). Other habitat features, such as overhead cover, debris, and vegetation, were also noted.

Table 1. General description of mesohabitat types used to characterize sampled areas at permanent sites in the Gila River drainage.

TYPE	HABITAT	DESCRIPTION
Slow	Isolated pool	Standing water not directly connected to wetted channel; depth and substrate variable.
	Embayment	An off-channel inundated area with mouth facing upstream; directly connected to wetted channel, generally shallow (<20 cm) with silt or sand substrate and no, or almost no, flow.
	Backwater	An off-channel inundated area with mouth facing downstream; directly connected to wetted channel, depth typically >20 cm and often >50 cm, substrate silt, sand, or gravel, banks may be undercut.
	Pool	An area of low-velocity water (<10 cm/sec), typically >20 cm deep and normally >50 cm with silt or sand substrate but sometimes gravel substrate. Pools often formed by and around instream obstructions such as boulders, uprooted trees, or in association with root masses.
	Shoal	A shallow (5 to 20 cm), low-velocity area (5 to 20 cm/sec) with sand and cobble substrate; shoals most typically found on inside curve of long bend.
Moderate	Eddy	Typically, a moderately deep (20 to 50 cm) area with slow to moderate velocity (5 to 30 cm/sec) reverse current and sand or small gravel substrate. Eddys most frequently found in association with riffles and instream obstructions.
	Pool run	An area of low to moderate-velocity water (10 to 20 cm/sec), moderately deep to deep water (30 to 100 cm), with sand or small gravel substrate. Although sometimes associated with instream obstructions, pool runs more often associated with channel bed depressions and low gradient reaches.
	Shore run	Moderate velocity (20 to 60 cm/sec) and moderately deep (30 to 70 cm) areas along stream margins. Substrate usually sand, gravel, or cobble. Banks steeply sloping and often undercut.
	Run	Moderate velocity (20 to 60 cm/sec) and moderately deep (30 to 70 cm) habitat. Substrate typically sand or gravel, but cobble often present. Instream cover rare.
	Mid channel run	Moderate to rapid velocity (20 to 80 cm/sec) and moderate to deep (30 to 80 cm) habitat with gravel or cobble substrate. Instream cover rare. Habitat typically astride thalweg.
Rapid	Riffle run	Areas with gradient somewhat steeper than run, water surface agitated, cobble predominant substrate but sand and gravel may be present. Water velocity moderate to rapid (30 to 80 cm/sec) and depths rarely >40 cm.
	Riffle	Moderately steep gradient areas with predominately cobble substrate, rapid velocity water (typically >50 cm/sec), and shallow to moderate depths (normally <30 cm). Water surface agitated.
	Chute	Steep gradient areas where bedform areally concentrates flow (typically central channel). Velocity frequently >100 cm/sec, depths usually 50 to 150 cm, and substrate large cobble

Mean average daily discharge and seasonal average daily discharge was estimated using average daily discharge data, obtained from the USGS gage on the Gila River (9430500) near Gila, New Mexico and on the San Francisco River (9442680) near Reserve, New Mexico (http://waterdata.usgs.gov/nwis/sw). Total precipitation in the Gila River watershed was estimated using data from the SNOWTEL site on Lookout Mountain. The Frisco Divide SNOWTEL site was used to estimate total precipitation in the San Francisco River watershed (http://www.wcc.nrcs.usda.gov/snotel/New_Mexico/new_mexico.html). Seasons were defined as: winter (December 1 – February 28(9)), spring (March 1 – May 31), summer (June 1 – August 31), fall (September 1 – November 30). Discharge and precipitation data are given in English units (cubic feet per second [cfs] and inches).

Data were entered into Excel® spreadsheets. One spreadsheet contains all information on the fishes collected. Habitat information was entered on a separate sheet. The spreadsheets were set up to facilitate use of pivot tables. The Excel® pivot table functions are useful to collate information contained in the spreadsheets. Column headings were used to categorize information, while field settings allow options such as sum, count, or average the data in each category. For habitat association analysis, spreadsheets were imported into an Access data base and individual records were cross-referenced between the two sheets using the collection number and habitat number.

Regression analyses were conducted using average daily discharge, total precipitation, and time as independent variables. Native and nonnative fish densities were dependant variables. Density was the number of fish divided by total area sampled. Three separate time (trend) regressions were analyzed. The entire sampling period was analyzed for all sites. The six original sites were also analyzed separately for the time periods pre and post 1997, when the Middle Box and Fisherman's Point sites were added. This break also coincided with the beginning of several years with low discharge. Regression analysis was also conducted for densities of each native species with time at each site. Species richness at each site was indicated by the number of species sampled in a given year. Diversity, a measure of how evenly individuals are spread out among species types, was calculated using Shannon-Weiner Diversity Index (H; proportion values transformed to natural log) for each site and year. This index increases as the probability of organisms being the same decreases, and therefore communities that are more diverse will have a higher Shannon-Weiner Index.

Combining data from all sites, comparisons were made of mesohabitat features (depth, velocity, and substrate) of the areas where each species was collected. Species were classified as either small- or large-bodied species. Large-bodied fishes were further divided into large-bodied adults (≥150 mm TL) and large-bodied juveniles (<150 mm TL) and t tests were used to differentiate between habitats where each was found. Single factor Analysis of Variance (ANOVA) comparisons were used to describe the differences in habitats among the various species within the three groups (i.e., small-bodied, large-bodied juveniles, and large-bodied adults).

RESULTS

Discharge and Precipitation – Gila River

Mean daily discharge for each year between 1988 and 2005 was determined from the U.S. Geological Survey gauge - 9430500 near Gila, NM. The highest water year during the sampling period was 1993, with mean daily discharge averaging more than 400 cfs. Several years (1989, 1990, 2000, 2002, and 2003) had average mean daily discharge less than 100 cfs (Figure 13). From 1988 through 1996, mean daily discharge in the Gila averaged 224 cfs and 142 cfs from 1997 through 2005. Total annual precipitation from 1988 through 1996 averaged over 21 inches (53.3 cm), but less than18 inches (45.7 cm) from 1997 through 2005. Discharge in the Gila River was generally highest in winter and spring (December through May). Summer (June through August) typically had the lowest average mean daily discharge; 1999 was the only year when seasonal average mean daily discharge was highest in the summer. July was the only month without an annual maximum flow event. Mean precipitation from 1988 through 2005 at the Lookout Site was highest in July and August at nearly 3.5 inches (8.9 cm) per month. April, May, and June had the lowest mean precipitation, less than 0.75 inches (1.9 cm) per month.

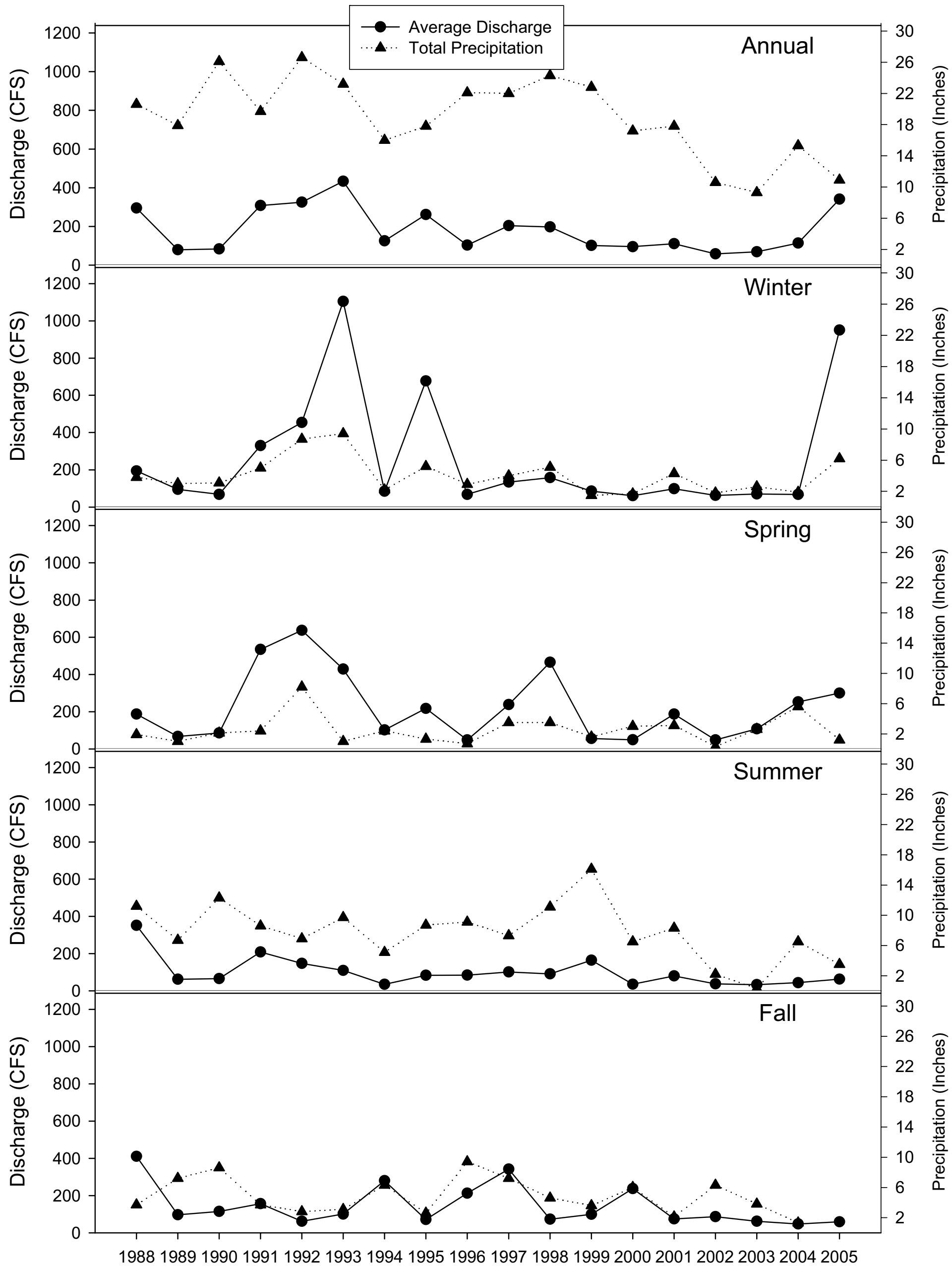


Figure 13. Average mean daily discharge (CFS) of Gila River near Gila, NM and total annual precipitation (inches) on Lookout Mountain.

Discharge and Precipitation-San Francisco River

Average mean daily discharge data for each year between 1988 and 2005 was obtained for the San Francisco River at the gauge (9442680) near Reserve, NM. As in the Gila River, 1993 had the greatest mean daily discharge, with an average exceeding 75 cfs, while several years (1990, 1996, 2002, 2003, and 2004) had average mean daily discharge less than 10 cfs (Figure 14). Mean daily discharge in the San Francisco River averaged 28 cfs from 1988 through 1996; and 14 cfs from 1997 through 2005. Annual precipitation averaged over 22 inches (55.9 cm) from 1988 through 1996; and less than 20 inches (50.8 cm) from 1997 through 2005. Discharge in the San Francisco was generally greater during winter and spring (December through May). Summer (June through August) had the lowest average mean daily discharge, but July and August had the highest average total precipitation, 2.5 and 4.0 inches (6.6 and 10.2 cm) per month (respectively). April, May, and June had the lowest precipitation, averaging less than 0.9 inches (2.3 cm) per month.

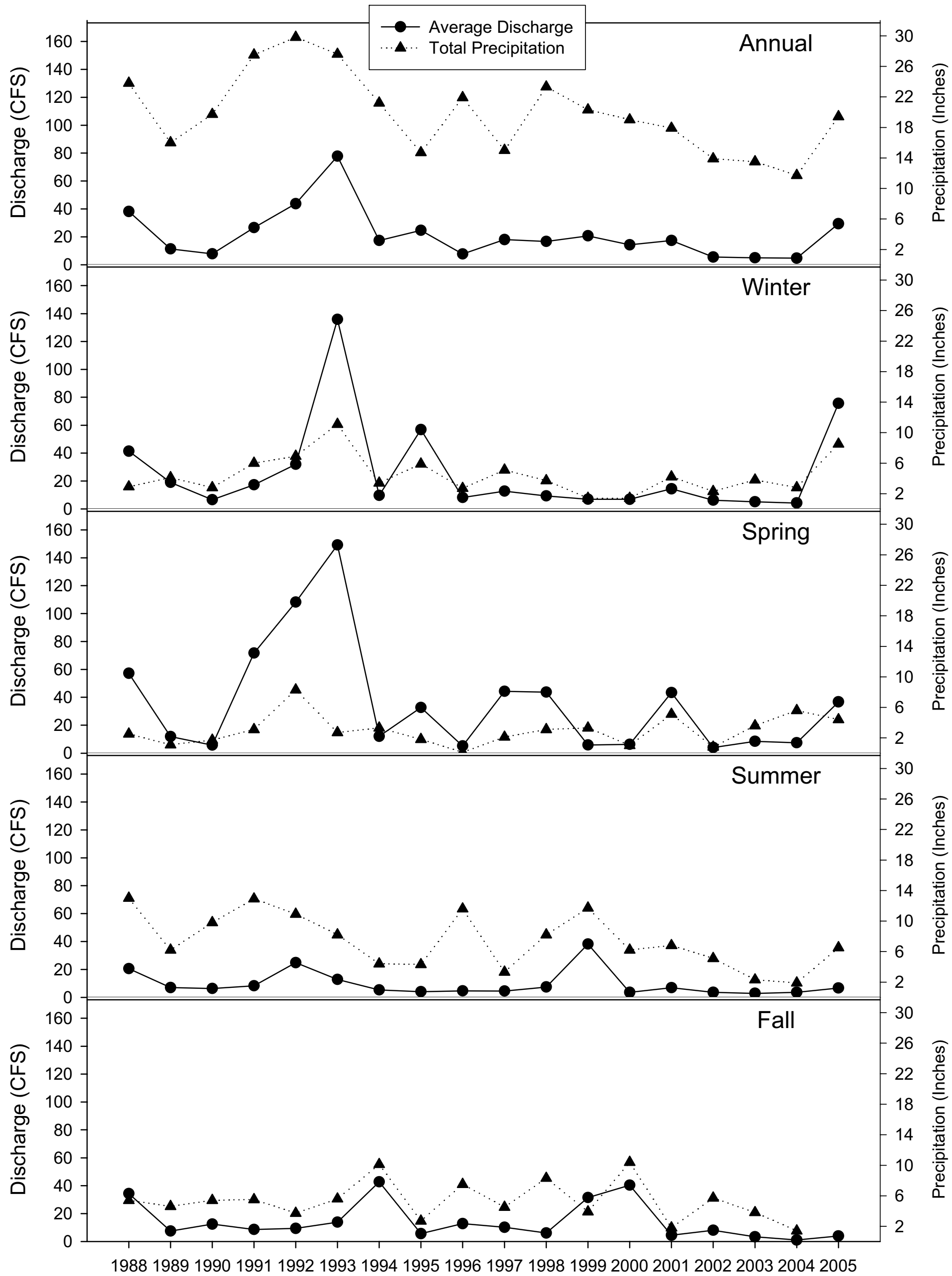


Figure 14. Average mean daily discharge (CFS) of San Francisco River near Reserve, NM and total annual precipitation (inches) on the Frisco Divide.

Fish Species

Twenty-three species of fish and 42,094 individuals were collected at permanent sites from 1988 through 2005. Seven native species were regularly collected at Gila River sites (Table 2). Sonora sucker and desert sucker were the most commonly collected and widely distributed native species followed by longfin dace and speckled dace. Due to changes in taxonomy (see introduction), chubs collected in the forks of the Gila River were classified as headwater chub *Gila nigra* and those downstream of confluence of forks as roundtail chub *Gila robusta*. Only one chub specimen was collected at mainstem Gila River sites (Riverside site 1991).

Fifteen nonnative species were collected from Gila-San Francisco River permanent sites. Western mosquitofish and red shiner were collected most frequently. Nonnative predators including smallmouth bass and yellow bullhead were the most commonly collected nonnative predators in the forks area, but were not commonly collected at mainstem Gila River or San Francisco River drainage sites.

Densities of fishes at each site (Appendix 1) varied annually. Densities of nonnative fishes appeared to be increasing while native fishes decreased at all Gila River sites except West Fork (Figures 15 and 16). Average density of native fishes from 1988 through 1992 was nearly twice the density of natives from 2001 through 2005 at all sites except West Fork Gila River and East Fork Gila River sites, where native abundance increased slightly. For the same time periods, densities of nonnative fishes more than doubled at all sites except for the West

Fork, where nonnative density decreased slightly. Densities of nonnative fishes were greater than native fishes in recent collections from Middle Fork, Middle Box, and Fisherman's Point. No native species was collected at Fisherman's Point in the last two years of sampling (2004 and 2005).

Table 2. Fish species and numbers of individuals collected in samples at permanent sites from 1988 – 2005.

Common Name	Species	Abbreviation	Number
Native Species			
Longfin dace	*Agosia chrysogaster*	AGOCHR	9205
Sonora sucker	*Catostomus insignis*	CATINS	8244
Headwater chub	*Gila nigra*	GILNIG	512
Roundtail chub	*Gila robusta*	GILROB	1
Spikedace	*Meda Fulgida*	MEDFUL	2273
Desert sucker	*Catostomus (Pantosteus) clarki*	PANCLA	7736
Speckled dace	*Rhinichthys osculus*	RHIOSC	4892
Loach minnow	*Tiaroga cobitus*	TIACOB	3233
Nonnative Species			
Black bullhead	*Ameiurus melas*	AMEMEL	84
Yellow bullhead	*Ameiurus natalis*	AMENAT	463
Brook stickleback	*Culaea inconstans*	COBINC	1
Common carp	*Cyprinus carpio*	CYPCAR	20
Red shiner	*Cyprinella lutrensis*	CYPLUT	1694
Western mosquitofish	*Gambusia affinis*	GAMAFF	2578
Channel catfish	*Ictalurus punctatus*	ICTPUN	278
Chihuahua catfish	*Ictalurus spp.*	ICTSPP.	48
Green sunfish	*Lepomis cyanellus*	LEPCYA	13
Smallmouth bass	*Micropterus dolomieui*	MICDOL	358
Largemouth bass	*Micropterus salmoides*	MICSAL	50
Rainbow trout	*Oncorhynchus mykiss*	ONCMYK	188
Fathead minnow	*Pimephales promelas*	PIMPRO	170
Flathead catfish	*Pylodictis olivaris*	PYLOLI	21
Brown trout	*Salmo trutta*	SALTRU	32

Nonnative predators, including smallmouth and largemouth basses, green sunfish, channel and flathead catfishes, black and yellow bullhead catfishes, and brown and rainbow trouts, were collected at Gila River permanent sites. Nearly all nonnative fishes collected from Gila River forks were in this group. Mainstem collections contained a larger percentage of small-bodied nonnatives, such as red shiner and fathead minnow, than Gila River forks collections. Nonnative fishes were rarely collected at the San Francisco drainage sites (Figure 17). Western mosquitofish, fathead minnow, and rainbow trout were irregularly collected at both sites. Largemouth bass was collected at the San Francisco site in 1991 and 1993. A single brook stickleback specimen was collected in the Tularosa in 2002.

Regression analyses of time versus native and nonnative fish densities was performed for the original six sites for the periods 1988 – 2005, 1988 – 1996, and 1997 – 2005 time period for all eight sites (Table 3). For the eighteen-year period, native fish densities declined with time (except at Riverside), significantly so at the West Fork Gila site. Nonnative fish densities did not change over the eighteen year period. None of the sites showed a significant trend for the first nine years of sampling, except at the San Francisco River site. There, the density of native fishes increased with time during the 1988-1996 period, but declined during the 1997-2005 period. Analysis of data from the last nine years also showed significant negative trends in native fish density at Middle Fork and Fisherman's Point sites. Nonnative fish densities decreased for the last nine years at Middle and West fork sites.

Table 3. Regression results of time series versus fish density in permanent sites samples. West Fork sampling began in 1989. *indicates significance (p<0.05)

	1988- 2005				1988-1996				1997-2005			
	Natives		Nonnatives		Natives		Nonnatives		Natives		Nonnatives	
Site	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
East Fork	-0.45	0.07	0.18	0.48	-0.07	0.87	0.14	0.75	-0.28	0.49	0.18	0.68
Middle Fork	-0.46	0.06	0.21	0.41	-0.03	0.95	0.53	0.14	-0.72*	0.04	-0.88*	0
West Fork	-0.59*	0.01	-0.4	0.11	-0.50	0.21	0.44	0.28	-0.53	0.18	-0.72*	0.04
Riverside	0.36	0.15	0.14	0.59	0.40	0.28	0.41	0.27	0.53	0.18	-0.5	0.2
Middle Box									0.3	0.48	0.59	0.12
Fisherman's Point									-0.81*	0.02	0.46	0.25
San Francisco	-0.17	0.52	0.31	0.23	0.66	0.05	0.20	0.60	-0.77*	0.02	-0.03	0.95
Tularosa	-0.04	0.89	0.39	0.11	0.35	0.35	0.06	0.89	0.23	0.59	0.38	0.36

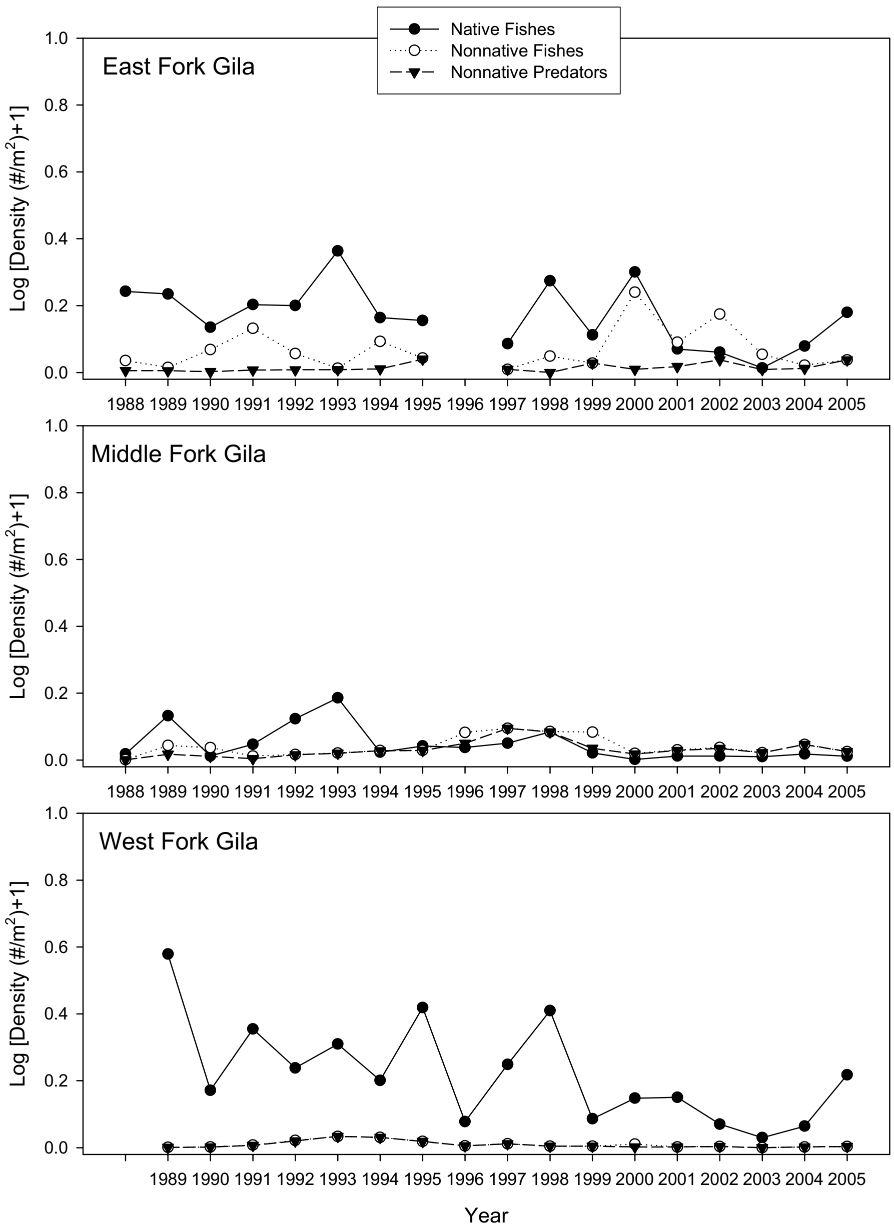


Figure 15. Density of native fishes, nonnative fishes, and nonnative predators at permanent sites in the Forks of the Gila River.

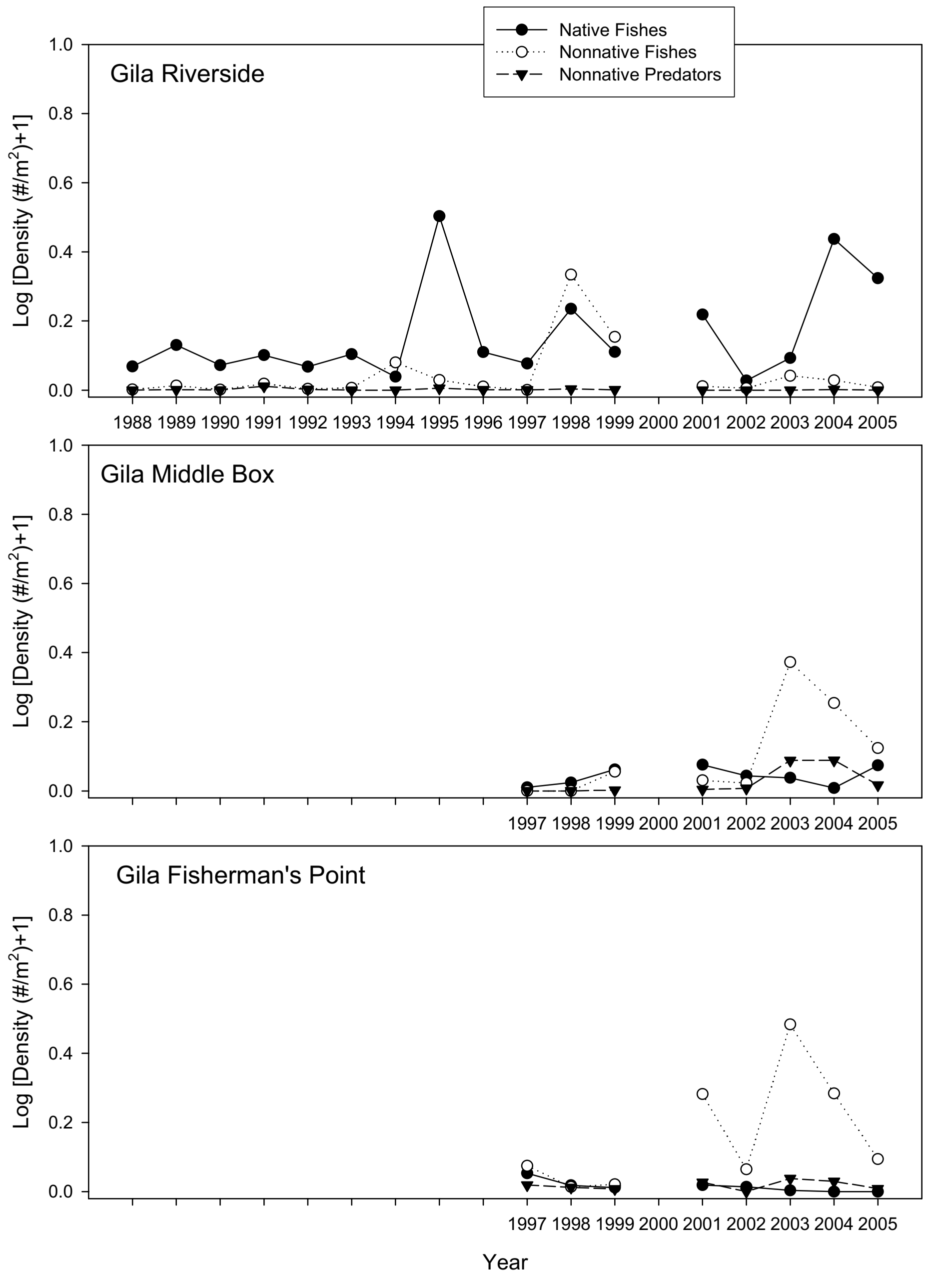


Figure 16. Density of native fishes, nonnative fishes, and nonnative predators at permanent sites in the mainstem of the Gila River.

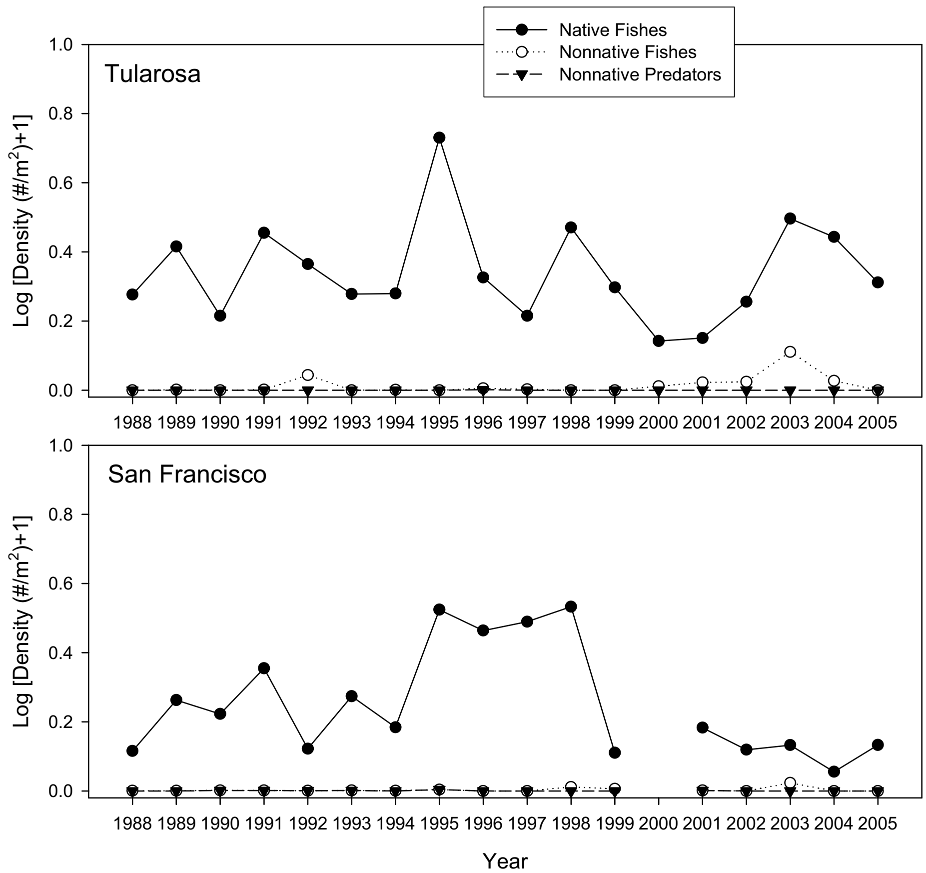


Figure 17. Density of native fishes, nonnative fishes, and nonnative predators in the San Francisco drainage permanent sites.

Species richness of native fishes ranged from six to two at the East Fork site (Figure 18). Native species richness peaked at seven at Middle Fork and West Fork but the Middle Fork site dropped to only one native species in 2000 and 2004, while the West Fork site was never fewer than two native species. Diversity of native species also declined in the Middle Fork, starting in 1996. Nonnative richness and diversity was variable, the highest richness of six species occurring in 1992 in the West Fork.

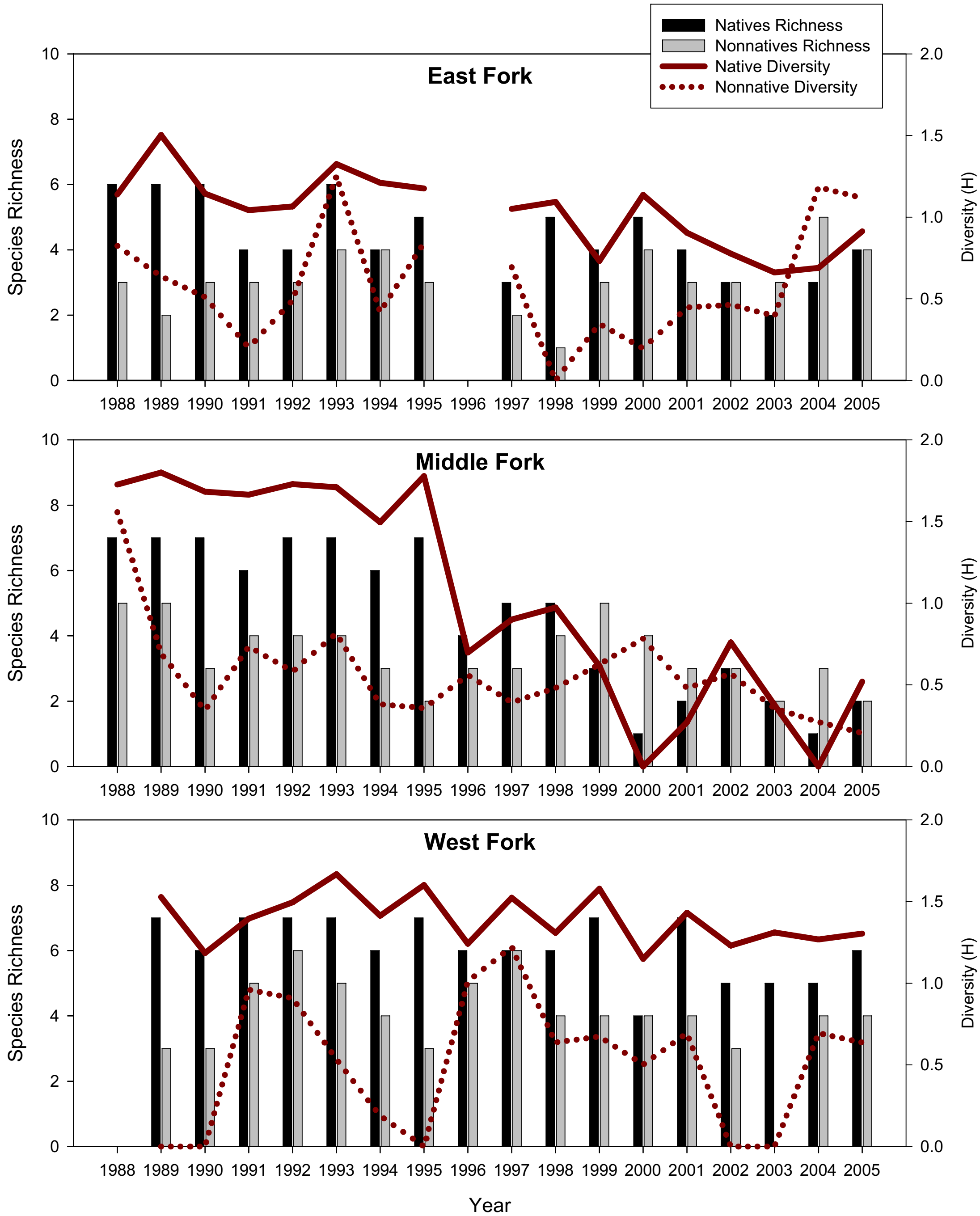


Figure 18. Species richness and diversity (H) for native and nonnative species at permanent sites in the forks of the Gila River.

Native diversity and richness remained relatively stable at the Gila Riverside site, richness ranging from four to six species (Figure 19). The number of nonnative species varied from one to six species. At the Middle Box site, native richness varied from three to five species, native diversity was lower in 2004 and 2005 than previous years. Nonnative richness varied from zero (1997 through 1998) to five (2001 and 2003) at the Middle Box permanent site; three to five nonnative species were collected in recent sampling efforts (2001 through 2005). Three native species were collected at the Fisherman's Point site in 1997, 1999, 2001-2002; zero in 2004-2005. Nonnative richness and diversity was variable at Fisherman's Point, ranging from two to five species.

Diversity and richness of native species remained relatively constant at both the San Francisco and Tularosa sites (Figure 20). In most years five native fishes were present at both sites. Native species richness was four from 2003 through 2005 at the Tularosa site when loach minnow was absent. Nonnative richness and diversity has been low at both San Francisco drainage sites, ranging from zero to three species in the San Francisco, zero to two in the Tularosa.

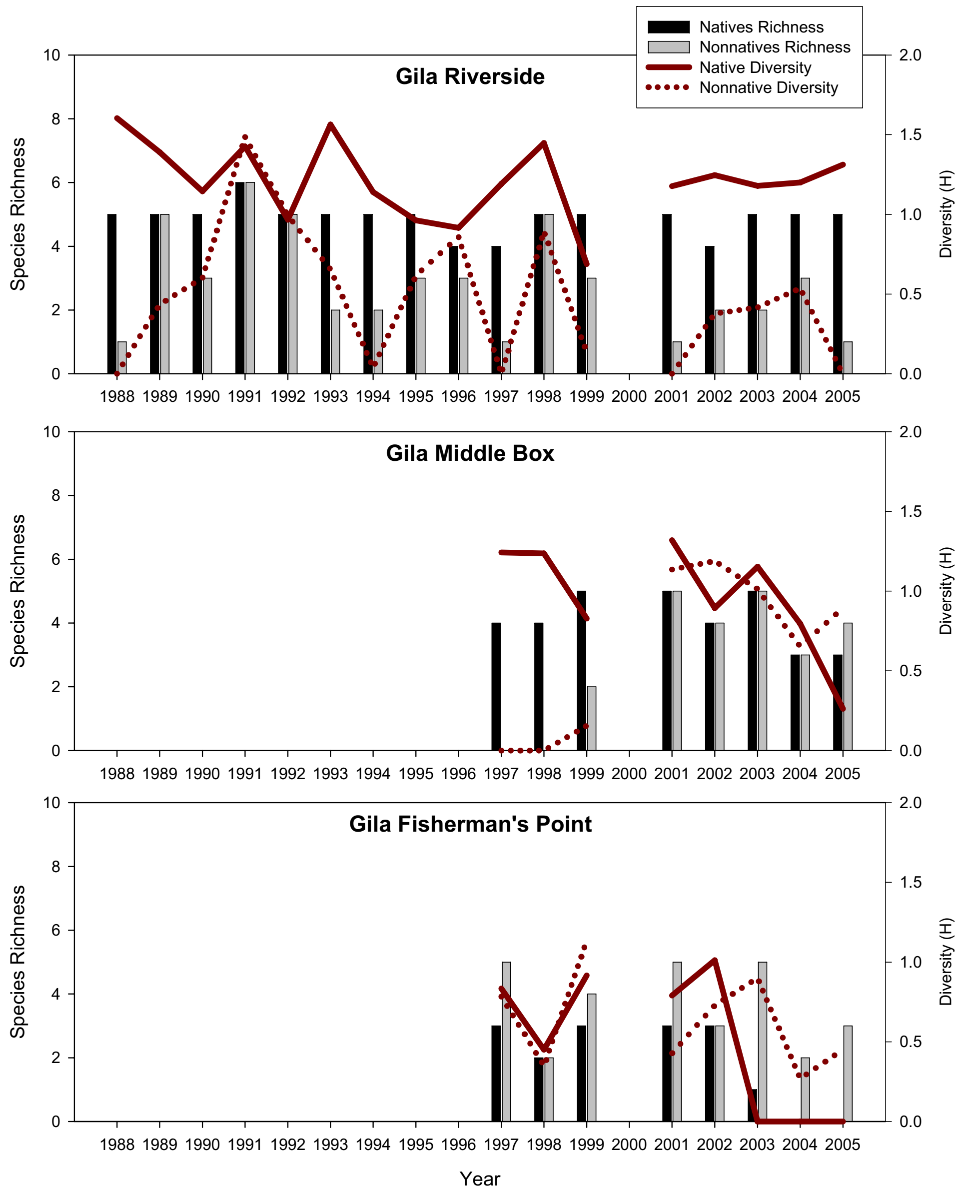


Figure 19. Species richness and diversity (H) for native and nonnative species at permanent sites in the mainstem of the Gila River.

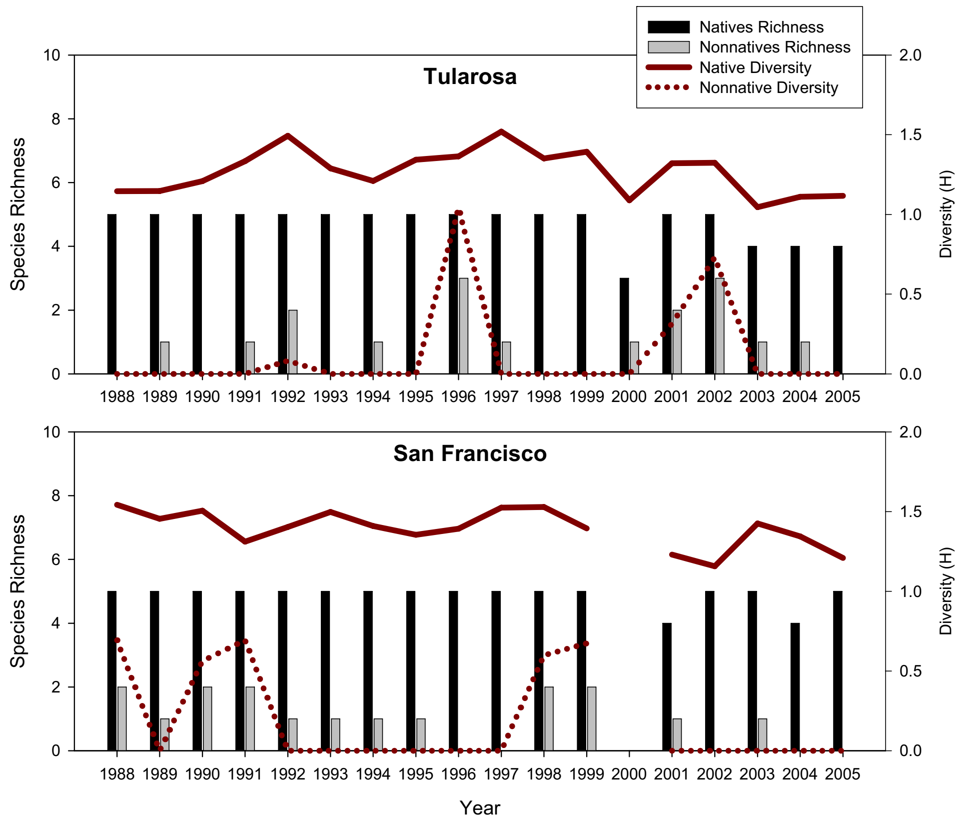


Figure 20. Species richness and diversity (H) for native and nonnative species at permanent sites in the San Francisco drainage.

Native fish density at Gila sites was generally positively correlated with mean annual daily discharge (Table 4). Significant relationships existed for density of native fishes in the Middle Fork with mean annual, winter, and spring daily discharge, East Fork native densities correlated with mean annual and winter daily discharge. Fisherman's point native fish densities were positively related to fall discharge. Nonnative fish densities were generally negatively correlated with discharge (Table 5); the noted exception was the West Fork where a significant positive relationship with mean annual and winter daily discharge occurred. There was a positive relationship with native fish densities at the East and Middle Forks sites and winter precipitation totals (Table 6). While the only relationship that was evident for precipitation and nonnative fish density was in the West Fork where nonnative density was positively correlated with winter precipitation (Table 7).

Table 4. Results of regression analysis of density of native fishes at permanent sites versus seasonal mean daily discharge. Asterisk (*) indicates significance p<0.05.

Native Fishes	Yearly Average		Winter (Dec-Feb)		Spring (March-May)		Summer (June-August)		Fall (Sep-Nov)	
	R	*p*	R	*p*	R	*p*	R	*p*	R	*p*
East Fork	0.56*	0.02	0.48*	0.05	0.37	0.15	0.25	0.33	0.17	0.52
Middle Fork	0.53*	0.02	0.51*	0.03	0.53*	0.02	0.09	0.74	-0.20	0.43
West Fork	0.28	0.29	0.24	0.35	0.26	0.31	0.19	0.47	-0.10	0.71
Gila Riverside	0.13	0.63	0.31	0.23	0.09	0.73	-0.23	0.38	-0.41	0.10
Gila Middle Box	0.16	0.71	0.46	0.25	-0.29	0.49	0.20	0.64	-0.41	0.32
Gila Fisherman's Point	0.09	0.83	-0.27	0.51	0.10	0.81	0.37	0.36	0.94*	0.00
Tularosa	0.04	0.86	0.11	0.65	-0.01	0.97	-0.16	0.53	-0.40	0.10
San Francisco	-0.04	0.89	0.02	0.95	0.06	0.82	-0.33	0.20	-0.22	0.39

Table 5. Results of regression analysis of density of nonnative fishes in permanent site samples versus seasonal discharge means. Asterisk (*) indicates significance p<0.05.

Nonnative Fishes	Yearly Average		Winter (Dec-Feb)		Spring (March-May)		Summer (June-August)		Fall (Sep-Nov)	
	R	*p*	R	*p*	R	*p*	R	*p*	R	*p*
East Fork	-0.32	0.22	-0.30	0.25	-0.23	0.37	-0.22	0.39	0.12	0.65
Middle Fork	-0.34	0.17	-0.34	0.17	-0.19	0.45	-0.20	0.43	0.04	0.89
West Fork	0.58*	0.01	0.52*	0.03	0.35	0.17	0.14	0.59	0.31	0.23
Gila Riverside	-0.09	0.73	-0.17	0.52	0.19	0.46	-0.04	0.89	-0.17	0.52
Gila Middle Box	-0.28	0.51	-0.07	0.87	-0.20	0.63	-0.54	0.17	-0.38	0.36
Gila Fisherman's Point	-0.42	0.30	-0.24	0.57	-0.25	0.54	-0.55	0.16	-0.30	0.47
Tularosa	-0.23	0.35	-0.23	0.35	-0.10	0.68	-0.13	0.61	-0.29	0.24
San Francisco	-0.23	0.38	-0.20	0.43	-0.18	0.49	-0.04	0.86	-0.17	0.51

Table 6. Results of regression analysis of density of native fishes in permanent site samples versus seasonal precipitation totals. Asterisk (*) indicates significance p<0.05.

Native Fishes	Yearly Average		Winter (Dec-Feb)		Spring (March-May)		Summer (June-August)		Fall (Sep-Nov)	
	R	*p*	R	*p*	R	*p*	R	*p*	R	*p*
East Fork	0.42	0.09	0.51*	0.04	-0.09	0.72	0.30	0.24	0.02	0.95
Middle Fork	0.45	0.06	0.71*	0.00	0.11	0.67	0.15	0.56	-0.11	0.68
West Fork	0.22	0.41	0.31	0.22	-0.14	0.58	0.15	0.58	0.04	0.89
Gila Riverside	-0.23	0.37	0.06	0.83	0.08	0.75	-0.03	0.92	-0.49	0.05
Gila Middle Box	-0.23	0.58	0.23	0.53	-0.63	0.10	0.08	0.86	-0.27	0.56
Gila Fisherman's Point	0.56	0.15	0.14	0.73	0.11	0.79	0.23	0.59	0.71	0.08
Tularosa	-0.20	0.43	0.17	0.50	0.02	0.95	-0.22	0.37	-0.32	0.21
San Francisco	0.03	0.90	0.11	0.69	-0.43	0.08	-0.00	0.99	0.26	0.32

Table 7. Results of regression analysis of density of nonnative fishes in permanent site samples versus seasonal precipitation totals. Asterisk (*) indicates significance p<0.05.

Nonnative Fishes	Yearly Average		Winter (Dec-Feb)		Spring (March-May)		Summer (June-August)		Fall (Sep-Nov)	
	R	*p*	R	*p*	R	*p*	R	*p*	R	*p*
East Fork	-0.27	0.30	-0.35	0.17	0.08	0.76	-0.27	0.29	0.23	0.39
Middle Fork	0.30	0.22	-0.27	0.27	-0.06	0.81	0.34	0.16	0.39	0.13
West Fork	0.28	0.28	0.53*	0.03	0.11	0.67	0.05	0.85	-0.16	0.56
Gila Riverside	0.24	0.35	-0.06	0.83	0.09	0.73	0.33	0.19	-0.08	0.78
Gila Middle Box	-0.60	0.12	-0.29	0.49	0.27	0.53	-0.54	0.17	-0.42	0.35
Gila Fisherman's Point	-0.54	0.16	-0.22	0.61	0.29	0.49	-0.54	0.16	-0.45	0.31
Tularosa	-0.28	0.27	-0.08	0.76	0.34	0.17	-0.38	0.12	-0.29	0.26
San Francisco	-0.20	0.44	-0.15	0.56	0.05	0.84	-0.24	0.34	-0.03	0.93

Rare Species

Rare species, including headwater chub, spikedace, and loach minnow, were collected from at least one site each year (Figures 21 & 22). Roundtail chub was only collected once between 1988 and 2005; one specimen was found at Riverside in 1991. Loach minnow has not been collected at a forks site since 2001. Spikedace has been absent in collections from East Fork Gila, Middle

Fork Gila, and Fishermen's Point sites for the past five years. Loach minnow was the only rare species present in the San Francisco drainage (Figure 23). Its density at the San Francisco River site was variable, but always at least 0.2/m^2. Loach minnow has not been collected at the Tularosa site since 2002.

Regression analysis of density of rare species over time revealed significant declines in headwater chub at the East Fork Gila River site (Table 8). Density of spikedace at all Gila Forks sites showed a significant negative relationship with time. Additionally, loach minnow densities significantly decreased in the Middle Fork, West Fork, and Tularosa collections. Density of rare fishes at other sites did not change over time.

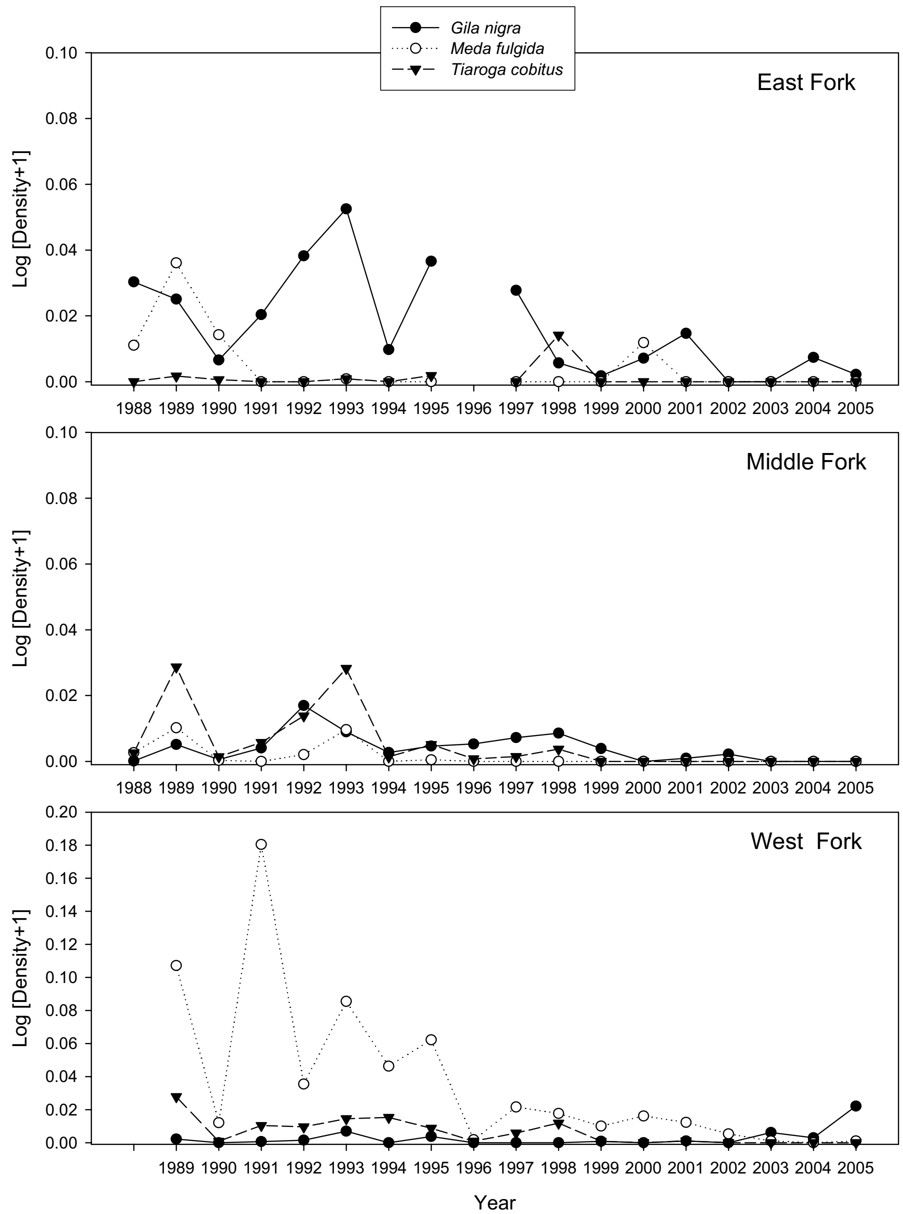


Figure 21. Densities of rare fish species at permanent sites in the Forks of the Gila River. Note difference in scale.

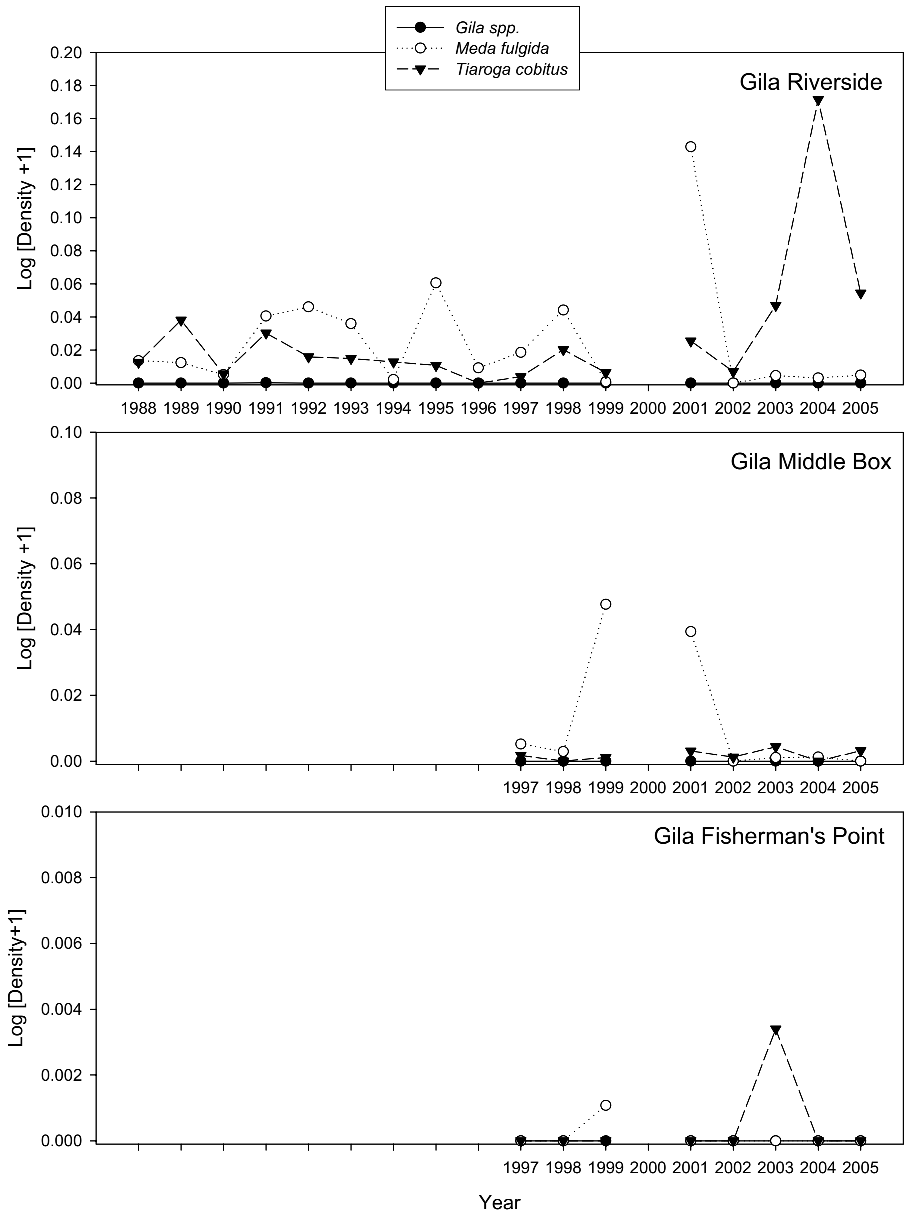


Figure 22. Densities of rare fish species at permanent sites in the mainstem of the Gila River. Note difference in scale.

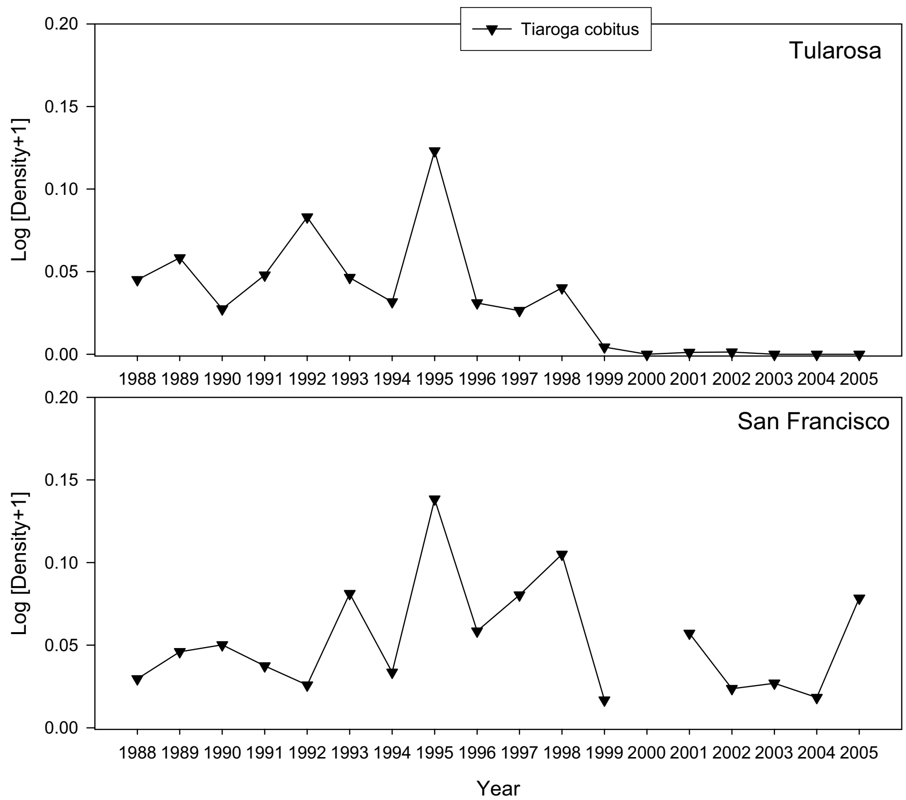


Figure 23. Densities of rare fish species at permanent sites in the San Francisco drainage.

Table 8. Regression results of time series versus fish density of rare species in permanent sites samples. *indicates significance (p<0.05)

	Gila nigra		*Meda fulgida*		*Tiaroga cobitis*	
	r	p	r	p	r	p
East Fork Gila	-0.61*	0.01	-0.50*	0.04	0.00	0.99
Middle Fork Gila	-0.37	0.14	-0.50*	0.03	-0.53*	0.02
West Fork Gila	0.40	0.11	-0.65*	0.01	-0.69*	0.00
Gila Riverside			0.03	0.91	0.45	0.07
Gila Middle Box			-0.33	0.43	0.36	0.38
Gila Fisherman's Point			-0.30	0.48	0.26	0.53
San Francisco					-0.01	0.95
Tularosa					-0.62*	0.01

Other Native Species

In addition to rare species, four other native fish species (longfin dace, speckled dace, desert sucker, and Sonora sucker) were collected in the Gila River forks; abundance of each was variable among sites. Speckled dace was only collected at the East Fork Gila site in 1988, 2001, and 2002 (Figure 24). Densities of Sonora sucker generally decreased at the East Fork Gila site through 2005 (Table 9). Longfin dace was absent from the East Fork Gila site four of the last five years.

Longfin dace was not collected in the Middle Fork Gila River in any of the past five years and speckled dace was last sampled at the Middle Fork site in 1998. Densities of Sonora sucker were at least three times as great as density of desert sucker in Middle Fork Gila River each year since 1996. Desert sucker was not collected in 2000, 2001, or 2004. Densities of longfin dace and speckled dace were both negatively correlated with time in Middle and West forks Gila River (Table 9).

All commonly collected native fishes, except desert sucker, had negative trends at the West Fork site. The average density of speckled dace the first five years of the study (1989-1993) was 0.40 fish/m^2, while density of speckled dace in the last five years (2001-2005) averaged 0.05 fish/m^2 at the West Fork site. Sonora sucker densities averaged 0.56 fish/m^2 from 1989 through 1993 and 0.13 fish/m^2 from 2001-2005. Longfin dace densities averaged 0.13 fish/m^2 and 0.03 fish/m^2, respectively. Longfin dace was collected at the West Fork Gila site every year except 2003; desert sucker was not collected in 2000.

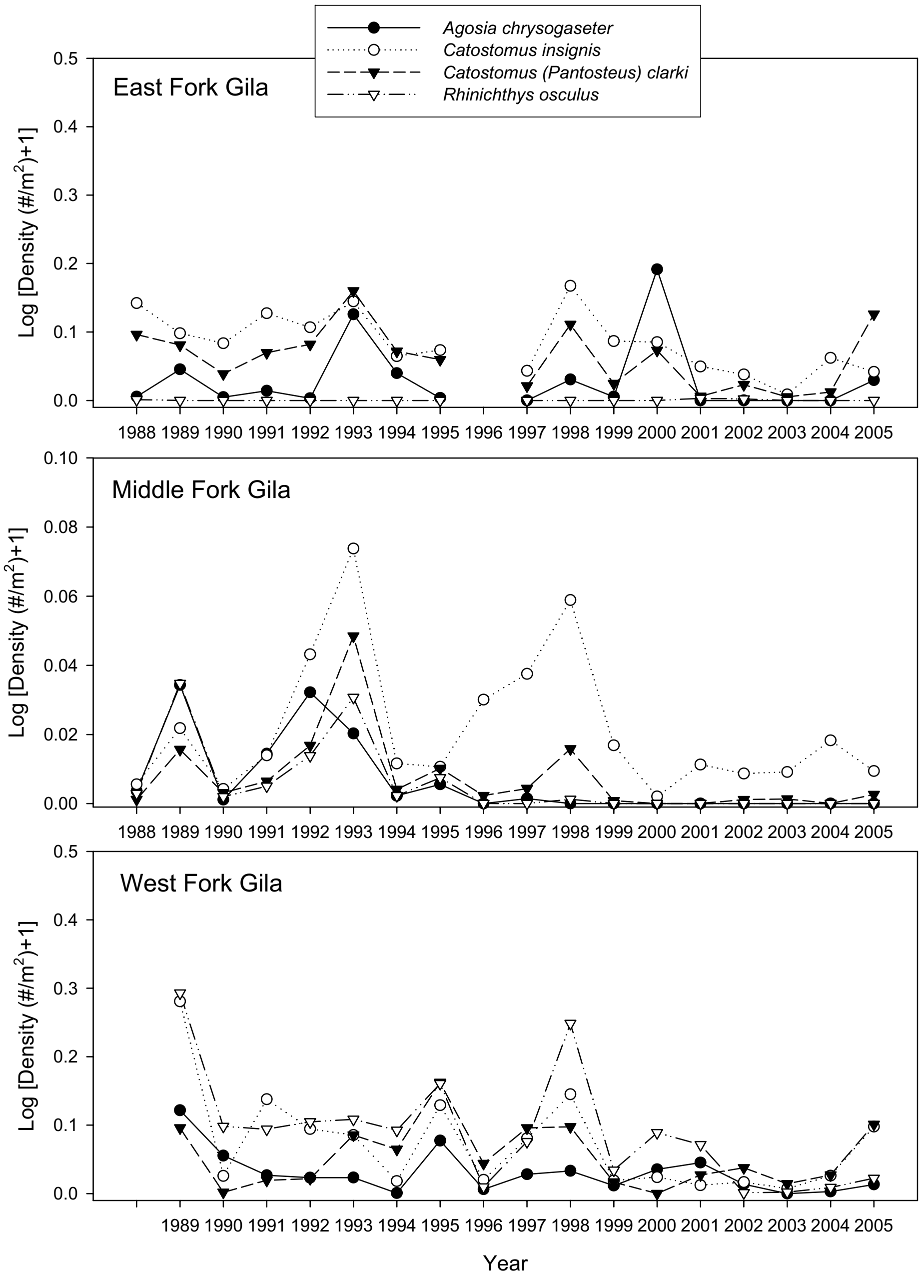


Figure 24. Densities of regularly collected native fish species at permanent sites in the Forks of the Gila River. Note change in scale.

At the Gila Riverside site, three common native species were present every year, except 1997 when longfin dace was absent (Figure 25). Longfin dace at Riverside was the only native species that had a positive trend, over time, in density. Density of neither desert nor Sonora sucker changed with time at the Riverside site (Table 9). Densities of native fishes at Middle Box site were variable, but each common species was present each year, except longfin dace, which was absent in 1997 and Sonora sucker, which was absent in 2004 and 2005. No native has been collected at Gila Fisherman's Point site since 2002.

Table 9. Regression results of time versus fish density of regularly collected native species at permanent sites samples in Gila-San Francisco River drainage, New Mexico. *indicates significance ($p<0.05$).

	Agosia chrysogaster		*Catostomus insignis*		*Catostomus (Pantosteus) clarki*		*Rhinichthys osculus*	
	r	p	r	p	r	p	r	p
East Fork Gila	0.00	1.00	-0.61*	0.01	-0.34	0.18	0.19	0.46
Middle Fork Gila	-0.59*	0.01	-0.16	0.51	-0.36	0.14	-0.53*	0.02
West Fork Gila	-0.53*	0.03	-0.51*	0.04	-0.11	0.67	-0.57*	0.02
Gila Riverside	0.55*	0.02	0.04	0.87	0.30	0.24		
Gila Middle Box	0.69	0.06	-0.34	0.41	-0.05	0.90		
Gila Fisherman's Point	-0.65	0.08	-0.83*	0.01	-0.43	0.28		
San Francisco	-0.26	0.31	-0.14	0.59	-0.14	0.58	-0.03	0.90
Tularosa	-0.06	0.83	-0.01	0.96	-0.12	0.64	0.48	0.05

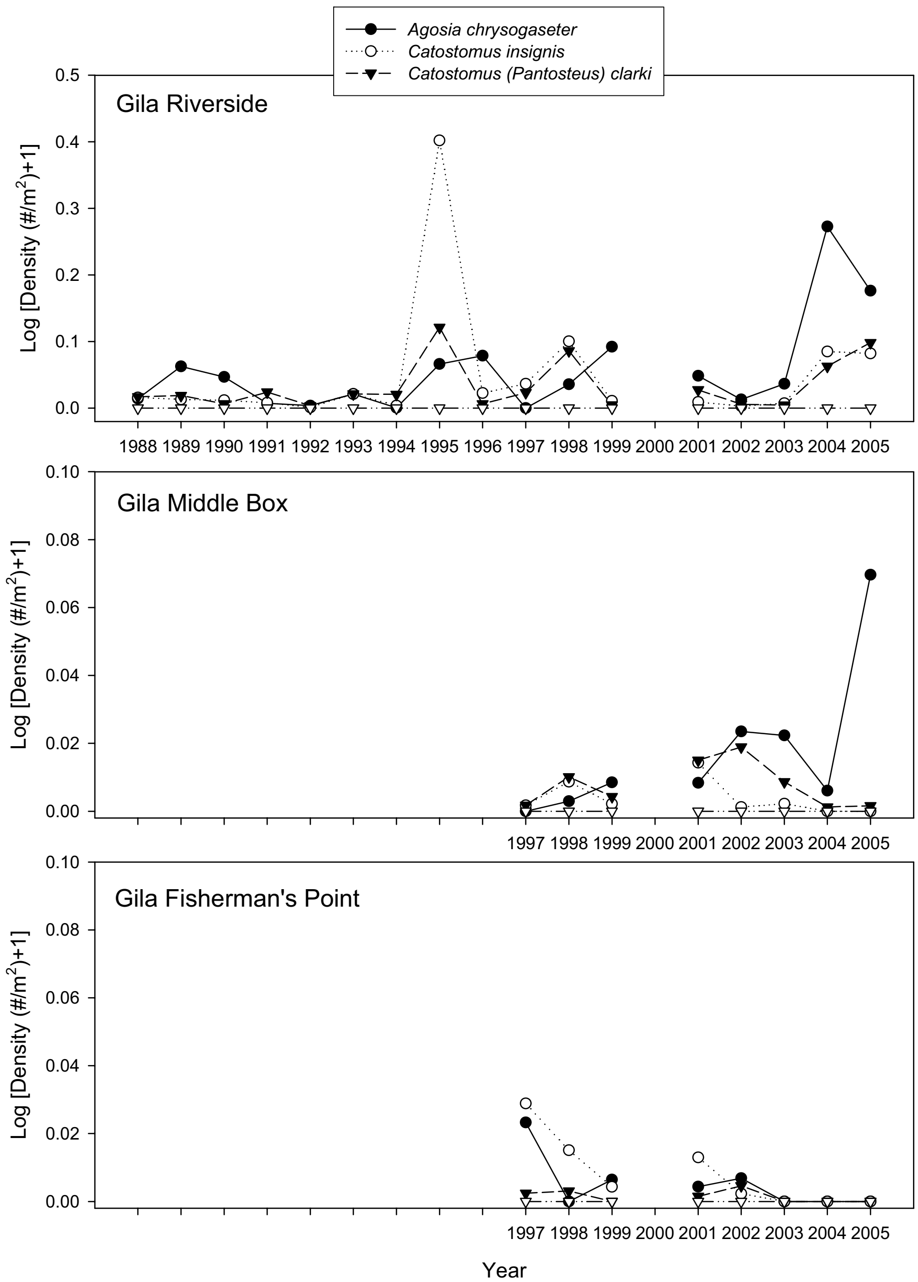


Figure 25. Densities of regularly collected native fish species at sites in the mainstem of the Gila River. Note change in scale.

At the San Francisco site each common native fish species was present each year, except longfin dace in 2001 and 2004 (Figure 26) Desert sucker was not present at the Tularosa site in 2000. Longfin dace was the most commonly collected fish at the Tularosa site in 13 of 18 years. Regression analysis revealed no significant correlation between species density and time at the San Francisco or Tularosa sites.

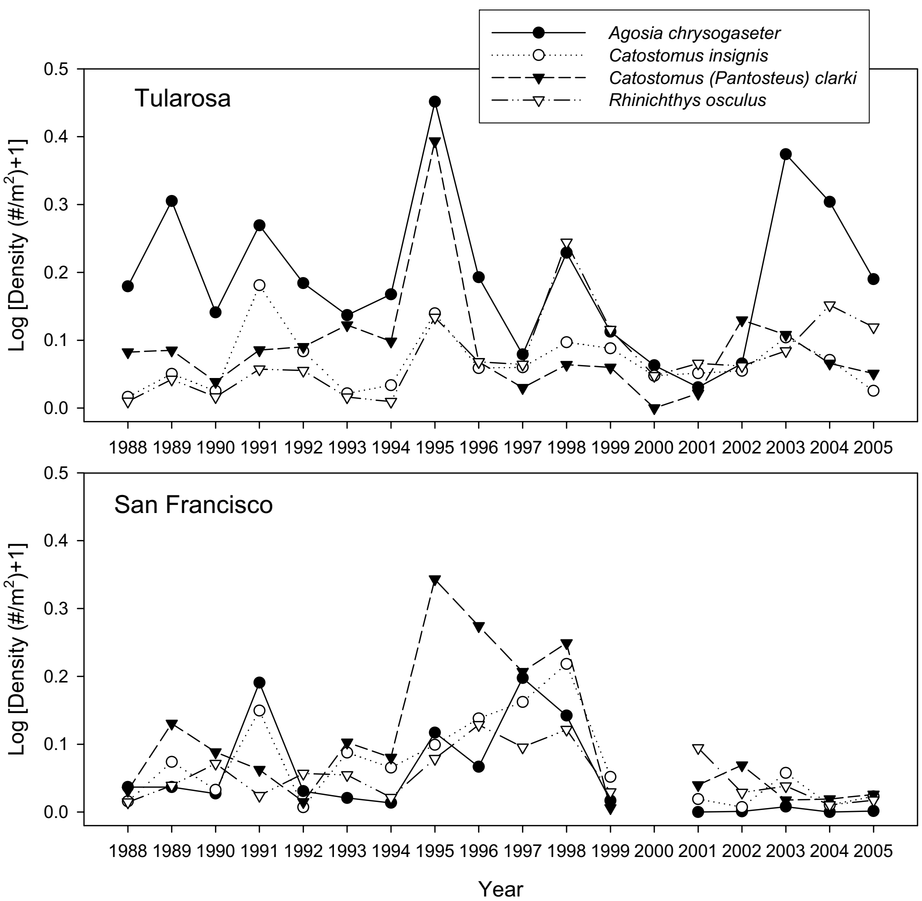


Figure 26. Densities of regularly collected native fish species at sites in the San Francisco Drainage. Note change in scale.

Habitat Use-Native Fishes

Table 10 presents mean depth, velocity and substrate size data for the mesohabitat categories used in our sampling. Backwaters had the slowest water velocity with smallest substrata, while riffles had the fastest water velocities and largest substrata. Pools had the greatest depth and shoals were the shallowest mesohabitat. Overall, more than 30% of the mesohabitats sampled were either run or shore run (Table 11). Riffles comprised the next largest category (17.5%). Pool was a larger proportion of sampled mesohabitats at the Gila River forks sites than at other sites.

Table 10. Mean value of physical features for habitat types (ordered by mean velocity) at Gila-San Francisco drainage permanent study sites.

Habitat		Depth (m)		Velocity (m/s)		Substrate (cat)	
	Number	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
isolated pool	4	0.27	0.12	0.00	0.00	2.00	1.41
embayment	17	0.13	0.06	0.01	0.01	1.76	0.83
backwater	336	0.56	1.00	0.03	0.05	1.93	0.82
pool	2203	0.76	0.57	0.15	0.23	2.45	1.09
pool run	1185	0.58	0.34	0.18	0.14	2.22	0.84
shore run	1094	0.41	0.30	0.20	0.21	2.32	0.91
eddy	179	0.63	0.78	0.24	0.35	2.27	0.95
shoal	213	0.21	0.18	0.30	0.20	2.60	0.85
run	1132	0.33	0.28	0.36	0.21	2.72	0.90
riffle run	1057	0.33	0.30	0.56	0.44	3.10	0.80
mid channel run	106	0.47	0.43	0.61	0.53	2.77	0.94
chute	207	0.43	0.18	0.63	0.22	3.18	0.90
riffle	1301	0.28	0.24	0.73	0.61	3.66	0.66

Table 11. Distribution of habitats sampled at Gila-San Francisco drainage permanent sites.

Habitat	East Fork	Middle Fork	West Fork Gila	Gila Riverside	Gila Middle Box	Gila Fisherman's Point	San Francisco	Tularosa	Grand Total
isolated pool	0.00%	0.00%	0.39%	0.83%	0.00%	0.00%	0.00%	0.44%	0.25%
embayment	0.00%	0.00%	1.56%	0.83%	0.79%	0.97%	0.52%	0.00%	0.55%
backwater	4.66%	3.67%	3.11%	7.85%	4.72%	4.85%	5.18%	2.62%	4.53%
pool	13.56%	22.45%	12.45%	6.61%	4.72%	4.85%	11.92%	7.86%	11.15%
pool run	9.32%	5.71%	7.00%	2.07%	1.57%	2.91%	9.84%	7.86%	6.19%
shore run	14.41%	8.98%	17.12%	18.60%	19.69%	38.83%	16.58%	3.93%	15.38%
eddy	6.78%	3.67%	5.06%	5.79%	8.66%	5.83%	1.04%	0.00%	4.35%
shoal	6.36%	1.63%	2.72%	11.98%	14.17%	16.50%	0.52%	1.75%	5.82%
run	15.25%	19.59%	19.07%	15.70%	8.66%	3.88%	15.03%	34.93%	18.08%
riffle run	10.17%	10.20%	9.73%	8.68%	3.94%	0.97%	11.40%	19.65%	10.29%
mid channel run	1.69%	4.08%	1.17%	4.96%	11.81%	4.85%	2.07%	0.44%	3.31%
chute	2.54%	0.41%	0.78%	3.31%	3.15%	5.83%	3.63%	0.87%	2.21%
riffle	15.25%	19.59%	19.84%	12.81%	18.11%	9.71%	22.28%	19.65%	17.59%

The highest percentage of native fishes was collected in shore run and riffle habitats (Table 12). Very few were collected in mid-channel run and shoal habitats. Loach minnow was collected most commonly in riffle habitat and headwater chub was most frequently found in slower-velocity pool and pool-run areas. Spikedace was typically found in shoal and run habitats. Nonnative fishes were most commonly collected in backwaters and shore run habitats (Table 13). Flathead catfish was the only nonnative species most commonly collected in swift riffle habitats. Both bass species and bullhead catfishes were collected most often in pool habitats.

Table 12. Distribution of native fishes among various habitat types. Acronyms refer to the first three letters of genus and species names for each species (see table 1).

Habitat	AGOCHR	CATINS	GILNIG	MEDFUL	PANCLA	RHIOSC	TIACOB	All Native Fishes
isolated pool	0%	0%	0%	0%	0%	0%	0%	0%
embayment	0%	0%	0%	0%	0%	0%	0%	0%
backwater	11%	9%	7%	1%	4%	1%	0%	6%
pool	6%	27%	41%	1%	8%	4%	0%	11%
pool run	5%	12%	25%	1%	7%	4%	0%	6%
shore run	10%	18%	7%	15%	13%	13%	2%	12%
eddy	5%	2%	3%	7%	1%	0%	0%	3%
shoal	2%	1%	0%	21%	1%	1%	0%	2%
run	30%	22%	8%	42%	19%	25%	8%	24%
riffle run	15%	5%	3%	6%	17%	20%	16%	13%
mid channel run	0%	0%	0%	1%	0%	0%	0%	0%
chute	0%	1%	5%	0%	2%	1%	0%	1%
riffle	14%	3%	1%	4%	28%	32%	72%	21%

Table 13. Distribution of commonly collected nonnative fishes among various habitat types. Acronyms refer to the first three letters of genus and species names for each species (see table 1).

Habitat	AMENAT	CYPLUT	GAMAFF	ICTPUN	MICDOL	MICSAL	ONCMYK	PIMPRO	PYLOLI	SALTRU	All Nonnative Fishes
isolated pool	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
embayment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
backwater	6%	1%	46%	0%	1%	2%	0%	35%	4%	6%	22%
pool	44%	1%	8%	6%	53%	77%	53%	15%	9%	22%	14%
pool run	15%	1%	1%	2%	22%	8%	28%	1%	4%	34%	5%
shore run	12%	27%	22%	36%	8%	2%	1%	11%	30%	6%	21%
eddy	1%	25%	7%	7%	1%	0%	0%	2%	0%	0%	11%
shoal	0%	21%	7%	16%	0%	0%	0%	21%	0%	0%	11%
run	12%	4%	6%	13%	6%	10%	3%	12%	4%	3%	6%
riffle run	4%	3%	2%	1%	4%	0%	7%	2%	9%	9%	3%
mid channel run	2%	2%	0%	11%	0%	0%	0%	1%	0%	0%	1%
chute	0%	13%	0%	1%	0%	0%	2%	0%	4%	0%	4%
riffle	4%	1%	0%	7%	4%	0%	6%	0%	35%	19%	2%

Of the seven native fish species collected at Gila-San Francisco drainage permanent sites, only Sonora sucker, desert sucker and headwater chub attain total lengths exceeding 250 mm (= large-bodied fishes). Other native Gila basin fishes (longfin dace, spikedace, speckled dace, and loach minnow rarely exceed 100 mm as adults (= small-bodied fishes). Large-bodied fishes were divided into two groups: 0-150 mm and >150 mm individuals.

Nearly 60% of the large Sonora sucker and headwater chub collected were found in pool habitats. Smaller individuals of both species were found in a variety of mesohabitats. Small-bodied Sonora suckers were most commonly found in run, pool, backwater, and pool run habitats while small individuals of headwater chub were most frequently collected in pool and pool-run habitats. Large individuals of desert sucker were most often found in pool, pool-run, riffle, and riffle-run areas. The highest percentage of small desert sucker individuals was found in areas with faster flows, namely riffle, riffle-run, and run habitats.

Significant differences were found between mean depths of habitats occupied by small and large individuals of Sonora sucker (t_{2004}= -12.7, p<0.005), desert sucker (t_{1846}= -13.3, p<0.005), and headwater chub (t_{367}= 3.4, p<0.005) (Table 14). Additionally, water velocities of mesohabitats were swifter where larger fish were more common, significantly so for Sonora sucker (t_{2004}= -2.8, p=0.005) and headwater chub (t_{367}= -2.4, p=0.016). Sonora sucker (t_{2004}= -8.1, p<0.005) and headwater chub (t_{367}= -6.3, p<0.005) larger than 150 mm were more common in areas with greater substrate size than were smaller individuals. The substrate in mesohabitats where larger desert suckers were found were smaller than the substrate in the mesohabitats where small desert suckers were found (t_{1846}= 2.7, p=0.007).

Table 14. Mean value of habitat features for those mesohabitats containing native species.

		Depth (m)		Velocity (m/s)		Substrate (cat)	
<150 mm	Number	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
AGOCHR	539	0.26	0.18	0.36	0.38	2.64	0.96
CATINS	823	0.47	0.33	0.19	0.21	2.18	0.80
GILNIG	179	0.55	0.45	0.12	0.14	1.78	0.91
MEDFUL	222	0.24	0.24	0.34	0.23	2.78	0.83
PANCLA	983	0.35	0.30	0.49	0.49	3.00	0.95
RHIOSC	448	0.30	0.23	0.39	0.32	3.02	0.95
TIACOB	292	0.27	0.22	0.60	0.43	3.34	0.80

		Depth (m)		Velocity (m/s)		Substrate (cat)	
>150 mm	Number	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
CATINS	1183	0.69	0.43	0.23	0.31	2.51	1.02
GILNIG	190	0.71	0.47	0.16	0.17	2.43	1.06
PANCLA	865	0.58	0.41	0.51	0.59	2.88	0.98

Figure 27 illustrates that both large-bodied and small-bodied headwater chub occupied slower, deeper habitats with finer substrates than either sucker species. Desert sucker was generally collected in shallow habitats with faster water velocity and larger substrate than Sonora sucker. Separate single factor ANOVA analysis revealed significant differences in depth, velocity, and substrate sizes for large and small fish groupings ($f_{2,2000+}$>45.0, p<0.05 for all six analyses) among habitats where Sonora sucker, desert sucker, and headwater chub were collected.

Among the four small-bodied species, single factor ANOVA did not detect significant differences in depth of habitats where they were found, but water velocity and substrate occupied did vary among the four species ($f_{3,1500+}$ >34.0,

$p<0.001$). Loach minnow was collected where larger substrate and faster water velocities were present (Figure 28). Longfin dace and spikedace were sampled in similar water velocities, but substrate sizes were finer in the habitats where longfin dace was found. Speckled dace was found in habitats intermediate in velocity and substrate size as compared to loach minnow, longfin dace, and spikedace.

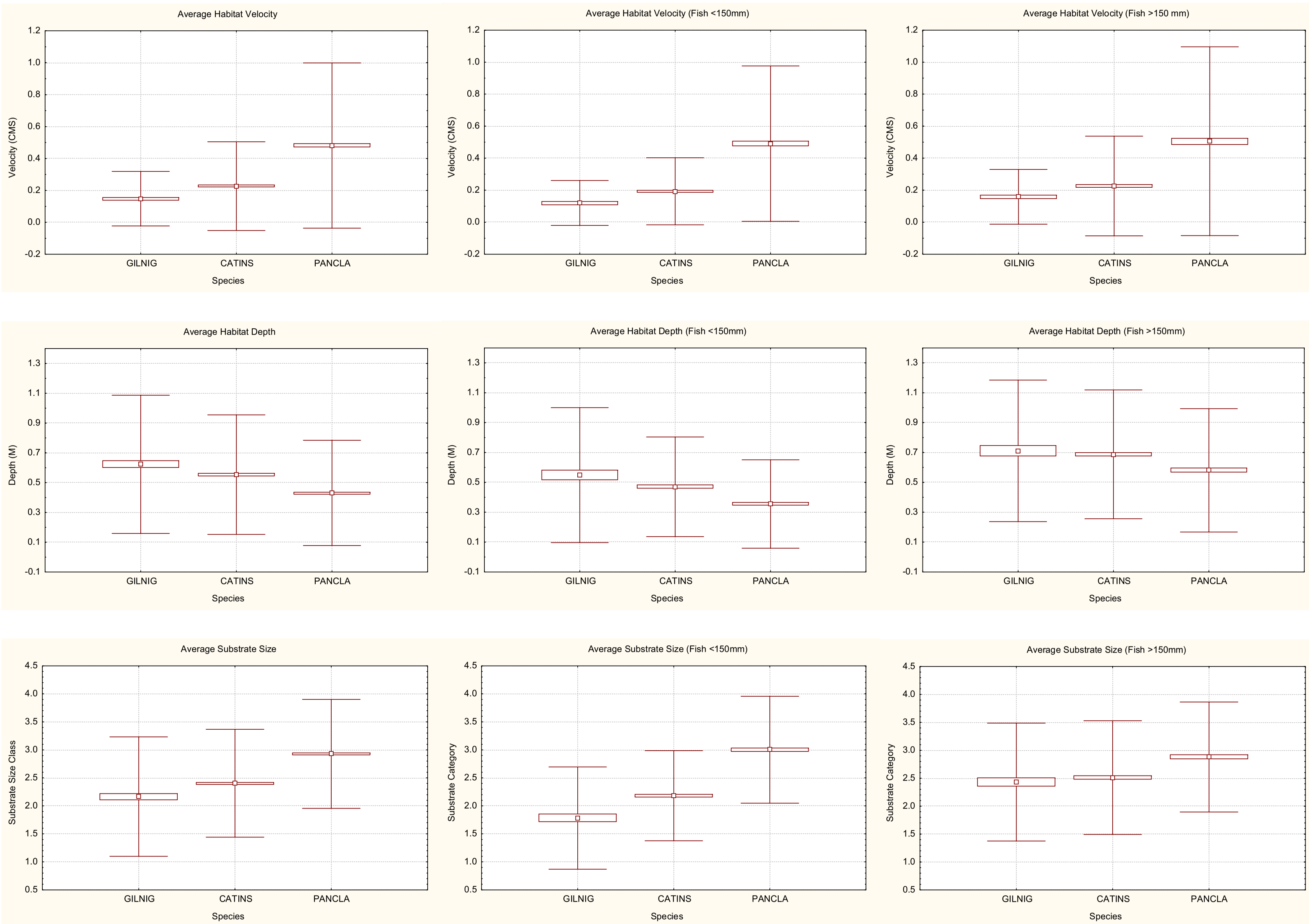


Figure 27. Average depth, velocity, and substrate category for habitats containing headwater chub (GILNIG), Sonora sucker (CATINS), and desert sucker (PANCLA). Points=means, boxes=standard error, and bars=standard deviation.

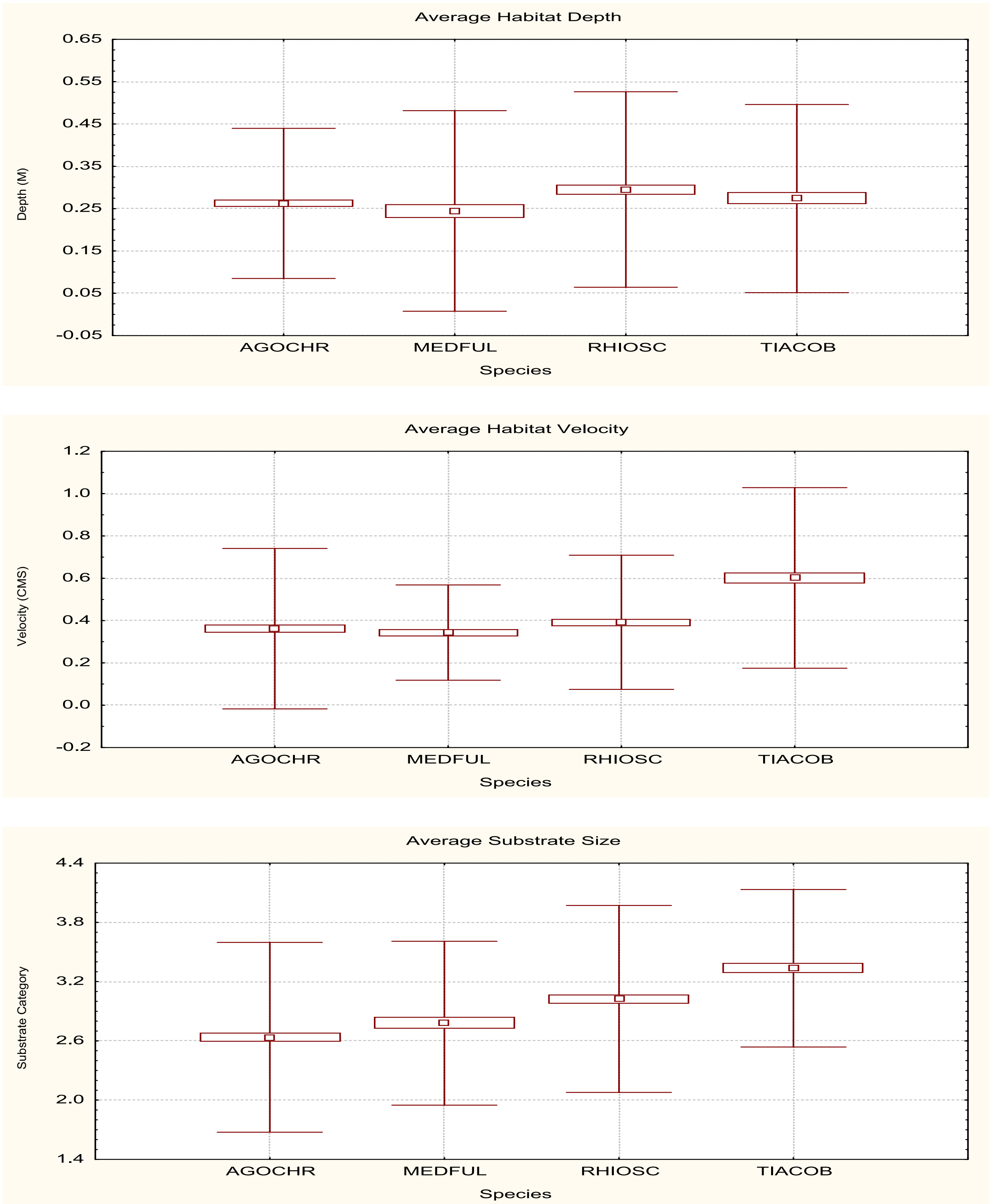


Figure 28. Average depth, velocity, and substrate category for habitats containing longfin dace (AGOCHR), spikedace (MEDFUL), speckled dace (RHIOSC) and loach minnow (TIACOB). Points=means, boxes=standard error, and bars=standard deviation.

SUMMARY

During the 18 years of study, there were notable changes in several attributes of fish assemblages at the Gila-San Francisco drainage permanent sites. Several factors likely caused these perceived changes. One factor may be that average annual discharge in the Gila and San Francisco rivers during the latter portion of the study (1997 through 2004) was about half the discharge for the first nine years (1988-1996). Discharge was greater in 2005 than during 1997 through 2004. From 1989 through 2004, a number of wildfires cumulatively burned much of the uplands portion of the watershed. As a consequence, most permanently-watered streams in the Gila watershed experienced ash flows and elevated sediment loads.

All native fish species collected at the beginning of the study, except roundtail chub, were still present in 2005. However, several species have not been collected for several years at sites where they were formerly present, and sometimes common. Densities of nonnative species increased at all sites, except West Fork Gila River. At the West Fork Gila River site, densities of both native and nonnative species decreased, which might be a result of ash flow events from the multitude of wild fires in the upper watershed.

Loach minnow was never abundant at Gila River forks sites, and has not been collected at any forks site for four years. Abundance of loach minnow also diminished at the Tularosa River site. Loach minnow has, however, remained comparatively abundant at the Gila Riverside and San Francisco sites. It was usually present in low numbers, at the Gila River Middle Box site, but was found only once at the Gila River Fisherman's Point site. Spikedace has not been collected at the East Fork Gila River, Middle Fork Gila River, or mainstem Gila River Fisherman's Point sites since 2000. Spikedace was collected at the West Fork Gila River site in 2005, but its density was much lower than in earlier portions of the study. It was found in most years at the Gila River Riverside site, occasionally in comparatively high numbers (particularly 2001). Headwater chub was usually found at Middle and East forks Gila River sites, but was irregularly collected at the West Fork Gila River site.

Speckled dace has been absent from the East Fork Gila River and Middle Fork Gila River sites since the late 1990s. It was most regularly found and common at the Tularosa River and San Francisco River Glenwood sites. Speckled dace, apparently, was historically absent in the mainstem Gila River downstream of the forks area, and none was collected at any mainstem site during this study. Longfin dace has not been found at the Middle Fork Gila River site since 1997, and is sporadically present at the East Fork Gila River site. Elsewhere in the drainage, it was comparatively common in most years. Desert sucker and Sonora sucker were collected at the forks sites in most years, but densities declined at all forks sites over the past 10 years. Both suckers were relatively common at the San Francisco River Glenwood and Tularosa River sites. In one year of eight sampled, a sucker species was the most abundant native fish at the Gila River Middle Box and Fisherman's Point sites. No native fish has been collected at Gila River Fisherman's Point site since 2003; nonnative channel catfish and red shiner comprised the majority of fishes found.

At most study sites, nonnative fish density and diversity were low in any particular year. The Middle Fork Gila River and Gila River Fisherman's Point sites were exceptions, particularly in nonnative fish densities. At each, nonnative fish density was higher than native fish density in each year since 1995 and 1997, respectively.

At the East Fork Gila River site, habitat diversity and quality was moderately high, but native fish density and diversity was variable, and generally declining over the past 10 years. Nonnative fishes were not abundant at this site, but those present were piscivores. Smallmouth bass was usually present at the East Fork Gila River site.

At the Middle Fork Gila River site, habitat diversity and quality is high, but native fish density and diversity has plummeted in past 10 years. Currently nonnative piscivores numerically dominate the fish assemblage at this site. Smallmouth bass was usually the most common nonnative fish at the Middle Fork Gila River site, but bullhead catfishes were also comparatively common.

Although nonnative fishes irregularly occurred at West Fork Gila River site and habitat diversity was high, native fish density declined in past 10 years. This is likely a consequence of diminished habitat quality resulting from ash flows and elevated sediment loads caused by extensive burning of the watershed. Rainbow trout are the most common nonnative sampled in recent West Fork surveys.

Despite comparatively low diversity and moderately degraded habitat, the Gila River Riverside site supported relatively high densities of native fishes during the first 8 to 10 years of this study. Densities of most native fishes have declined since the late 1990s, but these declines have been punctuated with abundance spikes.

The Gila River Middle Box site was moderately degraded but habitat diversity was fairly high. Nonnative fishes were mainly red shiner and fathead minnow. The native fish assemblage was diverse (5 of 6 possible species usually present), but abundance of each was comparatively low. Nonnative densities have exceeded that of native fishes for the last three years.

The Gila River Fisherman's Point site had low habitat diversity and nonnative fishes were moderately common. Native fishes were typically rare at the site, none being collected since 2003. Red shiner and channel catfish were normally the most common species at the Gila River Fisherman's Point site.

In most years, density of native fishes was comparatively high at Tularosa and San Francisco permanent sites. Nonnative fishes were rare or absent at both sites in all years, habitat diversity was comparatively high (particularly at the San Francisco site), and habitats generally unmodified by human activity. There were flood events of over 500 cfs in both August and September in 1999, as well as October 2000. This corresponded with decreased numbers of loach minnow in the Tularosa. Flows are normally at their lowest in the summer and fall on the San Francisco. However, the highest recorded daily discharges was in February 1993 (1360 cfs) and November 1994 (1510 cfs), which were followed with the greatest densities of loach minnow in the San Francisco and Tularosa samples in 1995.

Density of individual native species varied from year-to-year at each site, and a general decline in density of each was noted at most sites, particularly since late 1990s. Most notable is the absence or greatly diminished density of loach minnow and spikedace at several sites of regular occurrence early in the study. Although no native species present in the Gila-San Francisco drainage in New Mexico at initiation of this study has been extirpated, no site currently contains the numerically strong populations that were present in the past. Several factors likely have independently or in combination negatively affected native fish populations. These include extended drought, nonnative fishes (especially nonnative predators), wildfire and associated ash flows, scouring floods and flood control structures (e.g., levees that constrain and concentrate hydrologic energy), channel dewatering, and elevated sediment loads. Among sites, nonnative fishes were irregularly collected at most, but several species (e.g., smallmouth bass and yellow bullhead) were consistently present at several sites (e.g., East Fork and Middle Fork Gila River sites). Relative abundance of nonnative species compared to native species is highly variable. Some native species, such as longfin dace, are short-lived and experience large fluctuations in abundance from year to year, as do some nonnative species, such as red shiner. Generally, nonnative large-bodied predators with relatively long life spans, whose population numbers do not fluctuate greatly from year to year, might have far greater impacts than their numbers or relative abundance would imply. The trends in native fish densities we documented do not bode well for the future of these species, which have also become increasingly rare throughout their native ranges.

ACKNOWLEDGEMENTS

Annual field work was accomplished by funding from Sport Fish Restoration Grant FW-17 and grants from the U.S. Bureau of Land Management. This long term compilation and analysis was funded by the U.S. Bureau of Reclamation via the Central Arizona Project Biological Opinion. There are numerous individuals who assisted in data collection and include Amber Hobbes, Stephanie Carman, Jim Brooks, John Pittenger, Bill Brittan, Mark Whitney, Jerry Monzingo, Johnny Zapata, Art Telles, Sally Stefferud, Heidi Blasius, Tim Frey, Jeff Whitney, Bill Merhege, Beth Martinez, Chris Pease, Hugh Bishop, and Russell Ward. Administrative support was provided by Paul Barrett and Rob Clarkson. The comments and suggestions of Rob Clarkson are appreciated. Cover illustrations by W. Howard Brandenburg.

REFERENCES

Carman, S. 2006 (Draft), Headwater Chub (*Gila nigra)* listing investigation report. Conservation Services Division, New Mexico Department of Game and Fish. Santa Fe, New Mexico.

Minckley, W. L. and B. D. DeMarais. 2000. Taxonomy of chubs (Teleostei, Cyprinidae, Genus *Gila*) in the American Southwest with comments on conservation. *Copea:* 251-256.

Nelson, J. S. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico – Sixth Edition. American Fisheries Society, Special Publication 29. Bethesda, Maryland.

Appendix 1 –
Species Densities at Individual Sites

East Fork Gila Species

Table A1. Densities of fishes collected at East Fork Gila site.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	0.749	0.718	0.366	0.596	0.585	1.310	0.459	0.431		0.220	0.881	0.295	0.998	0.176	0.150	0.032	0.199	0.513	0.556
Nonnatives	0.085	0.035	0.171	0.356	0.139	0.030	0.239	0.105		0.022	0.119	0.067	0.737	0.231	0.494	0.132	0.051	0.090	0.172
AGOCHR	0.013	0.110	0.011	0.033	0.007	0.336	0.096	0.008			0.073	0.012	0.554					0.070	0.077
AMEMEL									NO COLLECTION			0.004							0.000
AMENAT												0.029		0.007	0.009	0.004	0.006		0.002
CATINS	0.387	0.253	0.212	0.341	0.279	0.396	0.161	0.184		0.104	0.470	0.221	0.216	0.121	0.091	0.020	0.154	0.101	0.238
GAMAFF	0.059	0.023	0.145	0.339	0.120	0.008	0.215	0.008			0.119		0.710	0.189	0.403	0.112	0.023		0.141
GILNIG	0.072	0.059	0.015	0.048	0.092	0.129	0.023	0.088		0.066	0.013	0.004	0.017	0.034			0.017	0.005	0.044
ICTPUN	0.013	0.012																	0.002
ICTSPP			0.006	0.015	0.009	0.012	0.014	0.029					0.006				0.011	0.030	0.008
LEPCYA																	0.006	0.005	0.000
MEDFUL	0.026	0.087	0.033			0.002							0.028						0.017
MICDOL				0.002	0.009	0.008	0.009	0.067		0.011		0.033	0.017	0.034	0.082	0.016	0.006	0.045	0.014
MICSAL							0.002			0.011								0.010	0.001
PANCLA	0.248	0.204	0.093	0.174	0.208	0.445	0.180	0.147		0.049	0.291	0.058	0.183	0.014	0.054	0.012	0.028	0.337	0.175
PIMPRO	0.013		0.021			0.002							0.006						0.004
RHIOSC	0.003													0.007	0.005				0.001
TIACOB		0.004	0.001			0.002		0.004			0.033								0.002

Middle Fork

Table A2. Densities of fishes collected at Middle Fork Gila site.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	0.043	0.357	0.029	0.115	0.330	0.535	0.056	0.102	0.091	0.124	0.214	0.050	0.005	0.028	0.028	0.024	0.043	0.028	0.132
Nonnatives	0.003	0.106	0.089	0.028	0.039	0.049	0.068	0.069	0.210	0.244	0.216	0.212	0.047	0.072	0.091	0.051	0.113	0.060	0.066
AGOCHR	0.008	0.082	0.003	0.034	0.077	0.048	0.005	0.013		0.003									0.023
AMEMEL	0.001							0.050				0.041							0.004
AMENAT	0.001	0.026	0.023	0.004	0.027	0.021	0.056		0.107	0.187	0.140	0.011	0.028	0.055	0.043	0.027	0.023	0.014	0.026
CATINS	0.013	0.051	0.010	0.033	0.104	0.185	0.027	0.025	0.072	0.090	0.145	0.040	0.005	0.026	0.020	0.021	0.043	0.022	0.045
GAMAFF		0.065	0.064	0.017	0.002		0.002		0.087		0.003	0.128	0.005	0.004	0.008				0.020
GILNIG	0.000	0.012	0.001	0.009	0.040	0.021	0.006	0.011	0.012	0.017	0.020	0.009		0.002	0.005				0.010
LEPCYA					0.001					0.003							0.002		0.000
MEDFUL	0.006	0.024	0.001		0.005	0.022		0.001											0.004
MICDOL	0.001	0.009	0.003	0.005	0.009	0.013	0.009	0.019	0.016	0.053	0.071	0.031	0.009	0.013	0.040	0.024	0.088	0.046	0.014
ONCMYK		0.005				0.013					0.003	0.002	0.005						0.001
PANCLA	0.003	0.037	0.007	0.015	0.039	0.118	0.009	0.024	0.005	0.010	0.037	0.002			0.003	0.003		0.006	0.018
PIMPRO	0.001			0.001		0.001													0.000
RHIOSC	0.007	0.083	0.005	0.012	0.032	0.073	0.005	0.017			0.003								0.016
SALTRU	0.000	0.001																	0.000
TIACOB	0.006	0.068	0.003	0.013	0.032	0.067	0.003	0.012	0.002	0.003	0.009								0.015

Table A3. Densities of fishes collected at West Fork Gila site.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	2.791	0.484	1.264	0.732	1.041	0.589	1.624	0.196	0.773	1.568	0.219	0.406	0.414	0.176	0.071	0.160	0.652	0.720
Nonnatives	0.003	0.004	0.018	0.050	0.080	0.073	0.044	0.012	0.027	0.010	0.010	0.024	0.005	0.007		0.005	0.007	0.023
AGOCHR	0.323	0.136	0.063	0.055	0.055	0.002	0.195	0.014	0.067	0.079	0.027	0.085	0.109	0.032		0.007	0.031	0.077
AMENAT								0.002	0.003									0.000
CATINS	0.908	0.061	0.373	0.242	0.217	0.043	0.346	0.047	0.204	0.396	0.045	0.057	0.029	0.039	0.017	0.062	0.252	0.178
GAMAFF			0.003	0.004								0.019						0.001
GILNIG	0.005		0.002	0.004	0.016		0.009				0.002		0.002		0.014	0.007	0.052	0.003
MEDFUL	0.280	0.028	0.515	0.085	0.217	0.112	0.154	0.004	0.051	0.041	0.023	0.038	0.029	0.012	0.002		0.002	0.097
MICDOL			0.005	0.005	0.002				0.005							0.002	0.005	0.002
ONCMYK	0.003	0.004	0.011	0.036	0.066	0.070	0.044	0.006	0.013	0.003	0.004		0.002			0.002		0.017
PANCLA	0.247	0.004	0.045	0.051	0.217	0.160	0.453	0.106	0.247	0.252	0.039		0.064	0.090	0.033	0.064	0.262	0.109
RHIOSC	0.962	0.253	0.242	0.273	0.283	0.237	0.447	0.022	0.190	0.772	0.081	0.227	0.178	0.002	0.005	0.021	0.052	0.238
SALTRU				0.005	0.012	0.003		0.004	0.005	0.007	0.006	0.005	0.002	0.007			0.002	0.003
TIACOB	0.066	0.002	0.024	0.022	0.034	0.036	0.020	0.002	0.013	0.028	0.002		0.002					0.014

Gila Riverside

Table A4. Densities of fishes collected at Gila Riverside site.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	0.171	0.350	0.181	0.262	0.168	0.271	0.093	2.185	0.288	0.194	0.719	0.289		0.654	0.066	0.239	1.736	1.107	0.321
Nonnatives	0.004	0.030	0.003	0.043	0.008	0.015	0.203	0.070	0.023	0.002	1.157	0.425		0.026	0.013	0.100	0.067	0.019	0.064
AGOCHR	0.033	0.155	0.114	0.017	0.009	0.050	0.001	0.165	0.198		0.086	0.236		0.118	0.031	0.087	0.873	0.501	0.097
AMEMEL				0.003				0.012											0.001
AMENAT					0.000				0.002	0.002	0.005		N						0.000
CATINS	0.037	0.030	0.027	0.018	0.003	0.050	0.009	1.524	0.053	0.087	0.260	0.026	O	0.021	0.006	0.017	0.216	0.208	0.070
CYPCAR				0.008			0.001						C						0.001
CYPLUT			0.000			0.010		0.002	0.006		0.412	0.009	O		0.011	0.015	0.007		0.011
GAMAFF	0.004	0.027	0.002	0.008	0.004	0.006	0.201	0.055	0.015		0.660	0.414	L	0.026	0.002	0.085	0.057	0.019	0.046
GILROB				0.000									L						0.000
ICTPUN		0.001											E C						0.000
LEPCYA		0.000		0.003									T						0.000
MEDFUL	0.032	0.029	0.012	0.098	0.112	0.086	0.005	0.150	0.021	0.044	0.107	0.002	I	0.390		0.010	0.007	0.011	0.056
MICDOL		0.001		0.001	0.003							0.002	O				0.004		0.001
MICSAL			0.000	0.019	0.000								N						0.002
PANCLA	0.040	0.045	0.015	0.057	0.008	0.050	0.048	0.322	0.015	0.054	0.219	0.011		0.065	0.013	0.010	0.156	0.254	0.049
PIMPRO											0.079								0.002
PYLOLI		0.000			0.000						0.002								0.000
TIACOB	0.030	0.092	0.013	0.072	0.037	0.035	0.030	0.025		0.009	0.048	0.015		0.060	0.016	0.114	0.484	0.134	0.049

Gila Middle Box

Table A5. Densities of fishes collected at Gila Middle Box site.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	0.024	0.057	0.153	N	0.190	0.106	0.090	0.020	0.185	0.112
Nonnatives			0.136	O	0.072	0.053	1.357	0.795	0.330	0.354
AGOCHR		0.007	0.020		0.019	0.056	0.053	0.014	0.174	0.039
CATINS	0.004	0.020	0.005	C	0.033	0.003	0.005			0.011
CYPLUT			0.131	O	0.032	0.011	0.902	0.561	0.228	0.240
GAMAFF				L	0.030	0.025	0.121			0.025
ICTPUN			0.005	L E	0.007	0.014	0.216	0.226	0.029	0.064
MEDFUL	0.012	0.007	0.116	C	0.095		0.003	0.003		0.037
PANCLA	0.004	0.024	0.010	T	0.035	0.044	0.020	0.003	0.004	0.020
PIMPRO				I	0.002		0.111	0.008	0.062	0.022
PYLOLI				O	0.002	0.003	0.008		0.011	0.003
TIACOB	0.004		0.002	N	0.007	0.003	0.010		0.007	0.004

Gila Fisherman's Point

Table A6. Densities of fishes collected at Gila Fisherman's Point site.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	0.129	0.042	0.027		0.044	0.032	0.008			0.043
Nonnatives	0.187	0.032	0.050	N	0.915	0.159	2.045	0.923	0.242	0.515
AGOCHR	0.055		0.015	O	0.010	0.016				0.015
AMENAT	0.003									0.000
CATINS	0.069	0.035	0.010	C	0.030	0.005				0.023
CYPCAR		0.004		O						0.000
CYPLUT	0.140		0.027	L	0.821	0.032	1.235	0.853	0.212	0.370
GAMAFF	0.003		0.005	L	0.024	0.117	0.684			0.097
ICTPUN	0.033	0.028	0.012	E C	0.061		0.075	0.070	0.020	0.036
MEDFUL			0.002	T						0.000
PANCLA	0.005	0.007		I	0.003	0.011				0.003
PIMPRO				O	0.007	0.011	0.035		0.010	0.007
PYLOLI	0.008		0.005	N	0.003		0.016			0.005
TIACOB							0.008			0.001

San Francisco Ranger Station

Table A7. Densities of fishes collected at San Francisco site.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	0.305	0.831	0.670	1.264	0.325	0.878	0.528	2.343	1.909	2.087	2.412	0.290	NO COLLECTION	0.524	0.316	0.357	0.136	0.358	0.773
Nonnatives	0.001	0.001	0.004	0.003	0.002	0.003	0.002	0.009			0.027	0.014		0.003		0.055			0.004
AGOCHR	0.088	0.089	0.064	0.551	0.073	0.049	0.032	0.309	0.166	0.576	0.387	0.039			0.002	0.018		0.003	0.130
CATINS	0.037	0.186	0.078	0.411	0.016	0.223	0.162	0.256	0.374	0.453	0.653	0.127		0.045	0.017	0.142	0.024	0.055	0.160
GAMAFF	0.001		0.001				0.002				0.008	0.008				0.055			0.002
MICSAL				0.001		0.003													0.000
ONCMYK			0.003	0.001	0.002			0.009						0.003					0.001
PANCLA	0.075	0.351	0.226	0.154	0.035	0.267	0.203	1.205	0.881	0.610	0.775	0.014		0.096	0.172	0.041	0.045	0.061	0.248
PIMPRO	0.001	0.001									0.019	0.006							0.001
RHIOSC	0.034	0.094	0.179	0.057	0.139	0.134	0.050	0.199	0.344	0.246	0.323	0.070		0.243	0.069	0.092	0.024	0.041	0.120
TIACOB	0.071	0.112	0.123	0.090	0.061	0.206	0.080	0.375	0.144	0.203	0.273	0.039		0.141	0.056	0.064	0.043	0.198	0.114

Tularosa, Eagle Peak Road

Table A8. Densities of species collected at Tularosa Eagle Peak Road site.

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Native	0.891	1.604	0.640	1.852	1.317	0.896	0.903	4.371	1.118	0.641	1.954	0.984	0.387	0.415	0.802	2.134	1.773	1.049	1.210
Nonnatives		0.003		0.003	0.105		0.002		0.012	0.006			0.027	0.053	0.056	0.290	0.064		0.029
AGOCHR	0.511	1.019	0.384	0.859	0.528	0.370	0.471	1.830	0.559	0.199	0.694	0.295	0.156	0.073	0.163	1.366	1.014	0.549	0.580
CATINS	0.038	0.123	0.059	0.517	0.212	0.051	0.081	0.379	0.145	0.148	0.250	0.225	0.116	0.126	0.135	0.271	0.177	0.060	0.164
CULINC															0.003				0.000
GAMAFF		0.003		0.003	0.104		0.002		0.003				0.027	0.048	0.013	0.290	0.064		0.026
ONCMYK									0.003										0.000
PANCLA	0.209	0.216	0.093	0.217	0.231	0.325	0.254	1.474	0.170	0.071	0.158	0.148		0.050	0.348	0.282	0.164	0.124	0.226
PIMPRO					0.002				0.006	0.006				0.005	0.041				0.003
RHIOSC	0.023	0.102	0.038	0.141	0.135	0.038	0.022	0.360	0.170	0.160	0.755	0.305	0.116	0.163	0.153	0.214	0.418	0.316	0.151
TIACOB	0.109	0.144	0.065	0.117	0.211	0.113	0.076	0.328	0.074	0.063	0.097	0.010		0.003	0.003				0.089