Chapter 13

Aquifer-Dependent Fishes of the Edwards Plateau Region

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Introduction

Texas is fortunate to have a wealth of water resources that support diverse natural ecosystems as well as human communities. To a large degree, water will determine the future of the State. From the driest deserts of West Texas to the wettest regions of the Gulf Coast, the quantity and quality of water drives population and economic growth as well as the rich biodiversity of wildlife. The underground water resources provide the foundation of the character of the land and the people who live within the Edwards Plateau.

Over the past century, development of the land and water resources of the Edwards Plateau has been limited primarily by economics and technology. Continued growth in the human population and advancements in technology are quickly removing these barriers and have brought the region to a crossroads that will determine the quality of life for future generations. For decades we have treated groundwater as if it were an endless supply of a renewable resource. The impacts of this approach are now evident: permanent loss of natural spring flows and headwater streams, declining instream flows of our rivers, and, ultimately, the degradation of freshwater inflows to our bays and estuaries. The aquifers of the Edwards Plateau are the source of the water that supplies the human and natural environments of Texas from the boundary with New Mexico to the Gulf Coast. In order to effectively consider the long-term conservation of these resources, we should consider the goal to be one of sustainable management. Alley and others (1999) defined sustainability as the "development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences." While groundwater is a renewable resource, it is not completely renewable in the same manner as wind or solar energy. The replenishment of groundwater usually takes place over long periods of time. The effects of which, therefore, may not be evident for considerable time and distance from the development activities. In other words, the actions taken today to utilize an aquifer may have

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unintended consequences many decades from now and many miles away. This reality necessitates that water planners take a broad, long-term assessment of each planned activity that affects aquifers. The actions taken in this region will have long-lasting implications throughout the State.

Regional planning efforts in this geographic area recognize that water supplies under current management scenarios are not likely sufficient to meet future water demands (RFWP, 2001; PRWP, 2001). Increasing water needs for agricultural, municipal, and industrial uses are expected to exceed anticipated supplies over the next 50 years, particularly during times of drought. While these plans acknowledge the region's rich ecological resources, such as rare fish and wildlife species, they also recognize that historic groundwater development and the resulting water-level declines have caused many springs to disappear, greatly diminished the flows from the springs that remain, and decreased flows from many tributary streams as well (RFWP, 2001; PRWP, 2001). However, there appear to be some inconsistencies, for example, "In most cases, ground water supplies have little impact on natural resources" (RFWP, 2001, p. 1-89). We believe this represents a misunderstanding about the relationship between groundwater and natural resources. Bridging this gap could be a significant step to improving the decision-making process by water planners.

Most water planning efforts give little consideration in the analysis of future water demands for the need to conserve the aquatic natural resources. Traditional human demands are presumed to be so great that we cannot afford to leave water in the stream and let it go downstream unused. We believe that to sustain the long-term health of our plant, wildlife, and fish communities, and also our human communities, we cannot afford not to provide water for our natural resources. Dry springs and rivers and sterile lakes and estuaries are too high a price to pay for short-term benefits.

In this paper we provide a review of the status of many of the important aquifer-dependent fishes found in the Edwards Plateau. These fishes occur both in the spring outlets that are directly dependent on aquifer levels to sustain their habitat and also in downstream rivers and streams that indirectly depend on groundwater. One characteristic that is of paramount importance to these environments is the overall stability of the physico-chemical environment, especially water temperature. This factor is often one of the primary determinants of the makeup of species assemblages. However, all aquatic-dependent plants and wildlife in the Edwards Plateau area rely on these aquifers to support essential components of their habitats.

We have chosen these fish species for review because they provide a summary assessment of the state of the natural resources of the Edwards Plateau. This is not a comprehensive list of fishes that occur in the area. For a comprehensive review of Texas fishes, see Hubbs and others (1991). We have separated the reviews into three categories: extirpated or extinct, species of concern, and indicator species. *Extirpated or extinct* are those fishes that no longer occur in Texas. Extirpated indicates the species still occurs outside the State; extinct means the species no longer exists anywhere. *Species of concern* are those species that are in some way threatened with extinction due to such conditions as few populations, limited or reduced range, or significant threats to habitats or populations. Many of these species are protected as threatened or endangered at either the State or Federal level, or both. *Indicator species* are not necessarily considered threatened, but are a unique component of the region's native fish fauna and are dependent upon aquifer discharges. Their status is a direct indicator of the overall health of the ecosystem.

Extirpated or Extinct

Rio Grande silvery minnows (*Hybognathus amarus*) originally occupied nearly all of the Rio Grande from near Embudo (New Mexico) downstream to Brownsville (Texas/Mexico) and in the Pecos River from near Santa Rosa (New Mexico) downstream to its confluence with the Rio Grande. Today, it is only found in a very limited portion of its range: a 275-km stretch of the Rio Grande between Cochiti Reservoir downstream to Elephant Butte Reservoir in central New Mexico (Bestgen and Platania, 1991). This species is a pelagic spawner, often timing their reproduction to flash flood events. The eggs and larvae often drift considerable distances downstream and need flowing water to survive these early life history stages (Platania and Altenbach, 1998). In part because of its great original geographic distribution, the reasons for their decline are many. Major factors include dewatering of streamcourses, water-flow changes due to reservoir construction, channelization and other modification of streams, and water-quality degradations (U.S. Fish and Wildlife Service, 1999).

Phantom shiners (*Notropis orca*) were originally found throughout the Rio Grande in Texas but are now extinct (Miller and others, 1989). Biological requirements are not known as only one specimen has been collected in the last 50 years. Factors attributed to the extinction include pollution, damming, and dewatering (Miller and others, 1989).

The Amistad gambusia (*Gambusia amistadensis*) was found in Goodenough Springs in Val Verde County, Texas, and the 1.3-km spring run downstream to its confluence with the Rio Grande (Peden, 1973). The species became extinct in the wild when the springs, once the third largest spring system in Texas, were inundated by Amistad Reservoir after the dam gates were closed in 1968 (Peden, 1973; Brune, 1981). The warm spring run, coming from the Edwards-Trinity aquifer (Peckham, 1963), rapidly flowed over limestone gravel and sand substrates along its course to the Rio Grande, and the spring had recorded flow of between 2,000 to 4,000 liters per second (70 to 140 cubic feet per second) (Brune, 1981). The habitat for the Amistad gambusia is now completely submerged by Amistad Reservoir, and the former spring openings are now recharge zones (Peden, 1973; Brune, 1981). Culture populations of *G. amistadensis* were maintained until the late 1970s at The University of Texas at Austin and at the U.S. Fish and Wildlife Service's endangered species culture facility in Dexter, New Mexico. However, these populations became contaminated by western mosquitofish (*Gambusia affinis*), which eliminated the *G. amistadensis* in these cultures sometime prior to 1983 (Hubbs and Jensen, 1984) and caused the final extinction of the species.

The blotched gambusia (*Gambusia senilis*) is a common member of the fish assemblages in the Rio Conchos and its tributaries in Chihuahua, Mexico. However, a disjunct population once inhabited the Devils River in Texas. Although infrequently collected, this population was probably extirpated shortly after Amistad Reservoir was constructed and their habitat was inundated as none have been taken since that time (Hubbs and others, 1991).

Species of Concern

The Devils River minnow (*Dionda diaboli*) is a rare species with a limited distribution. It is currently found in the Devils River, San Felipe, Sycamore, and Pinto creeks in Texas and perhaps the ríos Salado and San Carlos drainages in Mexico. It has been extirpated from Las Moras Creek, and possibly Sycamore Creek, because of reduced water quantity and quality (Garrett and others, 1992; Garrett and others, in press). Its range was reduced in the lower Devils River due to the construction and subsequent filling of Amistad Reservoir and in the upper Devils River (upstream of Pecan Springs) due to lack of stream flow. Many springs in the area have diminished flows; some have totally stopped (for example, Willow Springs, Beaver Springs, Juno Springs, and Dead Man’s Hole), thus reducing the overall length of the Devils River as well as the quantity of water flowing in it. Many of the perennial streams (Gray, 1919) of the area no longer flow. U.S. Geological Survey data from the Paffords Crossing gauging station on the Devils River reveal a general decrease in daily mean discharge for the period between the study by Harrell (1978) and that of Garrett and others (1992). Brune (1981) attributes the reduced spring flows in this area to heavy pumping from wells and overgrazed soils with lowered capacity to absorb water and thus recharge aquifers.

In 1989, Devils River minnows were rare throughout their remaining range compared to past collections (Garrett and others, 1992). In 25 sampling locations within the historic range, only 7 specimens were collected in the Devils River and San Felipe and Sycamore creeks, and data indicated the species had decreased in both absolute numbers and relative abundance. The Devils River minnow was the fifth-most abundant species in 1953 at Baker’s Crossing on the Devils River (Hubbs and Brown, 1956); sixth-most abundant species in the river in 1974 (Harrell, 1978); and one of the least abundant species in 1989 (Garrett and others, 1992). Our recent collections (2000 to 2003) in the Devils River and San Felipe Creek indicate their numbers have increased substantially, although the reasons for the population increase are unresolved.

A Conservation Agreement was developed in 1998 among the Texas Parks and Wildlife Department, the City of Del Rio, and the U.S. Fish and Wildlife Service that was designed to “eliminate or significantly reduce the probability that potential threats to the minnow will actually harm this species and to recover populations of the minnow to viable levels.” In addition, the Texas Parks and Wildlife Department and The Nature Conservancy of Texas now own a critical subset of the range of *D. diaboli*. However, no protection to the aquifers is afforded by these actions, and thus, threats remain.

Proserpine shiners (*Cyprinella proserpina*) are found in the spring-influenced rocky runs and pool habitats within its limited range, which originally included the Devils and lower Pecos rivers; Las Moras, Pinto, and San Felipe creeks in Texas; and the Río San Carlos in

Mexico (Matthews, 1980). This species has apparently been extirpated and replaced by *C. lutrensis* in Las Moras and Pinto creeks and its status in the Río San Carlos is unknown. Replacement was likely due to declines in water quality and quantity. It is a state-protected species and is also protected in Mexico.

Tamaulipas shiners (*Notropis braytoni*) are endemic to the Rio Grande (including the lower Pecos River) in Texas and Río Conchos in Mexico. Habitat preference includes rocky and sandy channels of large creeks and small to medium rivers (Page and Burr, 1991). Population abundance in Texas has declined in recent decades (Hubbs and others, 1991), with collections during the 1990s yielding no Tamaulipas shiners below Amistad Reservoir to the mouth of the river. The decline in abundance is likely due to reservoir construction, dewatering of stream courses, and decreases in water quantity and quality.

Rio Grande shiners (*Notropis jemezanus*) are endemic to the Rio Grande basin and were once abundant throughout the basin (Treviño-Robinson, 1955, 1959). This minnow inhabits larger streams in areas with gravel, sand, or rubble bottoms. They are pelagic spawners and their eggs and larvae can drift considerable distances downstream (Platania and Altenbach, 1998). The species has declined in recent decades due to reservoir construction, dewatering of stream courses, and decreases in water quantity and quality. Rio Grande shiners are now found in the Rio Grande downstream from the Río Conchos confluence to Amistad Reservoir; the lower Pecos River in Texas; and the ríos Conchos, San Juan, and Salado in Mexico (Hubbs and others, 1991). None have been taken below Amistad Reservoir in the last 10 years (personal observations).

The blue sucker (*Cycleptus elongatus*) is a state-threatened species. It is a big river fish found throughout the Mississippi Basin and large streams of Texas. Because these systems suffer from impoundment, pollution, and reduced water flows, abundances have decreased. The Rio Grande population is thought to be a different, as yet undescribed, species (Buth and Mayden, 2001).

Headwater catfish (*Ictalurus lupus*) are found in the clear, headwater habitats in the Pecos and Rio Grande basins of Texas, New Mexico, and Mexico. This species also was once found in the upper Nueces, San Antonio, Guadalupe, and Colorado basins, although the last appears to be from introductions (Conner and Suttkus, 1986; Hubbs and others, 1991). Regardless, the species appears to be extirpated from all of these systems (Kelsch and Hendricks, 1990). Because of habitat alterations and possible competition from channel catfish (*I. punctatus*), the species seems to have greatly reduced range in New Mexico (Sublette and others, 1990) and has only a limited range in Texas (Hubbs and others, 1991).

The Clear Creek gambusia (*Gambusia heterochir*) is listed as federally endangered by the United States and endangered by the state of Texas and was one of the first fishes recognized as endangered in the nation's original endangered species legislation (U.S. Fish and Wildlife Service, 1967). The species was first collected in the headwaters of Clear Creek, which arise from a series of springs emanating from the base of a limestone bluff in Menard County, Texas, and flow into the San Saba River.

The species primarily occupies the 1-hectare head pool formed by a small earthen dam built in 1880. In 1933, another dam was constructed downstream from the head pool forming a much larger pool that adjoins the uppermost dam. This downstream pool is occupied by large numbers of western mosquitofish (*G. affinis*) native to the San Saba River, which compete and hybridize with *G. heterochir* (Hubbs, 1957a). The two species of *Gambusia* occupy different environmental conditions: the spring head pool, favoring *G. heterochir*, has stenothermal waters with a pH near 7, while the downstream pool, just below the uppermost dam, has eurythermal waters with a pH near 8, favoring *G. affinis*. Although each species can do well in either environment, competitive interactions favor each species in their respective environments (Hubbs, 1971).

Although the two species differ in reproductive anatomy and behavior, those differences are not sufficient to preclude hybridization (Peden, 1970) and a long-standing hybrid swarm became established. By the late 1970s, the 1880 dam began to collapse allowing large numbers of *G. affinis* access to the uppermost spring pool. The dam was repaired, using primarily University of Texas graduate student labor, and the source of *G. affinis* ingress was blocked in 1980. Since then, hybridization frequency and competition has been drastically reduced (Edwards and Hubbs, 1985). At present, *G. heterochir* is very abundant in the head pool, but, because it is dependent upon the spring environment, it is potentially threatened by diminished spring flows from water withdrawals from the Edwards-Trinity aquifer. The U.S. Fish and Wildlife Service and the Rio Grande Fishes Recovery Team have developed a recovery plan for this species (U.S. Fish and Wildlife Service, 1982).

The San Felipe gambusia (*Gambusia* sp.) are found in San Felipe Creek, a spring-fed Rio Grande tributary in Del Rio, Texas. This species is a member of the *G. nobilis* species group and is differentiated from the rest of the members of this group by a combination of morphometric and pigmentation characters (Garrett and Edwards, 2003). It inhabits thermally consistent spring-flows and is apparently most common in edge habitats adjacent to flowing waters.

San Felipe Creek is an urban stream that has been modified over the years for bank stabilization, flood control, public access, road bridges, and diversion of irrigation water. Potential water-quality problems in the form of elevated levels of nitrates, phosphates, and orthophosphate in San Felipe Creek have been found (Texas Natural Resource Conservation Commission, 1994), and land uses in the immediate area of the springs and creek, such as runoff from the municipal golf course, may have contributed to these conditions.

Very little is known concerning the ecology of this species. The San Felipe gambusia appears to prefer edge or quiet water habitats in close association to areas with significant spring flows. It is thought that this species has long been present in San Felipe Creek, but in recent decades the numbers were low and perhaps associated with an as yet unidentified and rare habitat. Other rare species, including the federally-threatened Devils River minnow, *Dionda diaboli*, and the state-threatened proserpine shiner (*Cyprinella proserpina*) and Rio Grande darter (*Etheostoma grahami*), also occur in San Felipe Creek. In an effort to aid in the conservation of *D. diaboli*, the City of Del Rio and the

San Felipe Country Club have developed watershed management plans designed to better protect the creek environment. Some specific activities have been a reduction in fertilizer application and the establishment of a buffer zone along the creek banks where native vegetation can be restored. In 1998, a large flood caused considerable damage to portions of Del Rio and thoroughly flushed the creek system. We speculate that the progressive actions in the upper headsprings and the ecosystem flushing may have improved the environment in the creek to the extent that the previously restricted population of San Felipe gambusia was allowed to increase dramatically. A substantial increase in the Devils River minnow population was also noticed during this period. We assume the species is like all other spring-dependent fishes and its survival depends upon the stability of this habitat.

The Conchos pupfish (*Cyprinodon eximius*) is a state-threatened species occurring in the Río Conchos basin of Mexico and tributaries of the Rio Grande in Texas and Mexico (Echelle and Echelle, 1998). Some of these populations may be subspecifically distinct (Miller, 1976). *Cyprinodon eximius* was first taken in the Devils River during surveys by the Texas Game and Fish Commission in 1953 (Hubbs and Garrett, 1990). Subsequent human activities (for example, reservoir filling and stream rotenoning) reduced the Texas range to a small portion of the Devils River. In 1979, approximately 200 individuals from the remaining population were transported upstream, above a large waterfall, to reestablish them in one of their previous locations, Dolan Creek (Garrett, 1980; Hubbs and Garrett, 1990). The Texas Parks and Wildlife Department and The Nature Conservancy now own most of Dolan Creek and adjacent habitats in the Devils River. However, Conchos pupfish inhabit environments with limited amounts of water that are facing increasing threats from a growing human population. As the region becomes more urbanized, many aquatic environments will be modified to accommodate this growth.

The Pecos pupfish (*Cyprinodon pecosensis*) is listed as threatened by Texas and New Mexico. Originally occurring in the Pecos River system from Roswell, New Mexico, to Independence Creek, Terrell County, Texas, its range is now restricted to just a few locations (Propst, 1999). During 1954, Pecos pupfish were the most abundant fish in the Pecos River between New Mexico and Sheffield, Texas (Echelle and others, 1997). Abundance has declined dramatically since the early 1980s when non-native sheepshead minnows (*C. variegatus*) were inadvertently introduced into the Pecos River in Texas. As a result, *C. pecosensis* has been eliminated from the lower Pecos River as far upstream as Loving, New Mexico and replaced by a hybrid swarm (Echelle and others, 1997). Occurring in a variety of habitats and water-quality conditions, ranging from highly saline sinkholes to typical desert streams, their distribution is mostly limited by interspecific interactions (Echelle and Echelle, 1978). The imperiled status is due to habitat losses and especially to hybridization with introduced *C. variegatus*. A Conservation Agreement initiated in 1999 is designed to reduce threats to the species and establish populations in newly created habitats adjacent to the Pecos River. As with the Conchos pupfish, it relies upon a diminishing habitat.

The Guadalupe bass (*Micropterus treculi*) is a Central Texas endemic, occurring only in streams draining the Edwards Plateau region (Hubbs, 1957b). The native range includes streams of the San Antonio, Guadalupe, Colorado, and Brazos river systems. It also has been transplanted into the headwaters of the Nueces River (Edwards, 1980). In 1989, it was designated the State Fish of Texas by the Texas Legislature in recognition of the unique character of both the Guadalupe bass and its habitat.

Edwards (1980) determined many of the critical components of Guadalupe bass life history, including their preference for flowing waters of streams, between 2 and 10-m in width and in association with large rocks, cypress roots, stumps, and similar types of cover. They are usually found in waters with annual thermal fluctuations of 4 to 35 degrees C, but not in thermally stable, headspring-influenced locations, where largemouth bass (*M. salmoides*) predominate. Guadalupe bass overwinter in deep pools with currents; they spawn in quiet, shallow areas near a source of moving water; and their young occupy gradually swifter and deeper waters as they grow. Each of these life history traits, and probably several others, contribute to the allotopic distribution of Guadalupe bass and largemouth bass within the streams of Central Texas.

Hubbs (1976) indicated by classifying this species as "depleted" that numbers of Guadalupe bass have decreased substantially in recent history. The decline is due to a variety of factors, including decreased stream flow, reservoir construction, habitat degradation (Hurst and others, 1975; Edwards, 1978) and hybridization with smallmouth bass, *M. dolomieu* (Edwards, 1979, 1980; Garrett, 1991). For similar reasons, Guadalupe bass was listed as a species of special concern by Deacon and others (1979), Johnson (1987), Williams and others (1989), and Hubbs and others (1991).

Habitat loss and genetic contamination problems now exist throughout the range of Guadalupe bass. Stream-flow declines and habitat quality degradation are ubiquitous problems and are likely to continue due to human cultural activities and population growth (Edwards and others, 1989). Reservoir construction not only reduces available habitat, but also enables the proliferation of more lacustrine-adapted fish species, which displace Guadalupe bass.

Smallmouth bass are similar in life history to Guadalupe bass, and the two species lack reproductive isolating mechanisms (Garrett, 1991). In 1974, Texas Parks and Wildlife initiated an intensive smallmouth bass stocking program in the Edwards Plateau region with the objective of increasing angler harvest in Central Texas streams and reservoirs (Garrett, 1985). An unforeseen result of the stocking program was hybridization between these two allopatrically-evolved species (Edwards, 1979, 1980; Whitmore and Butler, 1982; Whitmore, 1983; Garrett, 1985, 1991). This genetic introgression may ultimately prove to be the most serious threat to the existence of Guadalupe bass.

An electrophoretic examination of *M. treculi* in 1989 showed extensive, introgressive hybridization with smallmouth bass in almost every Guadalupe bass stream system (Garrett, 1991). Allele frequencies at diagnostic loci for the two species revealed populations that were 20% - 46% hybrids throughout the range. Only six tributary streams (four in the native range, two introduced) were found to contain pure populations of *M. treculi*. Although Texas Parks and Wildlife Department now has a policy of not stocking smallmouth bass within the native range of Guadalupe bass, existing hybrid levels are problematic.

Since 1992, Texas Parks and Wildlife Department has been evaluating a stocking program whereby pure *M. treculi* are introduced into a contaminated river system in order to reestablish a dominant *M. treculi* population by displacing hybrids.

Rio Grande darters (*Etheostoma grahami*) inhabit the mainstream and spring-fed tributaries of the lower Pecos River and the Rio Grande downstream from their confluence, the Devils River and Dolan, San Felipe, and Sycamore creeks in the U.S. (Hubbs and others, 1991). They also occur in the headwaters of the ríos San Juan and Salado, Mexico (Harrell, 1980). This is a state-protected species because of its limited range and its dependence upon spring-fed habitats in flowing streams.

Indicator Species

The plateau shiner (*Cyprinella lepida*) is a Texas endemic that inhabits clear spring-fed streams over gravel and limestone substrates in the Nueces River Basin in the Edwards Plateau where it is moderately abundant. According to Mayden (1989), this species is also endemic to the upper reaches of the Guadalupe River Basin, although this is undergoing further investigation. A genetic study by Richardson and Gold (1995) found that *C. lepida* in the Frio and Sabinal rivers is a different species from the "*C. lepida*" in the Nueces River and that abundance appeared to have decreased considerably over the previous twenty years. A potential nomenclatural problem has arisen since the original description of the species came from specimens taken from the Frio River, while the majority of the morphological information on the species has come from Nueces River specimens (Matthews, 1987).

Manantial roundnose minnows (*Dionda argentosa*) are a sympatric congener of the Devils River minnow. They are limited to the spring-influenced waters of the Devils River, San Felipe, and Sycamore creeks (Hubbs and others, 1991). Although they have a limited distribution, they are abundant throughout these locations and, therefore, not legally protected. Reductions in water quantity and/or quality could easily change their status, but hopefully conservation efforts to recover the Devils River minnow will also benefit the manantial roundnose minnow.

The Nueces roundnose minnow (*Dionda serena*) is endemic to the spring-fed headwaters of the Nueces River Basin (Hubbs and others, 1991). It is apparently an ecological equivalent and perhaps closely related to the Devils River minnow. Although it has a limited distribution, it is abundant throughout these locations and, therefore, not legally protected. Reductions in water quantity and/or quality could easily change their status.

The Guadalupe roundnose minnow (*Dionda nigrotaeniata*) is endemic to the spring-fed headwaters of the Guadalupe and Colorado river basins. It is apparently an ecological equivalent and perhaps closely related to the roundnose minnow (*D. episcopa*). This species prefers habitat immediately downstream from springs and is primarily restricted to these habitats (Hubbs and others, 1953). In good environments, this species is common and abundant.

The speckled chub (*Macrhybopsis aestivalis*) is found in Texas streams from the Red River to the Rio Grande. Under good habitat conditions, it is common in flowing water with a sand or gravelly substrate and prefers turbid, riffle conditions (Hubbs and others, 1953).

The Texas shiner (*Notropis amabilis*) is one of the most common inhabitants of Edwards Plateau streams. It ranges throughout the swift-moving, spring-fed streams of the Edwards Plateau from the San Gabriel River on the northeast to the Pecos River in the west. The species is also found in Rio Grande tributaries in Mexico, including the ríos Salado and San Juan.

The species is abundant in streams with significant spring-flow components and is rarely found in the upstream portions of smaller tributary creeks. Texas shiners are often found in moderately large schools in midwater in streams with moderately fast currents. Oftentimes, this species can be found in the upstream ends of pools below riffle areas, in the swiftly moving waters along gravel bars and in moderately flowing pools. It is also commonly encountered in areas below low-water dams and road crossings where there is turbulent water flow creating eddy habitats. Where they are sympatric with red shiners (*Cyprinella lutrensis*) and blacktail shiners (*C. venusta*), Texas shiners generally select areas with a greater current velocity than the other minnows and also tend to maintain their school integrity to a greater extent than the red or blacktail shiners (Edwards, 1997).

Longnose dace (*Rhinichthys cataractae*) occur throughout the Rio Grande in Texas downstream to about Laredo (Hubbs and others, 1991). It is primarily found among rocks in gravel-rock substrates in flowing water (Sublette and others, 1990) where they feed on a variety of aquatic invertebrates, especially ephemeropterans and dipterans, as well as plant material (Gerald, 1966).

Greenthroat darters (*Etheostoma lepidum*) are common inhabitants of Edwards Plateau streams, especially spring-influenced headwaters in the Colorado River southward to the Nueces River basin (Hubbs and others, 1991). Additionally, a disjunct series of populations inhabit tributaries of the Pecos River in New Mexico (Sublette and others, 1990). In the Edwards Plateau streams, greenthroat darters are typically found in association with aquatic vegetation, over the slightly silted substrates found near spring sources, in addition to more riffle-like habitats.

Dusky darters (*Percina sciera apristis*) are a subspecies endemic to the Guadalupe River basin (Hubbs, 1954). This fish is specialized for fast flowing water over gravel substrate (Page and Burr, 1991) and deeper, boulder-strewn riffles (Hubbs and others, 1953).

Summary

It is evident that fish, along with other aquatic-dependent plant and wildlife species, need water to survive. Somewhat more difficult to demonstrate in many cases is the complex relationship between aquifer levels and surface-water flows. Even more challenging is defining the relationship between declining instream flows and unhealthy fish populations. Often there are many interrelated factors that affect how the quantity and quality of surface-water flows affect fish populations. In most cases, the science is not available to conclusively predict these kinds of complex relationships. However, we do know that when streams dry up, fish disappear. And somewhere between natural flow regimes and dry riverbeds, populations of plants, fish, and wildlife will suffer or even perish from changes in habitat when stream flows decline.

Springs are particularly unique habitats, often isolated from other similar environments. This has led to the evolution of exceptionally rare and unique species, such as the Clear Creek gambusia. These kinds of native Texas fishes are invaluable components of unique ecosystems whose conservation should be emphasized. The value of these and other species extends beyond their intrinsic worth, because they also serve as reminders that the existence of water resources is not guaranteed. Only our stewardship can prevent the permanent loss of a unique fish population in a natural stretch of stream. While we may not suffer directly from the loss of any particular fish population, it may be the first step in the disappearance of a larger resource. For example, the supporting underground aquifer may in time also be at risk without thoughtful management. Eventually, the water lost to the fish may be lost to the human community and greater efforts will be needed to find and pay for enough water to support human consumptive needs.

Management of the aquifers of the Edwards Plateau can go beyond the simple development approaches of the past that promote increasing the capacity of wells to withdraw more water and building more facilities to store it. The demands on the water resources can be managed as well to include emphasis on water conservation practices by the consumers. The luxury of unlimited, inexpensive water availability, regardless of the need, is a thing of the past. Human populations and water demands have increased with time and those responsible for managing growth (agricultural, municipal, and industrial segments of society) should strive for a sustainable intensity of water consumption at the local and regional level. Sustainable groundwater use will ensure the future, long-term vigor of the natural ecosystems that depend on these resources as well as our own quality of life. Responsible management of the waters from the aquifers of the Edwards Plateau conserves regional spring flows that maintain flowing rivers and allow healthy fish populations to persist. The consequences of our actions will be manifest for generations to come, even to those who may never see the fishes.

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