

**STATUS OF FEDERAL AND STATE LISTED WARM WATER FISHES
OF THE GILA RIVER BASIN,
WITH RECOMMENDATIONS FOR MANAGEMENT**

**Desert Fishes Team
Report Number 1**

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EXECUTIVE SUMMARY

Purpose: This report reviews the status of the twelve federal and state listed native warm water fishes in the Gila River basin and the post-1967 recovery and conservation actions taken by all agencies, organizations, or parties. The report includes recommendations for future actions for each species.

Organization: A summary for each species is given in the text. Table 1 describes historic range, known extirpations, and remaining populations of each species. Table 2 describes repatriation efforts and their success. Recovery and conservation actions are provided in Table 3. Table 4 contains recommendations for further transplants and repatriations, and recovery and conservation actions. A literature cited section completes the report—it provides examples of supporting documentation, but is not comprehensive.

Conclusions: Six species are extirpated from the basin, five others survive in less than 20% of their original range, and one remains in about 40% of its original range. The distribution and abundance of all listed species extant in the basin has declined since their original listing and the trend is continuing. Few successful recovery and conservation actions have occurred during the 36-year period assessed. Although repatriation has been the primary management effort, it has occurred for only a few of the species, and with limited success.

Recommendations: All of the federally listed species have existing and adequate biologically based recovery plans. However, few recommendations in those plans have been implemented. Additional planning for these species is unnecessary, but the other species need management plans. On-the-ground implementation of plan actions is paramount to conservation and recovery of the species. Existing recovery and conservation strategies and techniques would, if implemented, contribute substantially to stemming the decline of these fishes. Innovative strategies incorporating new knowledge and data are also important. We believe the control and removal of nonnative fishes and other aquatic flora and fauna is the most urgent and overriding need in preventing the continued decline and ultimate extinction of the native fish assemblage of the Basin.

STATUS OF FEDERAL AND STATE LISTED WARM WATER FISHES OF THE GILA RIVER BASIN, WITH RECOMMENDATIONS FOR MANAGEMENT

Like the entire indigenous fish fauna of the American southwest, the native warm water fishes of the Gila River watershed (Basin) in central Arizona and southwest New Mexico, USA, and northern Sonora, Mexico, are critically imperiled. In this report, we assess the status of the twelve federal and state listed, proposed, and/or petitioned warm water species of the Basin¹. Our assessment concludes that the status of all of these species has continued to decline notwithstanding federal and state protection. Conservation and recovery efforts have been limited in number and scope, and of little long-term effectiveness in stemming declines of these species.

Reasons for decline of these species are well documented in published literature and recovery plans. Introduction and spread of nonnative aquatic species continues to be a major factor in displacement of native species. Habitat destruction from a variety of human activities has been an equal and interactive factor. We believe the control and removal of nonnative fish and certain other aquatic flora and fauna is the most urgent and overriding need in preventing the continued decline and ultimate extinction of the native fish assemblage of the Basin.

Following this introduction is a brief summary narrative for each species, which is based upon information detailed in the

¹The Gila River basin has 20 native fish species. In addition to the twelve species considered here, two native trouts are also Federal and State listed. Because they are the only cold water species, and because as game species they have distinctly separate and more active recovery and conservation programs, we chose not to include them in this status report.

accompanying tables. Historic distribution, known extirpated, and remaining extant populations of these species are in Table 1. Accomplishments to date in establishing transplanted or replication populations are in Table 2. Recovery, conservation, and other activities for these twelve species are in Table 3, which also includes recommendations for sites for establishment of replication populations. The list of replication sites is not inclusive and other suitable replication sites likely exist, particularly for some species, such as Gila topminnow. Table 4 includes suggestions and recommendations for additional activities. A literature cited section completes the report—it provides examples of supporting documentation, but is not comprehensive.

These conclusions and recommendations are the culmination of deliberations of the Desert Fishes Team (Team), an independent group of biologists and parties interested in protecting and conserving native fishes of the lower Colorado River basin. The Team was formed to fill the void left by the 2002 disbanding by U.S. Fish and Wildlife Service of its Desert Fishes Recovery Team, and includes biologists and participants from U.S. Forest Service, Bureau of Reclamation, Bureau of Land Management, University of Arizona, Arizona State University, The Nature Conservancy, independent experts, and others².

²This report is the product of the Desert Fishes Team and content or opinion expressed does not necessarily represent views, policies, or official positions of any other entity, including agencies or organizations that may employ Team participants.

The information used in this report was gathered from many sources, including published and other documents, and the collective field and laboratory experience, knowledge, and expertise of participants, including (in alphabetical order): H. Blasius, R. Calamusso, R. Clarkson, K. Fitzsimmons, M. Haberstick, P. Marsh, R. Reinthal, J. Simms, J. Stefferud, S. Stefferud, W. Wall, and others.

We anticipate continuing the status review effort and expanding it to other lower Colorado River basin fishes and updating periodically, as needed. There may be additional limited information in the possession of agencies that was not made available for this effort. The information provided in the text and tables is offered in the hope it will assist the agencies and others in initiating and improving recovery and conservation efforts for these twelve highly imperiled and declining fishes.

Species accounts

***Cyprinodon arcuatus* Santa Cruz (Monkey Spring) pupfish.** This species is extinct. Once locally abundant in the upper Santa Cruz River drainage, the last population perished in 1971.

***Cyprinodon macularius* Desert pupfish.** Historically widespread in the lower Basin, no wild populations of the endangered desert pupfish remain in the Basin. It was transplanted to more than a dozen wild locations, only two of which are still occupied. A recovery plan is available but no recovery actions other than transplants have occurred for this species. We recommend additional transplants to suitable wild sites and implementation of the existing recovery plan. Evaluation of transplants of this species into the Santa Cruz River basin in lieu of the extinct Santa Cruz (Monkey Spring) pupfish is recommended.

***Gila elegans* Bonytail.** The endangered bonytail formerly penetrated far upstream in

main stem rivers of the Basin, but has been absent for many decades. A recovery plan is available but no recovery or conservation activities for bonytail have occurred in the Basin. We recommend implementation of the recovery plan and repatriation of bonytail to selected reaches of the upper Gila River.

***Gila intermedia* Gila chub.** Proposed as an endangered species, Gila chub remains in fewer than 30 small isolated waters throughout the Basin, which represent only about 10-15% of the historical range of the species. Two successful transplants are known. Recent renovations to remove nonnative fish in two streams, with subsequent restocking of Gila chub, have occurred, however wildfire eliminated one of those populations. We recommend replication of a portion of the remaining wild populations into protected waters, expedited federal listing of the species with critical habitat, and development of a biologically based recovery plan.

***Gila nigra* Headwater chub.** A state listed species, and petitioned for federal listing, headwater chub occurs in fewer than 20 wild locations--about 40% of its historical range. The species formerly occupied middle to headwater reaches of middle-size tributary streams in the Verde, Tonto, San Carlos, and upper Gila (New Mexico) drainages. No transplants are documented. Management activities have consisted only of changes in angling regulations. Removal of nonnative fishes from occupied habitats is recommended, as is reestablishment in formerly occupied waters. This species is deserving of protection under the federal Endangered Species Act, and a biologically based recovery plan needs to be prepared.

***Gila robusta* Roundtail chub.** Roundtail chub has been petitioned for federal listing as endangered, is state listed in New Mexico and Arizona, and is designated a sport species in Arizona. The species is extirpated from most main stem rivers of the Basin, and currently resides in fewer than

20 tributary streams, representing less than 20% of its original range. Fish barriers recently constructed on Aravaipa Creek have been the only management action to directly benefit the species. Protective conservation actions such as changes in angling regulations, protective fencing of stream banks and riparian areas, land acquisition, and cancellation or alteration of water development projects has occurred. Nonnative species should be removed from occupied habitats. The species is deserving of protection under the federal Endangered Species Act, and a biologically based recovery plan needs to be prepared.

***Meda fulgida* Spikedace.** Spikedace is federally listed as threatened. Available data justify up-listing the spikedace to federally endangered status, and a petition for up-listing has been found warranted by US Fish and Wildlife Service. Of all the Basin species, spikedace is probably the most vulnerable to extinction at this time. Populations remain in only seven locations (10-15% of original range) from an original distribution throughout the Basin in suitable habitats in low and intermediate streams. There have been no successful transplants or repatriations. A recovery plan is available. The only recovery activity taken to-date is the construction of barriers to nonnative fish invasion in Aravaipa Creek. Several conservation actions have been taken to remove or prevent increased threats to spikedace, most notably exclusion of livestock grazing from some occupied streams and their riparian corridors. We recommend several replication sites and implementing the existing recovery plan.

***Plagopterus argentissimus* Woundfin.** This federally endangered species was historically found in the Salt, Verde, and Gila rivers, but it now is extirpated from the Basin. Although certain waters were designated for stocking as experimental-nonessential, these actions were never implemented. We recommend revocation of the experimental-nonessential rule because its implementation would not assist in

recovery of the species. We advocate transplants and repatriations into appropriate historical habitat with full protection of the Endangered Species Act. Recovery actions prescribed in the recovery plan should be implemented.

***Poeciliopsis occidentalis* Gila topminnow.** Logistically, the endangered Gila topminnow could be the easiest species in the Basin to recover. Once the most abundant fish in the lower Gila River, it has been extirpated from more than 95% of its historical range, and now is restricted to fewer than a dozen small, isolated natural sites. Efforts to reestablish it at about 175 wild locations resulted in about two dozen established populations. Recovery efforts have included barrier construction, nonnative fish removal, land acquisition, habitat restoration and protection, and threat amelioration at several sites. We recommend aggressive re-implementation of the stocking program, and approval and implementation of the revised recovery plan that has been in draft status for several years.

***Ptychocheilus lucius* Colorado squawfish.** The top predator in the Basin, this minnow that could achieve 6 feet in length has been eliminated from the Gila River. An endangered species, the core of its Basin range has been designated experimental-nonessential. Nearly 20 years of extensive repatriation efforts have not resulted in reestablishment of the species. Recovery activities have been limited to stocking and changes in angling regulations, but other recommended actions in the recovery plan have not been implemented. We recommend the experimental-nonessential rule be revoked because its implementation would not assist in recovery of the species. We recommend active incorporation of the Basin into ongoing recovery efforts for the species.

***Tiaroga cobitis* Loach minnow.** Loach minnow is federally listed as threatened. Available data justify up-listing the loach

minnow to federally endangered status, and a petition for up-listing has been found warranted by the US Fish and Wildlife Service. Loach minnow has disappeared from more than 85% of its original range, and now remains in fewer than a dozen locations from an original distribution in suitable habitats in low to high elevation streams throughout the Basin. There have been no successful transplants and repatriations of this species. The only recovery activity taken to date is the construction of barriers to nonnative fish invasion in Aravaipa Creek. Other actions in the recovery plan have not been implemented. Several conservation actions have been taken to remove or prevent increased threats to loach minnow, most notably exclusion of livestock grazing from

some occupied streams and their riparian corridors. We recommend several replication sites and implementing the existing recovery plan.

***Xyrauchen texanus* Razorback sucker.**

Wild populations of the endangered razorback sucker are gone from the Basin where it once was widespread and abundant. No populations have been reestablished, notwithstanding an extensive repatriation program that has spanned more than 20 years and stocked millions of fish. We advocate the development and implementation of innovative recovery strategies, such as those recommended for razorback sucker in the lower Colorado River.

Table 1. Historical distributions, known extirpated populations, and known naturally occupied streams for federal or state listed warm water fishes of the Gila River basin.
 (E=endangered, T=threatened, S=state listed, Ex=Extinct, PE=proposed endangered.
 Parentheticals denote major tributary affiliations, question marks denote uncertain status.)

Table 1 Species	Historical distribution	Known extirpated populations	Known naturally occupied streams (exclusive of restoration sites; see Table 2)
<i>Cyprinodon arcuatus</i> (Ex) Santa Cruz (Monkey Spring) pupfish	-Low elevation streams, springs, cienegas, backwaters, and margins of larger rivers in the Santa Cruz River	-Santa Cruz River -Monkey Spring (Santa Cruz) -Sonoita Creek (Santa Cruz)	-Species is extinct
<i>Cyprinodon macularius</i> (E) Desert pupfish	-Low elevation streams, springs, cienegas, backwaters, and margins of larger rivers in the Gila River basin, including all major tributaries except the Santa Cruz River	-Agua Fria River -Gila River -Hassayampa River -Salt River -San Pedro River -Verde River	-Gila River basin populations extirpated
<i>Gila elegans</i> (E) Bonytail	-Low-intermediate elevation mainstem reaches of the Gila and Salt rivers	-Gila River -Salt River	-Gila River basin populations extirpated
<i>Gila intermedia</i> (PE) Gila chub	-Upper reaches of small-middle sized streams of the Gila River basin, including all major tributaries	-Agua Fria River (Gila) -Queen/Arnett creeks (Gila) -San Simon River (Gila) -Cave Creek/Seven Springs (Salt) -Fish Creek (Salt) -San Pedro River -Binghampton Pond (San Pedro) -Turkey Creek (San Pedro) -Santa Cruz River -Monkey Spring (Santa Cruz) -Big Chino Wash (Verde)	-Indian Creek (Agua Fria) -Little Sycamore Creek (Agua Fria) -Silver Creek (Agua Fria) -Sycamore Creek (Agua Fria) -Bonita Creek (Gila) -Eagle/East Eagle Creek (Gila) -Mineral Creek/Devil's Canyon (Gila) -Turkey Creek, NM (Gila) -San Carlos River -Blue River (San Carlos) -Dix Creek (San Francisco) -Harden Cienega (San Francisco) -San Pedro River, Mexico -Babocomari River (San Pedro) -Hot Springs/Bass Canyon (San Pedro) -Los Fresnos River, Mexico (San Pedro) -O'Donnell Creek (San Pedro) -Post/Freeman canyons (San Pedro) -Redfield Canyon (San Pedro) -Cienega Creek (Santa Cruz) -Empire Gulch (Santa Cruz) -Mattie Canyon (Santa Cruz) -Sabino Canyon (Santa Cruz) -Sheehy Spring (Santa Cruz) -Red Tank Draw (Verde) -Spring Creek (Verde) -Walker Creek (Verde) -Williamson Valley Wash (Verde)

Table 1 Species	Historical distribution	Known extirpated populations	Known naturally occupied streams (exclusive of restoration sites; see Table 2)
<i>Gila nigra</i> (S) Headwater chub	-Middle to headwater reaches of middle-sized tributary streams in the Verde, Tonto, San Carlos, and upper Gila River (NM) tributaries	-Beaver Creek (EF Gila River) -Taylor Creek (EF Gila River) -Christopher Creek (Tonto) -Horton Creek (Tonto) -Sharp Creek (Tonto) -Rye Creek (Tonto) -Dry Beaver Creek (Wet Beaver)	-Gila River, upper -San Carlos River -Ash Creek (San Carlos) -Tonto Creek -Buzzard Roost (Tonto) -Gordon Creek (Tonto) -Gunn Creek (Tonto) -Haigler Creek (Tonto) -Marsh Creek (Tonto) -Rock Creek (Tonto) -Spring Creek (Tonto) -Deadman Creek (Verde) -East Verde River (Verde) -Fossil Creek (Verde) -Webber Creek (Verde) -Wet Bottom Creek (Verde)
<i>Gila robusta</i> (S) Roundtail chub	-Middle-sized to larger streams of the Gila River basin, including all major tributaries except the Santa Cruz River	-Boneyard Creek (EF Black) -Gila River, middle reach (AZ) -Salt River, upper reach -San Francisco River (Gila) -Blue River (San Francisco) -San Pedro River -NF White River (White) ?	-Gila River, upper -Eagle Creek (Gila) -Salt River, lower reach -Salt River Project canals -Black River (Salt) -Canyon Creek (Salt) -Carrizzo Creek (Salt) -Cedar Creek (Salt) -Cherry Creek (Salt) -Cibequ Creek (Salt) -Corduoy Creek (Salt) -Salome Creek (Salt) -White River (Salt) ? -Aravaipa Creek and tributaries (San - Pedro) -Verde River -Fossil Creek (Verde) -Oak Creek (Verde) -West Clear Creek (Verde) -Wet Beaver Creek (Verde)
<i>Meda fulgida</i> (T) Spikedace	-Low-intermediate elevation streams in the Gila River basin, including all major tributaries except the Santa Cruz River	-Agua Fria River -Salt River -San Francisco River -San Pedro River, US and Mexico	-Eagle Creek (Gila) -Gila River, Middle Fork -Gila River, West Fork -Gila River, East Fork -Gila River, middle reach (AZ) -Mangus Creek (Gila) -Aravaipa Creek (San Pedro) -Verde River
<i>Plagopterus argentissimus</i> (E) Woundfin	-Low elevation streams in the Gila River basin, including all major tributaries except the Santa Cruz River	-Gila River -Salt River -Verde River	-Gila River basin populations extirpated

Table 1 Species	Historical distribution	Known extirpated populations	Known naturally occupied streams (exclusive of restoration sites; see Table 2)
<i>Poeciliopsis occidentalis</i> (E) Gila topminnow	-Low-intermediate elevation streams, springs, cienegas, backwaters, and margins of larger rivers in the Gila River basin, including all major tributaries	-Gila River -Ash Creek, North Fork (Gila) -Salt Creek (Gila) -San Simon River (Gila) -San Carlos River (Gila) -Salt River -Tonto Creek (Salt) -Frisco Hot Spring (San - Francisco) -San Pedro River -Arivaca Creek (San Pedro) -Cocio Wash (Santa Cruz) -Potrero Creek (Santa Cruz) -Sabino Canyon (Santa Cruz) -Sheehy Spring (Santa Cruz) -Tanque Verde Creek (Santa - Cruz) -Verde River -Other unnamed waters	-Bylas Springs (Gila) -Santa Cruz River, upper reach (US and Mexico) -Cienega Creek (Santa Cruz) -Cottonwood Spring (Santa Cruz) -Monkey Spring (Santa Cruz) -Sharp Spring (Santa Cruz) -Sonita Creek complex (Santa Cruz) -Redrock Canyon -Fresno Canyon -Coal Mine Canyon -Sonoita Creek
<i>Ptychocheilus lucius</i> (E) Colorado squawfish	-Low-intermediate elevation streams in the Gila River basin, including all major tributaries except the Santa Cruz River	-Gila River -Salt River -San Pedro River -Verde River	-Gila River basin populations extirpated
<i>Tiaroga cobitis</i> (T) Loach minnow	-Low-high elevation streams in the Gila River basin, including all major tributaries except the Santa Cruz River	-Gila River (AZ portion) -Salt River -San Pedro River, US and Mexico -Verde River	-Aravaipa Creek and tributaries (San Pedro) -Black River, North Fork of East Fork (Salt) -Blue River, and tributaries (San Francisco) -Eagle Creek (Gila) -Gila River, Middle Fork -Gila River, West Fork -Gila River, East Fork -San Francisco River and NM tributaries -White River, North Fork (Salt) -White River (Salt) -White River, East Fork (Salt)
<i>Xyrauchen texanus</i> (E) Razorback sucker	-Low-intermediate elevation streams in the Gila River basin, including all major tributaries except the Santa Cruz River	-Gila River -Salt River -San Pedro River -Verde River	-Gila River basin populations extirpated

Table 2. Status of transplant and repatriation activities for federal or state listed warm water fishes of the Gila River basin done by U.S. Fish and Wildlife Service (USFWS), Arizona Game and Fish Department (AZGFD), or New Mexico Department of Game and Fish (NMDGF) since 1967. (Abbreviations as follow: BTA = Pond on Queen Creek, Boyce Thompson Arboretum, Gila Co., AZ; CADFG = California Department of Fish and Game, NFH = USFWS National Fish Hatchery; NWR = USFWS National Wildlife Refuge, SFH = State Fish Hatchery, TNC = The Nature Conservancy. All locations are in Arizona unless specified otherwise.)

Table 2 Species	Successful population establishment	Unsuccessful population establishment
<i>Cyprinodon arcuatus</i> Santa Cruz (Monkey Spring) pupfish		-Conservation-based transplants to ASU Department of Zoology, Maricopa Co., AZGFD ponds in Deer Valley, Maricopa Co., and AZGFD Page Springs SFH, Yavapai Co., in 1969-1971, where the species persisted for a time after extirpation in the wild. The species became extinct when these refugium stocks perished in 1971 by failing to reproduce. No other transplant records are known.
<i>Cyprinodon macularius</i> Desert pupfish	-To Cold Springs Seep, Graham Co., from Flowing Wells Jr. HS, Tucson via BTA, and Dexter NFH (Mexico, Sonora, Santa Clara Slough stock), 1990, presumed extant -To Lousy Canyon, Yavapai Co., from El Doctor, Sonora, Mexico via Cibola and Imperial NWRs, 2001, presumed extant.	-Numerous stockings or reintroductions into more than a dozen wild locations (Minckley and Brooks 1985, Marsh and Sada 1993, Weedman and Young 1997)
<i>Gila elegans</i> Bonytail	-No documentation of any transplant to a wild site within the Gila River basin.	
<i>Gila intermedia</i> Gila chub	-To Larry Creek, Yavapai Co., from Silver Creek, Yavapai Co., 1995, status unknown -To Lousy Canyon, Yavapai Co., from Silver Creek, Yavapai Co., 1995, status unknown -To O'Donnell Creek, Santa Cruz Co., from same-site stock salvaged before stream renovation, 2002, extant.	-To BTA from Salt River at Tempe, Maricopa Co., 1930s, extirpated -To Garden Canyon, Cochise Co., from Turkey Creek, Cochise Co., 1988, extirpated (Weedman et al. 1996)
<i>Gila nigra</i> Headwater chub	-No documentation of any transplant to a wild site within the Gila River basin.	
<i>Gila robusta</i> Roundtail chub	-No documentation of any transplant to a wild site within the Gila River basin	
<i>Meda fulgida</i> Spikedace		-To Sonoita Creek, Santa Cruz Co., from Aravaipa Creek, Graham Co., 1968, extirpated -To Seven Springs Wash, Maricopa Co., from Aravaipa Creek, Pinal Co., 1970, extirpated
<i>Plagopterus argentissimus</i> Woundfin		-To Hassayampa River, Maricopa Co., from Virgin River, Coconino Co., 1972, extirpated -To Salt River, Maricopa Co., from Virgin River, Coconino Co., 1972, extirpated -To Sycamore Creek, Yavapai Co., from Virgin River, Coconino Co., 1972, extirpated -To Verde River Yavapai Co., from Virgin River, Coconino Co., date and status unknown

Table 2 Species	Successful population establishment	Unsuccessful population establishment
<i>Poeciliopsis occidentalis</i> Gila topminnow	<ul style="list-style-type: none"> -To AD Wash, Yavapai Co., from Dexter NFH (Sharp Spring stock), 1993, presumed extant -To Charlebois Spring, Pinal Co., from BTA, 1983, presumed extant -To Cold Springs, Graham Co., from Dexter NFH (Monkey Spring stock), 1985, presumed extant -To Dutchman Grave Spring, Yavapai Co., from BTA, 1983, presumed extant -To Heron Spring, Santa Cruz Co., from Sharp Spring, 1981 and 1987, extant -To Hidden Water Spring, Maricopa Co, from Monkey Spring, 1976, and from BTA, 1981, extant -To Johnson Wash Spring, Yavapai Co., from BTA, 1982, presumed extant -To Kayler Spring, Gila Co., from BTA, 1982, presumed extant -To Lime Creek, Yavapai from BTA via Lime Cabin Spring, before 1996, presumed extant -To Lower Mine Spring, Yavapai Co., from BTA, 1983, presumed extant -To Mescal Warm Spring, Gila Co., from Dexter NFH (Monkey Spring stock), 1985, presumed extant -To Mud Spring, Maricopa Co., from BTA, 1982 and 1997, extant -To Tule Creek, Yavapai Co., from BTA, 1981, presumed extant -To unnamed drainage #68, Maricopa Co., from BTA via Mesquite Tank #2, 1982-1985, presumed extant -To Walnut Spring, Maricopa Co., from BTA, 1982, extant -To Watson Wash, Graham Co., from unknown source, unknown date 1984-1989, presumed extant -To Yerba Mansa (Grapevine Spring), La Paz Co., from BTA via Tule Creek and Dexter NFH (Sharp Spring stock), 1984, 1985, and 1988, presumed extant -To Salt Creek (Bylas Springs), Graham Co., from Dexter NFH, 1998, presumed extant -To Lousy Canyon, Yavapai Co., from Dexter NFH, 2000, presumed extant -To Campaign Creek (includes upper Horrell Spring), Gila Co., from ASU (mixed Cienega Creek and Sharp Spring stocks, 2001, presumed extant -To Cottonwood Artesian, Gila Co., from ASU (Bylas Spring stock), 2001, presumed extant -To Empire Gulch, Pima Co., from Cienega Creek, 2001, presumed extant. 	<ul style="list-style-type: none"> -More than 200 reintroductions or natural dispersals from stocking at 175 wild locations, 17 of which remained in 1998, including one outside of historical range (Weedman 1998, USFWS 1999) -To NMDFG Red Rock Wildlife Management Area, Hidalgo Co., New Mexico, from Dexter NFH (Sharp Spring stock), 1989, likely extirpated

Table 2 Species	Successful population establishment	Unsuccessful population establishment
<i>Ptychocheilus lucius</i> Colorado squawfish		<p>-To multiple sites on Salt and Verde rivers, central AZ from Dexter NFH and/or AZGFD Bubbling Ponds SFH, 1981-1990. More than 750,000 individuals stocked (mostly larvae and fingerlings), 444 total recaptures, most within a few months of release. No evidence of long-term survival, reproduction, or recruitment (Creef et al. 1992, Hendrickson 1993, Young 1998, Jahrke and Clark 1999)</p> <p>-To two sites on Verde River, central AZ, from Dexter NFG and/or AZGFD Bubbling Ponds SFH, 1995-1998. 8537 individuals stocked (mostly sub adults), 84 total recaptures, most within a few months of release. No evidence of long-term survival, reproduction, or recruitment (Young 1998, Jahrke and Clark 1999)t</p> <p>-Current (1998-2003) data requested but not yet available</p>
<i>Tiaroga cobitis</i> Loach minnow		<p>-To Sonoita Creek, Santa Cruz Co., from Aravaipa Creek, Graham Co., 1968, extirpated</p> <p>-To 7 Springs Wash, Maricopa Co., from Aravaipa Creek, Pinal Co., 1970, extirpated</p>
<i>Xyrauchen texanus</i> Razorback sucker		<p>-To multiple sites on Gila, Salt, and Verde rivers, central AZ from Dexter NFH and/or AZGFD Bubbling Ponds SFH, 1981-1990. More than 11,000,000 individuals stocked, 519 total recaptures, most within a few months of release. No evidence of long-term survival, reproduction, or recruitment (Hendrickson 1993, Young 1998, Jahrke and Clark 1999)</p> <p>-To Verde River near Childs, central AZ from Dexter NFH and/or AZGFD Bubbling Ponds SFH, 1994-1998. 13,240 individuals stocked, 117 total recaptures, most within a few months of release. No evidence of long-term survival, reproduction, or recruitment (Young 1998, Jahrke and Clark 1999)</p> <p>-To Salt River at Horseshoe Bend, central AZ from Dexter NFH and/or AZGFD Bubbling Ponds SFH, 1996. 2,046 individuals stocked, 1 recapture. No evidence of long-term survival, reproduction, or recruitment (Young 1998, Jahrke and Clark 1999).</p> <p>-Current (1998-2003) data requested but not yet available.</p>

Table 3. Recovery and conservation activities (post-1967) for federal or state listed warm water fishes of the Gila River basin. (Recovery activities are those that directly benefit the species, e.g., increase its range and/or abundance, exclusive of stockings. Conservation activities are those that indirectly benefit the species, but may not produce immediately discernable effects, e.g., habitat improvement. Other activities ongoing or that have occurred in other parts of the native range of these species are not considered in this document. Abundant literature is available for each species, and the citations provided are only a few pertinent manuscripts. More complete literature reviews can be found in recovery plans and other recent documents.)

Table 3 Species	Recovery activities excluding transplants/repatriations	Conservation activities	Monitoring, surveys, captive populations, and research activities
<i>Cyprinodon arcuatus</i> Santa Cruz (Monkey Spring) pupfish			-Taxonomic recognition (Minckley et al. 2002)
<i>Cyprinodon macularius</i> Desert pupfish		-Recovery plan written (Marsh and Sada 1993) -Closure of Bog Hole to sport fishing -Pit digging by BLM along Gila Mtns. Adjacent to Gila River (Safford District)	-Regular monitoring of occupied sites (Weedman and Young 1997) -Ecological studies (Lowe et al. 1967, Hendrickson and Varela-Romero 1989, Minckley et al. 1991, Campoy-Favela 1996, Johnson 2002) -Genetics studies (Echelle et al. 2000) -Multiple transfers to hatcheries, laboratory facilities, refugium sites, public and private aquaria and other locations within and outside Arizona; not updated since the recovery plan was published in 1993
<i>Gila elegans</i> Bonytail		-Recovery plan written (USFWS 1990)	-Ecological studies (Ruppert and Muth 1997, Garrigan et al. 2002) -Genetics studies (Rosenfeld 1989, DeMarais and Dowling 1993, Douglas et al. 1998, Gerber et al. 2001), and ongoing -Gila R. Indian Res. Grow-out ponds for Lake Havasu -Bubbling Ponds State Hatchery
<i>Gila intermedia</i> Gila chub	-O'Donnell Creek and Sabino Creek renovations with subsequent reestablishment of species -Land acquisition in O'Donnell Creek (TNC)	-Rescue of Sabino Canyon populations (2003)	-Effects of crayfish on growth (Carpenter and McIvor 2000) -Effects of green sunfish on survival and habitat use (Dudley 1995, Dudley and Matter 2000) -Status review (Weedman et al. 1996) -Genetics studies (DeMarais 1986, DeMarais 1992), and ongoing -Ecological studies (Griffith and Tiersch 1989, Weedman et al. 1996, Dudley and Matter 1999)

Table 3 Species	Recovery activities excluding transplants/repatriations	Conservation activities	Monitoring, surveys, captive populations, and research activities
<p><i>Gila nigra</i> Headwater chub</p>		<ul style="list-style-type: none"> -Decommissioning of Childs/Irving hydropower facility (pending) -Crayfish trapping in Fossil Creek -Designation as sport fish in AZ -Water developments cancelled or altered (upper Gila River Connor/Hooker Dam, Upper Verde CAP water diversion) -Livestock grazing improvements (upper Verde, portions of middle Verde, upper Gila River, others) -Nonnative threat control (restrictions on live bait fish use and increased nonnative fish bag limits in AZ) 	<ul style="list-style-type: none"> -Taxonomic recognition (Minckley and DeMarais 2000) -Status review (Voeltz 2002) -Ongoing genetics studies
<p><i>Gila robusta</i> Roundtail chub</p>	<ul style="list-style-type: none"> -Aravaipa barriers -Stock Salt River (pending) 	<ul style="list-style-type: none"> -Designation as sport fish in AZ -Water development cancelled or altered (upper Gila River Connor/Hooker Dam, Upper Verde CAP water diversion) -Livestock grazing improvements (exclosure of upper Verde and portions of middle Verde) -Decommission of Childs/Irving hydropower facility (pending) -Nonnative threat control (restrictions on live bait fish use and increased nonnative fish bag limits in AZ) -Crayfish trapping in Fossil Creek -Land acquisition of Morgan Ranch (Verde River) 	<ul style="list-style-type: none"> -Annual monitoring in Gila R. in NM (Propst 2002), upper Verde R. (Rinne et al. 1998), Aravaipa Creek (Velasco 1997) -Propagation studies of Verde R population -Ecological studies (Barrett and Maughan 1995, Robinson et al. 1997, Robinson et al. 1998, Brouder et al. 2000, Brouder 2001) -Status review (Voeltz 2002, Bezzerides and Bestgen 2002) -Genetics studies (DeMarais 1992, Gerber et al. 2001), and ongoing

Table 3 Species	Recovery activities excluding transplants/repatriations	Conservation activities	Monitoring, surveys, captive populations, and research activities
<i>Meda fulgida</i> Spikedace	-Aravaipa barriers	<ul style="list-style-type: none"> -Recovery plan written (USFWS 1991c) -Water developments cancelled or altered (upper Gila River Connor/Hooker Dam, Upper Verde CAP water diversion) -Road and bridge activities cancelled or altered (East Fork Gila River road development, Romero Road bridge relocation on San Pedro, Aravaipa bridge) -Livestock grazing improvements (exclusion of river on upper Verde, portions of Gila in NM, Aravaipa Creek BLM lands, parts of Eagle Creek, Bonita Creek on BLM) -Nonnative threat control (restrictions on live bait fish use and increased nonnative fish bag limits in AZ) -Land acquisition of Morgan Ranch (Verde River) 	<ul style="list-style-type: none"> -Annual monitoring in Gila R. in NM (Propst 2002), upper Verde R. (Rinne et al. 1998), Aravaipa Creek (Velasco 1997) -Propagation studies at UNM -Multiple transfers to hatcheries or laboratory facilities (e.g., ASU Department of Biology, University of Arizona Environmental Research Laboratory, University of New Mexico Museum of Southwestern Biology). -Genetics studies (Tibbets 1993) -Distribution and life history studies (Propst et al. 1985, Propst et al. 1986) -Ecological studies (Propst et al. 1986, Marsh et al. 1989, Rinne 1992, Douglas et al. 1994)
<i>Plagopterus argentissimus</i> Woundfin		-Recovery plan written (USFWS 1984a)	-Multiple transfers to hatcheries or laboratory facilities (e.g., UNLV Department of Biology, Dexter NFH)

Table 3 Species	Recovery activities excluding transplants/repatriations	Conservation activities	Monitoring, surveys, captive populations, and research activities
<i>Poeciliopsis occidentalis</i> Gila topminnow	<ul style="list-style-type: none"> -Bylas Springs renovations (4?), barriers (3), and habitat restoration -Cottonwood Artesian and Mud Spring habitat construction (new ponds) -Tule Creek barrier -Arnett Creek barrier and renovation -Cienega Creek habitat reconstruction and dam removal -Upper Sonoita Creek railroad abutment removal 	<ul style="list-style-type: none"> -Recovery plan written (USFWS 1984b), additional actions prescribed in draft recovery plan (Weedman 1998) -Land acquisition: Sonoita Creek, Fresno Canyon, Coalmine Canyon (State and The Nature Conservancy) Cienega Creek (BLM) Sharp Spring (State) -Redrock Canyon – road closures -Cienega Creek basin closed to angling -Hidden Water Spring fenced from livestock grazing, although presence of wild burro population reduces effectiveness -Redrock Canyon (Gate Spring) deflectors -Cottonwood Spring erosion control structures -Miscellaneous livestock exclosures (Cottonwood Spring, Cottonwood Artesian, Johnson Wash, Hidden Water Spring, Redrock Canyon, Bylas Springs, Cienega Creek, Sharp Spring, Tule Creek, Kayler Spring, and others) -Mud Spring pond excavations 	<ul style="list-style-type: none"> -Regular monitoring of occupied sites (Weedman and Young 1997) -Genetics studies (Hedrick and Parker 1998, Parker et al. 1999, Hedrick and Parker 1999, Sheffer et al. 1999, Hedrick 2000, Hedrick et al. 2001a, Hedrick et al. 2001b) -Ecological studies (Schoenherr 1974, Schoenherr 1977, Schoenherr 1981, Constantz 1981, Meffe 1984a, Meffe 1984b, Simms and Simms 1992, Forrest 1992, Leberg and Vrijenhoek 1994, Stefferud and Stefferud 1995, Minckley 1999, Johnson 2002, Schultz et al. 2003) -Multiple transfers to hatcheries, laboratory facilities, refugium sites, public and private aquaria and other locations within and outside Arizona
<i>Ptychocheilus lucius</i> Colorado squawfish	<ul style="list-style-type: none"> -Stock Salt River (pending) 	<ul style="list-style-type: none"> -Recovery plan written (USFWS 1991a) -Change in angling regulations in Arizona -Salt River diversion dam modification into barrier -Nonnative threat control (restrictions on live bait fish use and increased nonnative fish bag limits in AZ) 	<ul style="list-style-type: none"> -Multiple transfers to hatcheries or laboratory facilities (e.g., Dexter NFH, Hotchkiss NFH, Willow Beach NFH, AZGFD Bubbling Ponds SFH, CADFG Chino SFH, Arizona-Sonora Desert Museum) -Ecological studies (Clarkson et al. 1993, Childs and Clarkson 1996, Robinson et al. 1997, Robinson et al. 1998)

Table 3 Species	Recovery activities excluding transplants/repatriations	Conservation activities	Monitoring, surveys, captive populations, and research activities
<i>Tiaroga cobitis</i> Loach minnow	-Aravaipa barriers	<ul style="list-style-type: none"> -Recovery plan written (USFWS 1991b) -Water development cancelled or altered (Connor/Hooker Dam, Pigeon Creek Reservoir, White River water diversion) -Road/bridge activities cancelled or altered (East Fork Gila River road development, Blue River road maintenance, ORV road closures on San Francisco and Blue, Aravaipa bridge) -Livestock grazing improvements (exclusion of river on portions of Gila in NM, Blue and San Francisco in AZ, Aravaipa Creek BLM lands, parts of Eagle Creek) -Nonnative threat control (restrictions on live bait fish use and increased nonnative fish bag limits in AZ) 	<ul style="list-style-type: none"> -Annual monitoring in Gila and San Francisco rivers in NM (Propst 2002), upper Verde R. (Rinne et al. 1998), Aravaipa Creek (Velasco 1997) -Propagation studies at Alchesay (David and Wirtanen 2001) -Multiple transfers to hatcheries or laboratory facilities (e.g., Alchesay NFH, AZGFD Bubbling Ponds SFH, ASU Department of Biology, Georgia Southern University Department of Biology, University of Arizona Environmental Research Laboratory) -Ecological studies (Propst and Bestgen 1991, Rinne 1992, Velasco 1997, Bagley 2002, Propst 2002) -Genetic studies (Tibbets 1993, Tibbets and Dowling 1996)
<i>Xyrauchen texanus</i> Razorback sucker	-Stock Salt River (pending)	<ul style="list-style-type: none"> -Recovery plan written (USFWS 1998) -Water development cancelled or altered (Upper Verde CAP water diversion) -Livestock grazing improvements (exclosure of upper Verde and portions of middle Verde) -Nonnative threat control (restrictions on live bait fish use and increased nonnative fish bag limits in AZ) 	<ul style="list-style-type: none"> -Multiple transfers to hatcheries, laboratory facilities, refugium sites, etc. (e.g., Dexter NFH, Hotchkiss NFH, Willow Beach NFH; Buenos Aires, Cibola, Havasu, and Imperial NWRs; AZGFD Page Springs and Bubbling Ponds SFH, CADFG Chino SFH, Arizona-Sonora Desert Museum, Phoenix Zoo, TNC Hassayampa River and San Pedro River Preserves). -Monitoring in Verde and Salt rivers (Hendrickson 1993, Jahrke and Clark 1999) Ecological studies (Marsh and Brooks 1989, Creef and Clarkson 1993, Johnson et al. 1993, Clarkson et al. 1993, Barrett and Maughan 1995, Robinson et al. 1998, Johnson and Hines 1999)

Table 4. Recommendations for transplants and replications, and conservation and recovery actions, for federal or state listed warm water fishes of the Gila River basin.

Table 4 Species	Recommended replication sites (not an exhaustive listing)	Recommendations for actions
<i>Cyprinodon arcuatus</i> Santa Cruz (Monkey Spring) pupfish	-Not applicable	
<i>Cyprinodon macularius</i> Desert pupfish	-Arnett Creek (Gila) -TNC San Pedro Preserve Pond (San Pedro) -Bingham Cienega (San Pedro) -Cienega Creek -Lewis Spring (San Pedro) -O'Donnell Canyon (San Pedro) -Turkey Creek (San Pedro) -Post Canyon (San Pedro) -Hidden Water Spring (Salt) -Suitable habitats in the Santa Cruz basin (Boghole, Sheehy Spring, Sonoita Creek, Sharp Spring, Cottonwood Spring, Agua Caliente) -Stock BLM pits along Gila River	-Implement recovery plan (Marsh and Sada 1993) -Evaluate use of <i>C. macularius</i> in former habitat of <i>C. arcuatus</i>
<i>Gila elegans</i> Bonytail	-Gila River, upper reach (AZ)	-Implement recovery plan (USFWS 1990)
<i>Gila intermedia</i> Gila chub	-Morgan City Wash (Agua Fria) -Cave Creek/Seven Springs (Salt) -San Simon Cienega -Martinez Creek (Gila) -San Pedro River -Turkey Creek, Post Canyon (Babocomari) -TNC San Pedro Preserve pond -Redrock Canyon (Santa Cruz) -Sharp Spring, Bog Hole (Santa Cruz) -Replicate Sabino pop in other appropriate sites, e.g., Coalmine Spring/Fresno Canyon, Scotia Canyon, Peck Canyon, Temporal Gulch, Tanque Verde Canyon -Replicate appropriate stock (Agua Fria?) into Cave Cr/7 Springs -Replicate Sheehy Spring stock into Sharp Spring and Boghole -Restock Turkey Creek	-Federal listing w/critical habitat (U.S. Fish and Wildlife Service 2002) -Develop biologically based recovery plan -Remove nonnative fishes from occupied habitats -Land acquisition at Coalmine Spring -Genetic studies of intra-population variation -Systematic monitoring and comprehensive reporting
<i>Gila nigra</i> Headwater chub	-Greenback Creek (Tonto) -Evaluate stocking in Horton Creek	-Federal listing w/critical habitat -Develop biologically based recovery plan -Construct barrier in Fossil Creek -Renovate Fossil Creek -Remove nonnative fishes from occupied habitats -Systematic monitoring and comprehensive reporting
<i>Gila robusta</i> Roundtail chub	-Blue River (San Francisco) -Salt River above Roosevelt Lake -WF Black (Black)	-Federal listing w/critical habitat -Develop biologically based recovery plan -Construct barrier in Fossil Creek -Renovate Fossil Creek -Remove nonnative fishes from occupied habitats -Systematic monitoring and comprehensive reporting

Table 4 Species	Recommended replication sites (not an exhaustive listing)	Recommendations for actions
<i>Meda fulgida</i> Spikedace	<ul style="list-style-type: none"> -Bonita Creek (Gila) -Blue River (San Francisco) -Hot Springs Canyon (San Pedro) -Redfield Canyon (San Pedro) -San Pedro River -Fossil Creek (Verde) -Tonto Creek (Salt) -Reintroduce in Fossil Creek upon completion of renovation -Identify suitable tributary sites for replications, e.g., Tonto Creek, Gila Box RNCA, San Pedro RNCA 	<ul style="list-style-type: none"> -Implement recovery plan (USFWS 1991c) -Survey Eagle Creek -Survey upper Verde River -Construct barrier in Fossil Creek -Renovate Fossil Creek -Remove nonnative fishes from occupied habitats -Systematic monitoring and comprehensive reporting
<i>Plagopterus argentissimus</i> Woundfin	<ul style="list-style-type: none"> -Gila River, upper reach (AZ) -Hassayampa River -Tonto Creek 	<ul style="list-style-type: none"> -Implement recovery plan (USFWS 1984a) -Revoke experimental-nonessential stocking rule (USFWS 1985) -Evaluate Gila Box RNCA for stocking
<i>Poeciliopsis occidentalis</i> Gila topminnow	<ul style="list-style-type: none"> -Aravaipa Creek tributaries -Arnett Creek -Additional waters identified in the draft Gila Topminnow Revised Recovery Plan 	<ul style="list-style-type: none"> -Reinstate aggressive stocking program into waters on public lands -Implement management recommendations (Minckley 1999) -Implement recovery plan (USFWS 1984b) -Finalize draft recovery plan (Weedman 1998) -Systematic monitoring and comprehensive reporting -Coalmine Canyon land acquisition and fencing -Improve habitat at Walnut Spring
<i>Ptychocheilus lucius</i> Colorado squawfish	<ul style="list-style-type: none"> -Gila River -Salt River -Verde River 	<ul style="list-style-type: none"> -Implement recovery plan (USFWS 1991a), and other innovative strategies (e.g., Minckley et al. 2003) -Revoke experimental-nonessential stocking rule (USFWS 1985)
<i>Tiaroga cobitis</i> Loach minnow	<ul style="list-style-type: none"> -Hot Springs, Redfield canyons (San Pedro) -San Pedro River -Open Draw (Black) -Tonto Creek (Salt) -Fossil Creek (Verde) -Bonita Creek (Gila) -Fossil Creek upon completion of renovation 	<ul style="list-style-type: none"> -Implement recovery plan (USFWS 1991b) -Construct barrier in Fossil Creek -Renovate Fossil Creek -Remove nonnative fishes from occupied habitats -Systematic monitoring and comprehensive reporting
<i>Xyrauchen texanus</i> Razorback sucker	<ul style="list-style-type: none"> -Gila River -Bonita Creek (Gila) -Eagle Creek (Gila) -Blue River (San Francisco) -Salt River -Verde River -Fossil Creek (Verde)once stream is renovated -Replicate populations into other suitable streams 	<ul style="list-style-type: none"> -Implement recovery plan (USFWS 1998), and other innovative strategies (e.g., Minckley et al. 2003) -Systematic monitoring and comprehensive reporting -Evaluate suitability of Bonita Creek for stocking

Literature cited

- Bagley, B.E. 2002. Survey of Verde River drainage, Arizona for loach minnow (*Tiaroga cobitis*). Final report to U. S. Fish and Wildlife Service, Arizona Ecological Services Field Office, Phoenix.
- Barrett, P.J., and O.E. Maughan. 1995. Spatial habitat selection of roundtail chub (*Gila robusta*) in two central Arizona streams. *Southwestern Naturalist* 40:301-307.
- Bezzlerides, N., and K.R. Bestgen. 2002. Status review of roundtail chub *Gila robusta*, flannelmouth sucker *Catostomus latipinnis*, and bluehead sucker *Catostomus discobolus* in the Colorado River basin. *Colorado State University Larval Fish Laboratory* 118:1-139.
- Brouder, M.J. 2001. Effects of flooding on recruitment of roundtail chub, *Gila robusta*, in a southwestern river. *Southwestern Naturalist* 46:302-310.
- Brouder, M.J., D.D. Rogers, and L.D. Avenetti. 2000. Life history and ecology of the roundtail chub *Gila robusta*, from two streams in the Verde River basin. Arizona Game and Fish Department, Research Branch, Technical Guidance Bulletin 3.
- Campoy-Favela, J.R. 1996. Evaluation of populations of *Cyprinodon macularius*, *Poeciliopsis occidentalis*, *Ictalurus pricei*, *Gila ditaenia* and *Gila intermedia* in shared watersheds between Arizona and Sonora. Instituto del Medio Ambiente y del Desarrollo Sustentable del Estado de Sonora (IMADES), Hermosillo, Sonora.
- Carpenter, J., and C.C. Mclvor. 2000. Effect of introduced crayfish on growth of two native fishes of the Colorado River basin. *Proceedings of the Desert Fishes Council* 32:24.
- Childs, M.R., and R.W. Clarkson. 1996. Temperature effects on swimming performance of larval and juvenile Colorado squawfish: implications for survival and species recovery. *Transactions of the American Fisheries Society* 125:940-947.
- Clarkson, R.W., E.D. Creef, and D.K. McGuinn-Robbins. 1993. Movements and habitat utilization of reintroduced razorback suckers (*Xyrauchen texanus*) and Colorado squawfish (*Ptychocheilus lucius*) in the Verde River, Arizona. Completion report to U.S. Fish and Wildlife Service. Arizona Game and Fish Department, Phoenix, Arizona.
- Constantz, G.D. 1981. Life history patterns of desert fishes. Pages 237-290 in R. J. Naiman and D. L. Soltz, editors. *Fishes in North American deserts*. John Wiley and Sons, New York.
- Creef, E.D., and R.W. Clarkson. 1993. Movement patterns and habitat use of razorback suckers (*Xyrauchen texanus*) in the Verde River, Arizona. *Proceedings of the Desert Fishes Council* 24:63
- Creef, E.D., R.W. Clarkson, and D.K. McGuinn-Robbins. 1992. Razorback sucker (*Xyrauchen texanus*) and Colorado squawfish (*Ptychocheilus lucius*) reintroduction and monitoring, Salt and Verde Rivers, Arizona, 1991-1992. Unpublished report, Arizona Game and Fish Department, Phoenix.
- David, R.E., and L.J. Wirtanen. 2001. Artificial propagation of loach minnow, *Rhinichthys cobitis*. *American Currents* 27:1-13.
- DeMarais, B. D. 1986. Morphological variation in *Gila* (Pisces: Cyprinidae) and geologic history: lower Colorado River basin. Unpublished Master's thesis, Arizona State University, Tempe.
- DeMarais, B. D. 1992. Genetic relationships among fishes allied to the genus *Gila* (Teleostei: Cyprinidae) from the American southwest. Unpublished PhD. dissertation, Arizona State University, Tempe.
- DeMarais, B.D., and T.E. Dowling. 1993. Introgressive hybridization and evolution of Colorado River basin *Gila* (Teleostei: Cyprinidae). *Proceedings of the Desert Fishes Council* 24:67
- Douglas, M.E., P.C. Marsh, and W.L. Minckley. 1994. Indigenous fishes of western North America and the hypothesis of competitive displacement: *Meda fulgida* (Cyprinidae) as a case study. *Copeia* 1994:9-19.
- Douglas, M.E., R.R. Miller, and W.L. Minckley. 1998. Multivariate discrimination of Colorado Plateau *Gila* spp.: the "art of seeing well" revisited. *Transactions of the American Fisheries Society* 127:163-173.
- Dudley, R. K. 1995. The effects of green sunfish on the distribution, abundance and habitat use of Gila chub in Sabino Creek, Arizona. Unpublished Master's thesis, University of Arizona, Tucson.
- Dudley, R.K., and W.J. Matter. 1999. Effects of a record flood on fishes in Sabino Creek, Arizona. *Southwestern Naturalist* 44:218-221.
- Dudley, R.K., and W.J. Matter. 2000. Effects of small green sunfish (*Lepomis cyanellus*) on recruitment of Gila chub (*Gila intermedia*) in Sabino Creek, Arizona. *Southwestern Naturalist* 45:24-29.
- Echelle, A.A., R.A. Van den Bussche, T.P. Malloy, Jr., M.L. Haynie, and C.O. Minckley. 2000. Mitochondrial DNA variation in pupfishes assigned to the species *Cyprinodon macularius* (Atherinomorpha: Cyprinodontidae): taxonomic implications and conservation genetics. *Copeia* 2000:353-364.
- Forrest, R. E. 1992. Habitat use and preference of Gila topminnow. Unpublished Master's thesis, University of Arizona, Tucson.
- Garrigan, D., P.C. Marsh, and T.E. Dowling. 2002. Long-term effective population size of three endangered Colorado River fishes. *Animal Conservation* 5:95-2002.
- Gerber, A.S., C.A. Tibbets, and T.E. Dowling. 2001. The role of introgressive hybridization in the evolution of the *Gila robusta* complex (Teleostei: Cyprinidae). *Evolution* 55:2028-2039.
- Griffith, J.S., and T.R. Tiersch. 1989. Ecology of fishes in Redfield Canyon, Arizona, with emphasis on *Gila robusta intermedia*. *Southwestern Naturalist* 34:131-134.
- Hedrick, P.W. 2000. Microsatellite and MHC variation to distinguish natural lineages of the Sonoran topminnow. Department of Biology, Arizona State University, Tempe, Arizona.
- Hedrick, P.W., and K.M. Parker. 1998. MHC variation in the endangered Gila topminnow. *Evolution* 52:194-199.
- Hedrick, P.W., and K.M. Parker. 1999. Genetic characterization of Sonoran topminnow populations. Unpublished report, Arizona State University.

- Hedrick, P.W., K.M. Parker, and R.N. Lee. 2001b. Using microsatellite and MHC variation to identify species, ESUs, and MUs in the endangered Sonoran topminnow. *Molecular Ecology* 10:1399-1412.
- Hedrick, P.W., T.J. Kim, and K.M. Parker. 2001a. Parasite resistance and genetic variation in the endangered *Gila* topminnow. *Animal Conservation* 4:103-109.
- Hendrickson, D.A. 1993. Evaluation of the razorback sucker (*Xyrauchen texanus*) and Colorado squawfish (*Ptychocheilus lucius*) reintroduction programs in central Arizona based on surveys of fish populations in the Salt and Verde rivers from 1986 to 1990. Unpublished report, Arizona Game and Fish Department, Phoenix.
- Hendrickson, D.A., and A. Varela-Romero. 1989. Conservation status of desert pupfish, *Cyprinodon macularius*, in Mexico and Arizona. *Copeia* 1989:478-483.
- Jahrke, E., and D.A. Clark. 1999. Razorback sucker and Colorado pikeminnow reintroduction and monitoring in the Salt and Verde rivers. Nongame and Endangered Wildlife Program Technical Report 147. Arizona Game and Fish Department, Phoenix.
- Johnson, J.E. 2002. Predator recognition and avoidance by four endangered southwestern USA fishes. Pages 197-207 in M. L. Lozano-V., editor. Libro jubilar en honor al Dr. Salvador Contreras Balderas. Universidad Autonoma de Nuevo Leon, Monterrey, Mexico.
- Johnson, J.E., and R.T. Hines. 1999. Effect of suspended sediment on vulnerability of young razorback suckers to predation. *Transactions of the American Fisheries Society* 128:648-655.
- Johnson, J.E., M.G. Pardew, and M.M. Lyttle. 1993. Predator recognition and avoidance by larval razorback sucker and northern hog sucker. *Transactions of the American Fisheries Society* 122:1139-1145.
- Leberg, P.L., and R.C. Vrijenhoek. 1994. Variation among desert topminnows in their susceptibility to attack by exotic parasites. *Conservation Biology* 8:419-424.
- Lowe, C.H., D.S. Hinds, and E.A. Halpern. 1967. Experimental catastrophic selection and tolerances to low oxygen concentration in native Arizona freshwater fishes. *Ecology* 48:1013-1017.
- Marsh, P.C., and D.W. Sada. 1993. Desert pupfish (*Cyprinodon macularius*) recovery plan. U. S. Fish and Wildlife Service, Albuquerque, New Mexico.
- Marsh, P.C., and J.E. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to re-establishment of hatchery-reared razorback suckers. *Southwestern Naturalist* 34:188-195.
- Marsh, P.C., F.J. Abarca, M.E. Douglas, and W.L. Minckley. 1989. Spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*) relative to introduced red shiner (*Cyprinella lutrensis*). Unpublished report to Arizona Game and Fish Department. Arizona State University, Tempe.
- Meffe, G.K. 1984a. Density-dependent cannibalism in the endangered Sonoran topminnow (*Poeciliidae:Poeciliopsis*). *Southwestern Naturalist* 29:500-503.
- Meffe, G.K. 1984b. Effects of abiotic disturbance on coexistence of predator prey fish species. *Ecology* 65:1525-1534.
- Minckley, W.L. 1999. Ecological review and management recommendations for recovery of the endangered *Gila* topminnow. *Great Basin Naturalist* 59:230-244.
- Minckley, W.L., and B.D. DeMarais. 2000. Taxonomy of chubs (Teleostei, Cyprinidae, Genus *Gila*) in the American southwest with comments on conservation. *Copeia* 2000:251-256.
- Minckley, W.L., and J.E. Brooks. 1985. Transplantations of native Arizona fishes: records through 1980. *Journal of the Arizona-Nevada Academy of Sciences* 20:73-89.
- Minckley, W.L. and coauthors. 2003. A conservation plan for native fishes of the lower Colorado River. *BioScience* 53(3):219-234.
- Minckley, W.L., G.K. Meffe, and D.L. Soltz. 1991. Conservation and management of short-lived fishes: the Cyprinodontoids. Pages 247-282 in W. L. Minckley and J. E. Deacon, editors. *Battle against extinction: native fish management in the American West*. University of Arizona Press, Tucson.
- Minckley, W.L., R.R. Miller, and S.M. Norris. 2002. Three new pupfish species, *Cyprinodon* (Teleostei, Cyprinodontidae), from Chihuahua, México, and Arizona, USA. *Copeia* 2002:687-705.
- Parker, K.M., K. Hughes, T.J. Kim, and P.W. Hedrick. 1998. Isolation and characterization of microsatellite loci from the *Gila* topminnow (*Poeciliopsis o. occidentalis*) and their utility in guppies (*Poecilia reticulata*). *Molecular Ecology* 7:357-363.
- Parker, K.M., R.J. Sheffer, and P.W. Hedrick. 1999. Molecular variation and evolutionarily significant units in the endangered *Gila* topminnow. *Conservation Biology* 13:108-116.
- Propst, D.L. 2002. Systematic investigations of warm water fish communities. Unpublished report, New Mexico Department of Game and Fish, Santa Fe.
- Propst, D.L., and K.R. Bestgen. 1991. Habitat and biology of the loach minnow, *Tiaroga cobitis*, in New Mexico. *Copeia* 1991:29-38.
- Propst, D.L., K.R. Bestgen, and C.W. Painter. 1986. Distribution, status, biology, and conservation of the spikedace (*Meda fulgida*) in New Mexico. U.S. Fish and Wildlife Service Endangered Species Report 15, U.S. Fish and Wildlife Service, Albuquerque, NM.
- Propst, D.L., P.C. Marsh, and W.L. Minckley. 1985. Arizona survey for spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*): Fort Apache and San Carlos Apache Indian Reservations and Eagle Creek, 1985. U.S. Fish and Wildlife Service, Albuquerque, NM.
- Rinne, J.N. 1992. Physical habitat utilization of fish in a Sonoran desert stream, Arizona, southwestern United States. *Ecology of Freshwater Fish* 1:35-41.
- Rinne, J.N., J.A. Stefferud, D.A. Clark, and P.J. Sponholtz. 1998. Fish community structure in the Verde River, Arizona, 1974-1997. *Hydrology and Water Resources in Arizona and the Southwest* 28:75-80.
- Robinson, A.T., P. Hines, J.A. Sorensen, and S.D. Bryan. 1997. Parasites, pathogens, and health of fishes in the Verde River, Arizona, and implications for management of razorback suckers (*Xyrauchen texanus*) and Colorado squawfish (*Ptychocheilus lucius*). *Proceedings of the Desert Fishes Council* 28:73-74.
- Robinson, A.T., P.P. Hines, J.A. Sorensen, and S.D. Bryan. 1998. Parasites and fish health in a desert stream, and management implications for two endangered fishes. *North American Journal of Fisheries Management* 18:599-608.

- Rosenfeld, M.J. 1989. Morphometry of fishes in the genus *Gila* (Cyprinidae) from the upper Colorado River basin. University of Utah, Salt Lake City.
- Ruppert, J.B., and R.T. Muth. 1997. Effects of electrofishing fields on captive juveniles of two endangered cyprinids. *North American Journal of Fisheries Management* 17:314-320.
- Schoenherr, A. A. 1974. Life history of the topminnow *Poeciliopsis occidentalis* (Baird and Girard) in Arizona and an analysis of its interaction with the mosquitofish *Gambusia affinis* (Baird and Girard). Unpublished Ph.D. dissertation, Arizona State University, Tempe.
- Schoenherr, A.A. 1977. Density dependent and density independent regulation of reproduction in the Gila topminnow, *Poeciliopsis occidentalis* (Baird and Girard). *Ecology* 58:438-444.
- Schoenherr, A.A. 1981. The role of competition in the replacement of native fishes by introduced species. Pages 173-204 in R. J. Naiman and D. L. Soltz, editors. *Fishes in North American deserts*. John Wiley and Sons, New York.
- Schultz, A.A., O.E. Maughan, S.A. Bonar, and W.J. Matter. 2003. Effects of flooding on abundance of native and nonnative fishes downstream from a small impoundment. *North American Journal of Fisheries Management* 23:503-511.
- Sheffer, R.J., P.W. Hedrick, and A.L. Velasco. 1999. Testing for inbreeding and outbreeding depression in the endangered Gila topminnow. *Animal Conservation* 2:121-129.
- Simms, J.R., and K.M. Simms. 1992. What constitutes high quality habitat for Gila topminnow (*Poeciliopsis o. occidentalis*)? An overview of habitat parameters supporting a robust population at Cienega Creek, Pima County, Arizona. *Proceedings of the Desert Fishes Council* 23:82
- Stefferd, J.A., and S.E. Stefferud. 1995. Status of Gila topminnow and results of monitoring the fish community in Redrock Canyon, Coronado National Forest, 1979--1993. Pages 361-369 in L. F. DeBano, G. J. Gottfried, R. H. Hamre, C. B. Edminster, P. F. Ffolliott, and A. Ortega-Rubio, editors. *Biodiversity and management of the Madrean Archipelago: the sky islands of southwestern United States and northwestern Mexico*. September 19-23, 1994, Tucson, Arizona. USDA Forest Service, General Technical Report RM-GTR-264, Fort Collins, Colorado.
- Tibbets, C. A. 1993. Patterns of genetic variation in three cyprinid fishes native to the American southwest. Unpublished Master's thesis, Arizona State University, Tempe.
- Tibbets, C.A., and T.E. Dowling. 1996. Effects of intrinsic and extrinsic factors on population fragmentation in three species of North American minnows (Teleostei: Cyprinidae). *Evolution* 50:1280-1292.
- U.S. Fish and Wildlife Service. 1984a. Recovery plan for woundfin, *Plagiopterus argentissimus* Cope. U.S. Fish and Wildlife Service, Albuquerque, NM.
- U.S. Fish and Wildlife Service. 1984b. Sonoran topminnow (*Gila* and Yaqui) recovery plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico.
- U.S. Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; determination of experimental population status for certain introduced populations of Colorado squawfish and woundfin. *Federal Register* 50:30188-30195.
- U.S. Fish and Wildlife Service. 1990. Bonytail chub recovery plan. U. S. Fish and Wildlife Service, Denver, Colorado.
- U.S. Fish and Wildlife Service. 1991a. Colorado squawfish recovery plan. U. S. Fish and Wildlife Service, Denver, Colorado.
- U.S. Fish and Wildlife Service. 1991b. Loach Minnow (*Tiaroga cobitis*) recovery plan. U.S. Fish and Wildlife Service, Phoenix, AZ.
- U.S. Fish and Wildlife Service. 1991c. Spikedace (*Meda fulgida*) recovery plan. U.S. Fish and Wildlife Service, Phoenix, AZ.
- U.S. Fish and Wildlife Service. 1998. Razorback sucker (*Xyrauchen texanus*) recovery plan. U.S. Fish and Wildlife Service, Denver, CO.
- U.S. Fish and Wildlife Service. 1999. Memo AESO/SE POOC/CYMA of January 15, 1999, from Field Supervisor to Interested Party. U.S. Fish and Wildlife Service, Arizona Ecological Services Field Office, Phoenix, AZ.
- U.S. Fish and Wildlife Service. 2002. Endangered and threatened wildlife and plants; listing the Gila chub as endangered with critical habitat; proposed rule. *Federal Register* 67(154):51948-51985.
- Velasco, A. L. 1997. Fish population response to variance in stream discharge, Aravaipa Creek, Arizona. Unpublished Master's thesis, Arizona State University, Tempe.
- Voeltz, J.B. 2002. Roundtail chub (*Gila robusta*) status survey of the lower Colorado River basin. Nongame and Endangered Wildlife Program Technical Report 186. Arizona Game and Fish Department, Phoenix.
- Weedman, D.A. 1998. Gila topminnow, *Poeciliopsis occidentalis occidentalis*, revised recovery plan (draft of July 1998). Unpublished report, Arizona Game and Fish Department, Phoenix.
- Weedman, D.A., A.L. Girmendonk, and K.L. Young. 1996. Status review of Gila chub, *Gila intermedia*, in the United States and Mexico. Nongame and Endangered Wildlife Program Technical Report 91. Arizona Game and Fish Department, Phoenix.
- Weedman, D.A., and K.L. Young. 1997. Status of the Gila topminnow and desert pupfish in Arizona. Nongame and Endangered Wildlife Program Technical Report 118. Arizona Game and Fish Department, Phoenix.
- Young, K.L. 1998. Annual performance report: Razorback sucker and Colorado squawfish reintroduction and monitoring in the Verde and Salt rivers. Unpublished report, Arizona Game and Fish Department, Phoenix, AZ.