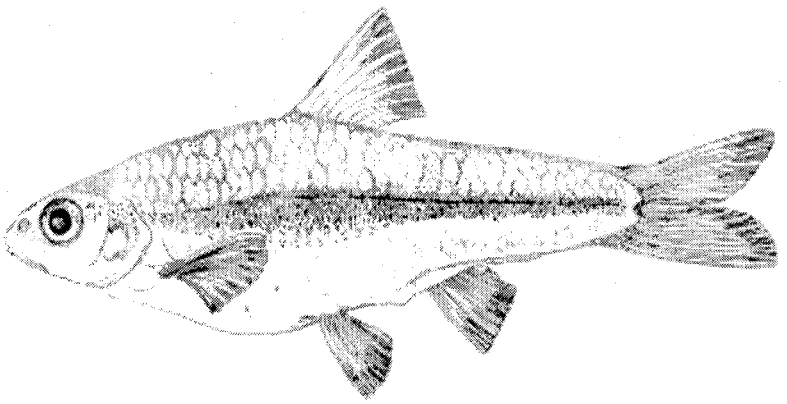
SPECIAL PUBLICATIONS

Museum of Texas Tech University

NUMBER 46 12 May 2003

AQUATIC FAUNA OF THE NORTHERN CHIHUAHUAN DESERT



CONTRIBUTED PAPERS FROM A SPECIAL SESSION WITHIN
THE THIRTY-THIRD ANNUAL SYMPOSIUM OF
THE DESERT FISHES COUNCIL

HELD
17 NOVEMBER 2001
AT
SUL ROSS STATE UNIVERSITY, ALPINE, TEXAS

EDITED BY
GARY P. GARRETT AND NATHAN L. ALLAN

Aquatic Conservation and The Nature Conservancy in West Texas

John Karges

Abstract

Aquatic biodiversity in the Chihuahuan Desert portion of West Texas is high and of increasing conservation concern because of the high incidence of endemism, limited range distributions for both species and natural communities and the limited areas where surface waters still occur. Surface waters include remaining intact or restorable reaches of principal river systems, perennial or permanent-pool streams, and isolated springs with their attendant outflows and marshes. Some aquatic sites are well known and conserved by either government agencies or private conservation organizations, while other areas are either not protected or perhaps not even identified. Over the last decade, The Nature Conservancy has invested considerable money, time and resources in conserving specific, critical areas harboring rich aquatic biodiversity in the northern Chihuahuan Desert by purchasing preserves and partnering on adjacent lands with conservation easements to provide permanent protection of rare aquatic areas. The Conservancy's protection and conservation efforts include identifying and mapping the distribution of rare aquatic species, assemblages and communities within a landscape context (ecoregional planning), long-term landsite protection and research, monitoring and stewardship management on the site and its biological elements. In addition, research and planning for groundwater issues of depletion and delineation of watersheds and recharge zones is crucial to sustainable, long-term conservation of these imperiled systems (site conservation planning). The Nature Conservancy presently is involved at five sites in West Texas with aquatic conservation elements, and through ecoregional planning will identify additional "action sites" to protect the aquatic biodiversity of the Chihuahuan Desert.

Introduction

A recurrent and contemporary conservation issue throughout deserts involves aquatic biota and the impacts of declining surface water availability on populations, species, assemblages of organisms or ecological function and integrity of entire systems (Rinne and Minckley, 1991). Throughout continental aridlands, surface waters frequently harbor endemic, rare or limitedly distributed species and in many cases, unique aquatic natural communities. The water may be flowing or stationary and either ephemeral or perennial, depending upon climatic cycles, seasonal durations, topography and underlying geology. Surface water bodies of springs and seeps, creeks, rivers, marshlands and playa basins are widely scattered across the northern Chihuahuan Desert landscape in Trans-Pecos Texas. With gradual but significantly increased aridification of the Chihuahuan Desert region since the end of the Pleistocene, surface waters have been greatly reduced. Consequently in many cases of isolated springs and perennial, relictual stream reaches, organisms isolated from wider, formerly contiguous distributions have differentiated into distinct genetic entities, in some instances at the full species level, but often at least to recognizable populations or subspecies level.

The rapid diminution and sometimes total loss of surface water in the past century due to a combination of climatic and anthropogenic factors is an additional and much more contemporary threat to the desert's aquatic biodiversity. Aside from Chihuahuan Desert annual or seasonal droughts (typically from mid-winter to mid-summer), relatively long-term droughts of variable duration (up to nearly a decade in some cases),

have occurred periodically since the inception of record keeping in the late 1800s. This coupled with increased human demands and water extraction have contributed to the measurable depletion of most surface spring systems in the Chihuahuan Desert (Hubbs, 1995), and has even included total elimination of some historically robust springs and outflows (e.g., Comanche Springs at Fort Stockton, Pecos County, see also Scudday, this volume). The threat to biodiversity by water reduction and over-harvest has already been manifested in the extirpation of the Comanche Springs pupfish (*Cyprinodon elegans*) at the type locality (U.S. Fish and Wildlife Service, 1981). In fact, within the Chihuahuan Desert portion of Texas, 56.4 percent (22) of the 39 total native fish species are of conservation concern as endangered, threatened or declining by the Texas Organization for Endangered Species (Edwards et al., 1989). An additional human-induced threat to regional aquatic biodiversity is the introduction of competitive exotics, which can seriously impact or degrade ecological integrity and even species' genetic purity through hybridization (Hubbs, 1990).

Among the types of systems and surface features containing identified "hotspots" of aquatic biodiversity within the northern Chihuahuan Desert are relatively intact or potentially restorable reaches of the major rivers, some remaining perennial or permanent pool streams fed by either springflows or runoff drainage from mountainous basins; and desert springs and their associated streams and marshes (ciénegas). The major river system of the region is the mainstem of the Rio Grande (Río Bravo del Norte) and its significant tributaries, the Río Conchos in Chihuahua, the Pecos River of New Mexico and Texas, and the Devils River entirely within Texas. Perennial streams are scarce and widely distributed. Some of the tributaries of the Devils and Pecos rivers in the eastern Trans-Pecos are spring-fed from aquifers in the limestone matrix of the Stockton Plateau. This is an ecotonal region of plants, animals and biotic communities between the eastern Chihuahuan Desert and the western Edwards Plateau. Farther west in the Trans-Pecos, streams in Big Bend National Park and Big Bend Ranch State Park contain permanent reaches of surface water, fed by subirrigated flow and augmented by periodic precipitation related episodes of flash-flooding. These surface pools and runs can be extremely variable in size, depth, distribution and extent, but as long as some permanent water remains throughout the year, refugia populations of aquatic species persist through seasonal droughts and even flourish during pluvial cycles and events. The last category of surface water types is the remaining desert springs and their attendant outflow runs and marshland systems (Hubbs, 1995) that typically harbor endemics or extremely limited range taxa. These spring systems often are individually distinctive in water volume and chemical parameters. Considered cumulatively across the desert, they include a wide range of dissolved mineral contents, thermal conditions and regimes and even subterranean aquifer linkages between other nearby springs.

HISTORY AND FOCUS OF THE NATURE CONSERVANCY IN AQUATIC CONSERVATION IN WEST TEXAS

Since 1990, The Nature Conservancy has operated a West Texas Program and office within the region, primarily to facilitate stewardship, administration and other organizational functions. The Nature Conservancy's conservation actions are predicated on its mission "to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive" and specifically within the region, the biodiversity of the Trans-Pecos and northern Chihuahuan Desert. Because much of the endemism and biological richness of the desert occurs at aquatic sites, the Conservancy focuses its conservation attention and resources on remaining springs and creeks with rare or endemic species and intact ecological function. Typically, sites were identified through the Natural Heritage Program database system of cataloguing and mapping biodiversity, specifically rare species' occurrences, across each state. Several of the conservation sites for The Nature Conservancy within the Trans Pecos region are established primarily for preservation of aquatic resources and systems, including endemics. These sites may be either the Conservancy's preserves owned in fee-title or private partnership lands upon which the Conservancy holds conservation easements with protective but consensual legally binding deed

restrictions. At some sites (see specific details below), notably Independence Creek and the Devils River, the Conservancy uses a combination of fee-ownership and easements on lands owned by others to affect conservation across a broader spatial scale than could be done by using only a single conservation tool. At others, The Nature Conservancy owns the preserve entirely, for example, Diamond Y Spring Preserve and Sandia Springs Preserve.

ECOREGIONAL PLANNING FOR THE CHIHUAHUAN DESERT

In the past few years, The Nature Conservancy has refined its conservation vision to focus on ecologically functional conservation areas within ecoregions (The Nature Conservancy, 2001). A functional conservation area includes either focal species, natural communities or entire ecological systems, and the supporting ecological processes necessary to sustain them over the long term (Poiani and Richter, 2000). This planning effort is called ecoregional planning and a designed conservation portfolio represents the full distribution and diversity of conservation elements (including native species, natural communities and ecological systems) within the ecoregion. Ecoregional planning is designed to maximize conservation of biodiversity within and across ecoregions, while optimizing critical resource allocation toward site-specific conservation actions by the Conservancy and its conservation partners.

The basic steps in ecoregional planning are: 1) identifying the species, communities and ecological systems, 2) setting specific goals for the number and distribution of these conservation elements to be captured by the portfolio, 3) assembling information and relevant data on the location and quality (contemporary status) of conservation elements, 4) designing a network of conservation areas that most effectively meets the goals, and 5) selecting the highest priority conservation areas in the portfolio for the Conservancy's action and involvement.

Although The Nature Conservancy has just initiated the Chihuahuan Desert ecoregional planning process, most of the aquatic elements of conservation concern (species, assemblages and communities) have been identified and many occur at what will be unequivocal portfolio sites for conservation action. The sites where the Conservancy is currently involved within the ecoregion reaffirm that early assessments about where biodiversity occurs on the land (and waters!) and past decisions about whether the Conservancy should work there, were in alignment with what is now termed ecoregional planning and "Conservation by Design". Future Conservancy "action sites" will undoubtedly include additional intact perennial or permanent pool stream segments and more mountain ranges with isolated springs with aquatic endemics or high composite conservation values based on species and communities.

DIAMOND Y SPRING PRESERVE

This 607-ha (1,502-acre) preserve, located about 20 km NNW of Fort Stockton, Pecos County, contains the sole naturally occurring population of the endangered Leon Springs pupfish (*Cyprinodon bovinus*). Originally described in the 1850s from the now obliterated Leon Springs area due west of Fort Stockton, the pupfish was not substantiated for nearly a century and was presumed extinct. Then in 1965, W. L. Minckley and W. E. Barber collected Leon Springs pupfish from Diamond Y Draw (see Echelle and Miller, 1974 for the historical account). With the rediscovery of the pupfish, academic and agency attention focused on the Diamond Y Spring area, and the importance of the site soon was found to include other aquatic taxa as well, including the federally endangered Pecos gambusia (*Gambusia nobilis*) and an obscure species of salt-tolerant sunflower (Pecos or puzzle sunflower, *Helianthus paradoxus*) growing in permanently hydric soils along the stream course. In addition, three species of aquatic and littoral zone snails also occur at the preserve. Two are endemic, the Diamond Y spring snail (*Tryonia circumstriata*, formerly *T. adamantina*,

Hershler et al., 1999) and the Gonzalez spring snail (*Tryonia stocktonensis*). The third species, Pecos assiminea (*Assiminea pecos*) has a wider distribution but is still essentially endemic to the middle Pecos River basin and was recently proposed for listing as federally endangered. Other groups that may be represented as endemics or at least genetically distinct forms in the Diamond Y Spring system include the amphipod genus *Gammarus* and an undescribed crayfish, both of which are under investigation currently.

Diamond Y Spring is a solution cavity in the middle of an alluvial basin with a stream outflow into an alkaline marshland. The stream flows across the preserve to the confluence with Leon Creek which ends there as a named topographic feature. Diamond Y Draw continues northeastward through the preserve and across Pecos County to the Pecos River. There are two primary stretches of surface water with the rare, aquatic species, one from the spring to and beyond the Leon Creek confluence, and a second reach about 2 km downstream to the north. Both reaches are augmented by small peripheral springs and seeps along their borders, and some of these harbor the endemic invertebrate fauna.

The Nature Conservancy acquired Diamond Y Spring Preserve in 1990, and began to initiate on-site stewardship almost immediately. The site is in an actively producing oil and gas field. Energy production companies have been partners by providing supporting funds for the purchase of the preserve and helped with certain safeguards for the protection of the surface waters from any contaminants that had threatened or plagued the site in the past. The measures included decommissioning buried corrosible metal pipelines in areas adjacent to vulnerable aquatic resources and their replacement with synthetic surface lines that could be easily monitored and repaired if necessary, as well as emergency shut-off valves installed at both sides of any creek crossings. At production sites, oil well pads were bermed to sufficiently contain any potential contaminant spill volume prior to detection. A matching grant in the mid-1990s from an energy producer and the National Fish and Wildlife Foundation provided the mechanism to remove some abandoned pad sites and their raised access roads from Diamond Y Draw which actually had impeded surface water flow through the marshland.

An urgent conservation issue arose when genetic contamination of the Leon Springs pupfish was detected with measurable introgression and both ecological and genetic competition from the introduced congeneric sheepshead minnow (*C. variegatus*) (Echelle and Echelle, 1997; Echelle et al., this volume). This genetic contamination had been addressed at Diamond Y Spring in the mid-1970s (Hubbs et al., 1978), but apparently persisted even after an intensive attempt to eradicate the exotic sheepshead minnows and hybrids. Another effort to eradicate the sheepshead minnow genome was initiated in the late 1990s and is presently ongoing. Investigators representing the Rio Grande Fishes Recovery Team outlined and implemented a restoration plan. The plan's sequential actions addressed the hybridization and competition issues through elimination of introgressed genomes and replacement with genetically pure Leon Springs pupfish stock from the reserve population held at Dexter National Fish Hatchery in Dexter, New Mexico. Preliminary results on the effectiveness of the genetic restoration are promising (A. A. Echelle, Oklahoma State University, pers. comm.). For additional discussion on the conservation and ecology of the Pecos gambusia and the elimination of the competitive exotic largespring gambusia (*Gambusia geiseri*), in the Diamond Y Spring system see Hubbs (this volume and Echelle et al. this volume).

Another conservation concern of paramount urgency is the pervasive threat to groundwater availability and spring discharge that sustains the suite of endemic and rare obligate aquatic species and communities at Diamond Y. Although the Conservancy has been effective at securing the immediate land around the spring and the watercourse with surface water, the issue of recharge and discharge volume is much larger than the presently protected land-base. Topographically, Leon Creek enters the property with minimal (and sporadic) surface runoff and some subirrigated flow through the valley alluvium. The creek headwaters and surface drainage basin begin at the now dry Leon Springs west of Fort Stockton and courses northeastward for approximately 16 km before entering the preserve. Surface flow of Leon Creek is ephemeral and seasonally episodic in the last km before the confluence with Diamond Y Draw, which does have permanent discharge from Diamond Y Spring and peripheral seeps (Veni, 1991). Surface water presently

only extends for perhaps another one km before disappearing in the alluvium. A. A. Echelle and S. E. Kennedy (pers. comm.) recall much more extensive surface flow during the 1970s, including relatively broad standing water "flats" downstream, depicted in Kennedy's (1977) map of the upstream segment. Emergent flows again appear on the surface approximately 2-3 km downstream with peripheral spring discharge supplementing the subirrigated alluvial flows in the valley floor at the northeastern end of the preserve.

The Conservancy and its conservation partners from agencies and academia face a tremendous challenge with the problematic perpetuation of the spring discharge and therefore the sustenance of the aquatic system and species. Groundwater recharge and aquifer interactions still are imperfectly defined for the entire area (Veni, 1991; Boghici, 1997; Boghici and Van Broekhoven, 2001), and long-term measures to ensure that discharge is sufficient to maintain the system's functional integrity and conservation values are not in place. There are crucial adjacent tracts the Conservancy should protect at the immediate preserve boundary but this does not adequately protect a system fed by an ostensibly large but beleaguered off-site aquifer and potentially huge recharge zone that likely covers hundreds of square kilometers. These broader groundwater issues will be addressed through the Conservancy's Site Conservation Planning process, a formal assessment of the conservation elements and threats with a strategic plan for permanent and effective conservation as well as through species specific Recovery Plans. However, each of these planning efforts will have to take on the complicated and controversial issue of groundwater that will have far-reaching political and economic implications.

The Conservancy's on-site stewardship has included aggressive salt cedar (*Tamarix ramosissima*) and mesquite (*Prosopis glandulosa*) control along the watercourse to reduce water consumption by these invasive species, both of which are relatively voracious water users. With the addition of prescribed fire, mechanical and judicious chemical treatment of these trees, this effort is to reduce as much superfluous water consumption as possible and retain it in the surface water segments of Diamond Y Draw.

SANDIA SPRING PRESERVE

At the northeastern outwash plain of the Davis Mountains is a complex, interrelated system of springs that include Phantom Lake, San Solomon, Giffin and Sandia springs as well as some relatively smaller seeps. Phantom Lake Spring is of grave conservation concern currently with virtually no outflow and consequently critical endangerment to the suite of aquatic rarities found in the immediate cave entrance, including Comanche Springs pupfish, Pecos gambusia and the invertebrate assemblage of snails and amphipods. San Solomon Spring in Balmorhea State Park has a strong discharge still, although heavily manipulated into a recreational impoundment and channelized outflows serving as pupfish refugia including a flow-through demonstration ciénega for public interpretation. Another portion of the spring complex just east of Balmorhea is East and West Sandia springs on 97 ha (240 acres) owned by the Conservancy. West Sandia Spring is a tiny spring, often with no apparent flow. It emanates from a cavity in the alluvial valley floor and the outflow channel is only several hundred meters in length with no known connection to either a larger drainage or even the irrigation canal system that surrounds it. Currently, no species of conservation concern are known from this system. However the larger East Sandia Springs, located several hundred meters to the east, does harbor species of concern including snails, amphipods, puzzle sunflower and Pecos gambusia with historical occurrences of Comanche Springs pupfish. It also contains aggressive native predatory species like green sunfish (*Lepomis cyanellus*), as does the San Solomon system, but they are relatively inconsequential to the rare fish species (Hubbs, 1993).

At Sandia Springs, the critical issues are the same as those facing all of the other springs in the Balmorhea complex as well as at Diamond Y Spring. Exotic saltcedar invasion draining shallow groundwater reserves and the possibility of sheepshead minnow genetic contamination of pupfish are two localized threats to the system's integrity. The mature saltcedars have been removed mechanically but rapid and recurrent

recruitment will require punctual, intensive and continuous control. The overarching conservation dilemma for the entire Balmorhea Spring complex is diminished spring flows, delineation of the recharge zone and replenishment rates of aquifer(s) that contribute to surface discharge. Until these questions are answered and comprehensive threat abatement strategies are designed and implemented, most localized and proximate land conservation efforts are myopic stopgap solutions at best.

INDEPENDENCE CREEK MEGASITE

The Pecos River is divided into two distinct segments in Texas from its entry at Red Bluff Reservoir on the New Mexico border to the confluence with the Rio Grande. Across the Pecos Plain (Permian Basin), the Pecos River is a slow, meandering river impacted by dewatering from diversions, groundwater withdrawal, saltcedar infestation and erosion (Hoagstrom, 2000). There is virtually no supplementary inflow from tributaries or springs. After entering the limestone canyonlands it has carved downstream of Iraan, it is augmented by very few perennial streams and some relatively small springs. Of these contributory sources, one of the most important in terms of both water quality and volume is Independence Creek, which merges with the Pecos River in Terrell County, approximately 45 km south of Sheffield.

Independence Creek has long been recognized as a biologically diverse site because of strong perennial instream flow and its riparian corridor. Ichthyologists have heralded Independence Creek as a clear, spring-fed refugium for the native Pecos River fish fauna, particularly as a repopulating source of the Pecos River following episodic and lethal mass fish mortalities resulting from red tides related to dinoflagellate (*Prymnesium parvum*) blooms. These recurrent outbreaks periodically decimate fish populations along stretches of the Pecos River. Independence Creek and only a few other smaller freshwater tributaries between Iraan and the Rio Grande confluence at Lake Amistad are reestablishment sources as native fishes return to the river after the effects of the red tide blooms have abated (Rhodes and Hubbs, 1992). The assemblage of native Pecos River fishes of conservation importance includes the Rio Grande darter (*Etheostoma grahami*), proserpine shiner (*Cyprinella proserpina*), headwater catfish (*Ictalurus lupus*). The shiner and darter recently have been confirmed in Independence Creek (Valdes, 1994; Karges, field notes, 2000-2001).

Independence Creek is only 16 km in length from its outflow source spring to the confluence with the Pecos River, although the catchment basin extends northwestward nearly to Fort Stockton in Pecos County. The site is called a megasite because of the Conservancy's recognition that it is not sufficient to conserve just a small area immediately around the creek but also an imperative opportunity to work at the landscape scale on a large and significant watershed which affects the creek's functional integrity. The Nature Conservancy's conservation actions at Independence Creek began with the 1990 acquisition of a 284-ha (702-acre) conservation easement with private landowners along the last 3.2 km of the creek including the Pecos River confluence. The easement is structured principally to eliminate degradation of the creek and adjacent riparian corridor, and to retain as much instream flow as possible. In 2000, the Conservancy acquired an 3517-ha (8,690-acre) ranch immediately upstream from the easement property, with the primary purpose of protecting an additional 4.8 km of surface water. The ranch also contains Caroline Springs, a significant, large volume instream source supplementing the creek. However, the springs have been impounded into two relatively large recreational lakes. These lakes, when combined with an additional source of evaporative loss through a large-scale aerial sprinkler array for lawns and channelized irrigation network for improved pastures, precludes much of the spring waters from rejoining the Independence Creek mainstem. Also, introduced large, predatory fishes including largemouth bass (*Micropterus salmoides*) and channel catfish (*Ictalurus punctatus*) in the reservoirs, could hinder the persistence of the native fishes.

The Conservancy is designing a water budget monitoring strategy for assessing water losses between the spring and the creek, with the goal of redirecting

water for conservation of the target species and restoring the strength and integrity of the creek. An additional acquisition of the next upstream ranch adds another 4.4 km of Independence Creek under the Conservancy's management and stewardship, leaving only the remaining 3.2 km from the headwaters without conservation protection. Another stewardship action to restore instream water volume along the managed reach of Independence Creek is the initiation of an aggressive saltcedar eradication campaign and reduction of the native, but pervasive, false willow (*Baccharis neglecta*), both of which rob water from the creek.

DOLAN FALLS/DEVILS RIVER MEGASITE

The Devils River is the next major Rio Grande tributary east of the Pecos, in the overlap zone between the Chihuahuan Desert to the west, the Edwards Plateau to the east and the Tamaulipan Thornscrub ecoregion to the south. This system is defined by a catchment basin that is relatively small on a continental scale. It is of considerable significance for both terrestrial and aquatic conservation elements that represent the biodiversity where these three ecoregions converge. The surface water of the Devils River extends for approximately 90 km from its headwaters to Lake Amistad on the Rio Grande, entirely within Val Verde County. The river is generally characterized by long flat-water pools of varying depths with slow-moving currents punctuated by broad, shallow riffles, stair-step cascades, and channelized flow constrained within the fluted bottom topography of the limestone bedrock. Just above Dolan Falls, Dolan Creek joins the Devils River with a substantial spring-fed contribution as the largest tributary along the river, although there are numerous spring-fed smaller rivulets and basal springs along much of the river between the headwaters and Lake Amistad. Neither dams nor pollution have yet impacted the Devils River, and it remains the most intact free-flowing river in West Texas (Harrell, 1978).

Texas Parks and Wildlife Department initiated the first conservation land acquisition along the river with a purchase of about 7,689 ha (19,000 acres) in the 1980s creating the Devils River State Natural Area. The purchase included 2 km of riverfront and the headwaters of Dolan Creek. Subsequently, The Nature Conservancy purchased the Dolan Falls Ranch, about 7,284 ha (18,000 acres) in 1991, protecting Dolan Creek from the headwaters to the confluence. This also encompassed land on either side of Dolan Falls, including nearly 6.4 km of riverfront on the Devils River. The integrity of the hydrology and its diverse biota in the contributing springs, creek and river has been the primary focus of both entities' land protection efforts. In 2000, the Conservancy also acquired the 8,903-ha (22,000-acre) Devils River Ranch downstream from Dolan Falls adjacent to Lake Amistad National Recreation Area, protecting an additional 19-km segment of the river that harbors the native fish fauna and other aquatic elements. All of the land conservation activity in this area includes terrestrial species and communities as well as abating local threats of development and subdivision within the watershed. The Nature Conservancy has developed a site conservation plan for the entire megasite, which includes much of the watershed but focuses specifically on the surface waters and immediate drainages of the surface water portion of the Devils River.

The formation of Lake Amistad in the late 1960s - early 1970s has impacted the fish fauna of the Trans-Pecos portion of the Rio Grande basin including its Pecos River and Devils River tributaries. Inundation of the confluences as the lake filled fragmented the contiguous distribution of the native guild of river-adapted fishes. Subsequent introduction of exotic predatory species such as striped bass (*Morone saxatilis*) and smallmouth bass (*Micropterus dolomieu*) has likely contributed to the decrease of some native species to some extent. Three native fish species are considered extirpated within the system and it is unlikely that residual populations or remaining suitable habitats exist in any peripheral areas. Most of the rare species of this riverine fauna require the flowing waters found in the Pecos and Devils rivers (Valdes Cantu and Winemiller, 1997). Three other rare fishes are associated with flowing waters of the Devils River, including proserpine shiner, Devils River minnow (*Dionda diaboli*) and Rio Grande darter, and popula-

tions have been confirmed in the Devils River recently (Garrett et al., 1992). Headwater catfish have also been confirmed in the last two decades from both the lower Pecos River (Kelsch and Hendricks, 1990) and Devils River system (Dolan Springs/Creek in 1980, Garrett et al., 1992). This species is morphologically very similar to the widespread and frequently introduced channel catfish, but is known principally from clear, spring-fed systems.

The Devils River below Dolan Falls is primarily lentic with only short reaches of swift water, riffles and limited suitable habitat for fishes requiring those conditions (Harrell, 1978). The local pupfish has been identified as the Conchos pupfish (*Cyprinodon eximius*) but may represent a disjunct, undescribed form that is endemic to the Devils River above the lake (Hubbs et al., 1991). The pupfish has been reestablished in Dolan Creek through introduction from populations in the Devils River (Hubbs and Garrett, 1990) and may be found in lentic pools along the Devils River downstream to at least Pafford's Crossing (Davis, 1980) and Big Satan Canyon (Karges, unpublished field notes). An additional aquatic species that may prove to be an undescribed endemic is a neotenic salamander in the genus *Eurycea*. A few specimens are known from springs along Dolan Creek.

Most of the on-site stewardship and monitoring actions related to aquatic conservation at Dolan Falls Preserve have been the continuation of periodic surveys of the fish fauna (Valdes Cantu and Winemiller, 1997; G. P. Garrett, Texas Parks and Wildlife Department, pers. comm.), aquatic invertebrate inventories, and in redirecting visitor use and foot traffic at the fragile micro-habitats at the spring outflows.

MADERA CANYON PRESERVE

Within the Davis Mountains, few perennial streams remain and of these, Little Aguja Canyon (Jeff Davis County) on the northern slopes is among the most important because of the presence of two aquatic species. The federally endangered Little Aguja pondweed (*Potamogeton clystocarpus*) is a cryptic species known only from this canyon, in plunge pools and subirrigated permanent pools along the middle and upper reaches of the drainage. Also in these permanent pools, the Rio Grande chub (*Gila pandora*) survives as the only relict population remaining in Texas (Miller and Hubbs, 1962). Although the species has not been collected in 16 years, 4 individuals were seen in a pool on the Conservancy's Madera Canyon Preserve in 2000 (Karges, unpublished field notes) and likely remains in other similar pools throughout the upper and middle sections of the canyon. The Nature Conservancy includes this area in the overall site conservation plan for the Davis Mountains which includes other rare aquatic species including Davis Mountains spring snail (*Fontilicella davisi*) (Taylor, 1987) and the possibility of reintroducing Rio Grande cutthroat trout (*Oncorhynchus clarki*) to Davis Mountains streams (Garrett and Matlock, 1991) if some highland streamcourses can be restored to perennially flowing montane systems with landscape scale watershed management to restore recharge and instream flows.

DEDICATION

This paper and my conference presentation are dedicated to the memory of Dr. W. L. Minckley for his contributions to desert fish research and conservation. Also, during a Chihuahuan Desert conference in Monterrey, Nuevo Leon (the only time we ever met), he recounted the delightful and intriguing story of his role in the rediscovery of the "extinct" Leon Springs pupfish.

ACKNOWLEDGEMENTS

I thank N. Allan, A. A. Echelle, A. F. Echelle, G. Garrett, C. Hoagstrom, and C. Hubbs for inspiration, challenging "brainstorms," invitations to participate in fieldwork and sharing their time, knowledge and exuberance for desert fish diversity and its conservation.

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Address of author:

JOHN KARGES

The Nature Conservancy
P.O. Box 2078
Fort Davis, TX 79734
email: jkarges@tnc.org