OUR DISAPPEARING DESERT FISHES

BY DAVID L. SOLTZ

Deserts with aquatic habitats and fish? It seems impossible but, even in places as arid as Death Valley, green patches on the horizon indicate areas where the water table is near the surface along faults or over impermeable clay or rock strata. In these isolated springs, streams, or marshes, fish have managed to persist and even flourish in the midst of the sun-baked desert. The life history of some of these fishes is a fascinating story.

At the end of the Pleistocene Epoch, 10,000 to 20,000 years ago, the glaciers that covered much of North America receded for the last time. The southwestern portion of the continent, although untouched by glaciation except in some of the highest mountains, was much cooler than today and surface water was abundant. The Colorado River drainage was tremendous, cutting the Grand Canyon as it rushed to the Gulf of California. The State of Arizona was criss-crossed with the Colorado's tributaries, such as the Gila, Salt, and Bill Williams Rivers. There were myriad internal drainages containing lakes that are now the dry valleys of the Great Basin. Lake Manley, receiving water from the Owens, Amargosa, and Mojave Rivers, formed in Death Valley. At its maximum extent, Lake Manley filled the valley to a depth of over 650 feet. Fishes were surely widely distributed within and between these drainage systems.

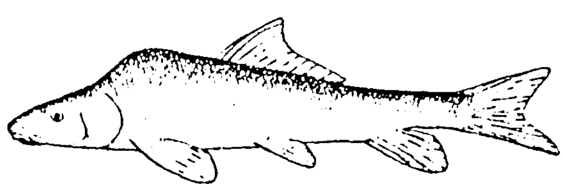
About 10,000 years ago a drying trend began. The major lakes and rivers today are greatly reduced and most aquatic habitats have dried completely. During this time the deserts of the American Southwest formed. A few large rivers, like the Colorado and its major tributaries, persisted. However, most waters shrank away leaving only isolated, small streams and springs as refuges for remnants of the once abundant aquatic life.

Today, these isolated springs and streams are "islands" in a "sea" of desert. The many distinct species and subspecies of pupfish and killifish that have evolved in isolated aquatic islands of the Death Valley System provide scientists with a small scale natural laboratory similar to the Galapagos Islands that so strongly influenced the thinking of Charles Darwin. Today there are more than 20 populations of pupfish in the Death Valley System that have evolved into 10 distinct species or subspecies. Each species of pupfish has taken on a distinct shape and markings as well as a unique set of biological adaptations.

The pupfishes of the Death Valley System are an example of the differentiation and evolution of desert fishes. Ancestral pupfish presumably inhabited shallow lake margins, marshes, and streams where environmental parameters (temperature, salinity, dissolved oxygen, etc.) fluctuated daily and seasonally. These pupfish were probably highly variable in character and were able to withstand wide environmental extremes. Today some Death Valley pupfish populations are isolated in extremely variable environments, like the Amargosa River and Salt Creek. Others are isolated in stable springs with constant temperature, such as Devils Hole, School Spring, and The Nature Conservancy's Big Spring. In isolation there is no interbreeding between populations, and selection pressures of the different environments gradually act on the genetic make-up of populations. Slow evolution into different species and subspecies results, with each species adapted to a specific isolated habitat. The most divergent pupfishes of the Death Valley System are those isolated for the longest periods (more than 10,000 years). The Owens pupfish (*Cyprinodon radiosus*), found most distant from the center of pupfish distribution, and Devils Hole pupfish (*Cyprinodon diabolis*), existing in a higher, inaccessible habitat, are two such examples. In contrast, Amargosa pupfish (*Cyprinodon nevadensis*) habitats have been intermittently connected, reducing the length of isolation to spans ranging from 400 to 5,000 years. Consequently the Amargosa pupfish has changed less than others, evolving into several subspecies but not into distinct species.

The unique quality of desert fishes stems from their isolated evolution in a harsh desert environment. Each species or group of species has adapted to its specific aquatic world, which varies widely in the few remaining lakes, in rivers like the Colorado, in the abundant streams of Arizona and New Mexico, in marshes, or in the springs of California and Nevada.

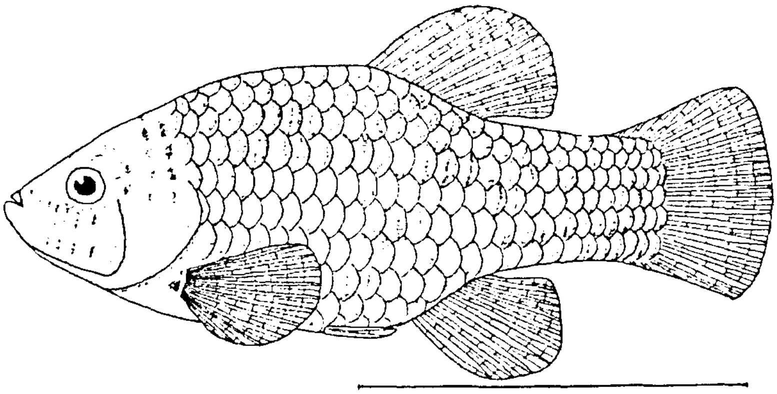
HUMPBACK SUCKER, *Xyrauchen texanus*



DESERT PUPFISH

Cyprinodon macularius

Cyprinodon = tooth carp
macularius = spotty



Of the lakes, very few persist today. A rare habitat like Pyramid Lake in Nevada should act as a refuge for some of the large species of fishes that were widespread during the Pleistocene. Unfortunately, a dam built for irrigation and the resultant lowering of Pyramid by almost 100 feet has long since ended the spawning runs of Lahontan cutthroat trout (*Salmo clarki*). Two other, once abundant fish--the tui chub (*Gila bicolor*) and the endangered cui-cui (*Chasmistes cujus*)--have been nearly wiped out of the lake by loss of spawning and feeding habitat.

The lower Colorado River and a major tributary, the Gila River, were naturally turbid, strong-flowing rivers varying tremendously with the seasons and supporting vast marshes along their courses. Their fast-flowing, gravel-bottomed main channels supported a number of large, specialized fishes of the minnow (*Cyprinidae*) and sucker (*Catostomidae*) families. Most spectacular of these is a huge minnow, the Colorado River squawfish (*Ptychocheilus luceus*), a giant predatory fish, known locally as the Colorado salmon, that used to reach a length of 6 feet. They lived and spawned in the deepest, swiftest portions of the main river channels.

Several Colorado River fishes have an unusual adaptation--an extremely pronounced hump on the dorsal surface immediately behind the head, which allows them to stay in position on the bottom while feeding in fast water. The hump acts as a barrier to passing water, forcing the fish's body against the bottom. This bizarre adaptation is best developed in the humpback chub (*Gila cypha*) and razorback sucker (*Xyrauchen texanus*).

The Colorado River has been altered drastically by a series of huge dams constructed for water diversion and hydro-electric power production. Today the river and its tributaries are essentially channelized canals, with greatly reduced flows, lacking seasonal variation but receiving abnormally cold water released irregularly from the bottom of reservoirs. Virtually the entire lower Colorado is now nothing like the natural environment in which its fish communities evolved. Miraculously none of the native fishes have been totally exterminated, though all native fish populations are greatly reduced. Some of the larger species are on the verge of extinction, two are officially endangered species, and most are confined to the few remaining areas that have nearly natural feeding and spawning conditions in the Grand Canyon and some portions of the upper river basin.

The Colorado River originates from high elevation, crystal-clear, cool tributaries that do not support the desert species. Many of these headwaters are isolated in mountain islands surrounded by desert and often support native trout. These trout are probably derivatives of the once widespread cutthroat trout. Many of them have evolved brilliant colorations. Several "desert trout" populations are threatened by water diversion and hybridization with rainbow trout which ill-advisedly have been introduced into many isolated mountain streams for sport fishing. Some "desert trout" are already gone and others probably will be lost.

Most fish in the southwestern desert today live in small streams that are common in the Death Valley System and throughout Arizona and New Mexico. Desert streams are variable and unpredictable, drying during summer to a series of disconnected pools, swelling in a few hours to the flash floods for which the southwest is famous. Flooding is disastrous to fishes and aquatic invertebrates, particularly the smaller ones, battering and isolating them downstream away from their chosen homes or in side pools that evaporate when the flood recedes. Disaster comes very quickly. After one day of rain in September 1972, the Amargosa River rose from less than a 1-inch trickle through a road-crossing culvert to a torrent that completely washed out the road. Interestingly, the fishes often balance these flood disasters with immediate spawning. I have seen the Amargosa River teeming with young pupfish two weeks after a flood.

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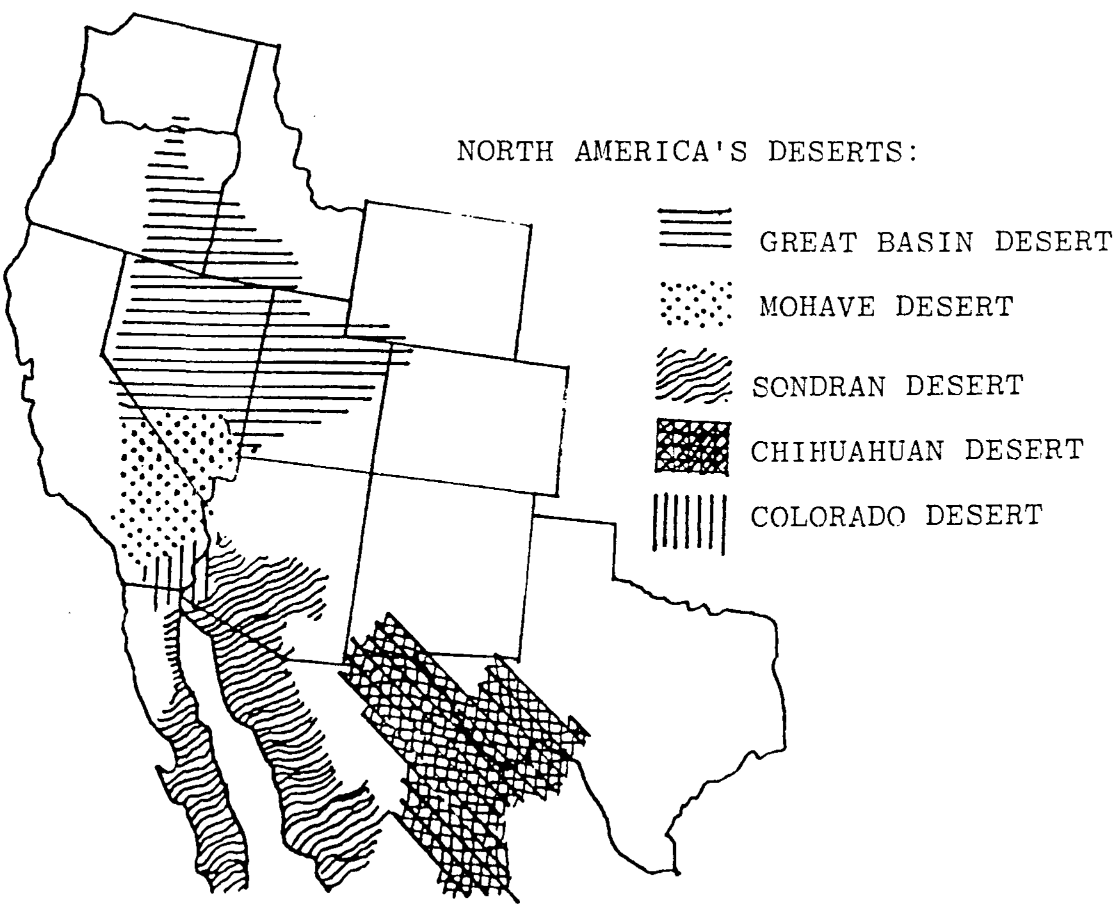
Desert stream-dwelling fishes must also adapt to variations of temperature, salinity and dissolved oxygen. Streams in the Death Valley System vary seasonally from 32° to 113°F. Furthermore, in the summer the water temperature can rise or descend in one day by as much as 45°F. Salinities can vary from pure fresh water at some stream origins, to more than twice the salt content of seawater downstream and in side pools. Dissolved oxygen concentrations in the water often drop below 1 part per million and can reach zero on hot summer nights in highly productive desert streams. Death Valley pupfishes inhabit what are probably the most stressful stream environments and are able to tolerate briefly temperatures as low as 33.7° and as high as 107.6°F, salinities to about 70 parts per thousand (twice seawater), and dissolved oxygen concentrations as low as 0.5 part per million. These abilities are records for freshwater fishes.

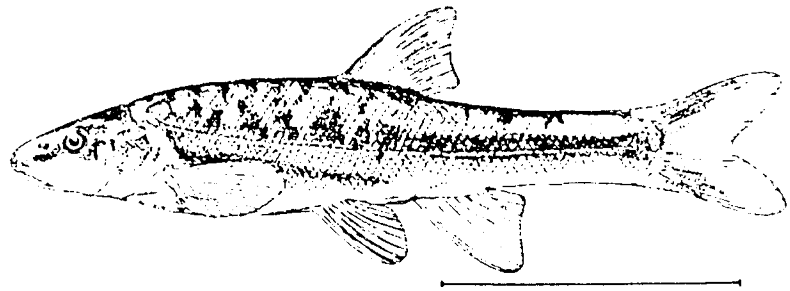
Extremely isolated and variable streams, such as Salt Creek on the floor of Death Valley at 181 to 229 feet below sea level, contain few fishes. The creek supports a single endemic species, the Salt Creek pupfish (*Cyprinodon salinus*). The somewhat more benign habitat of the Amargosa River supports two native fishes, a subspecies of Amargosa pupfish, and a population of the widespread specked dace (*Rhinichthys osculus*). The desert stream with the most diverse native fish fauna is Aravaipa Creek in Arizona, which supports a seven-species fish community. The prime habitat surrounding the stream, Aravaipa Canyon, was purchased by The Nature Conservancy and was transferred to Defenders of Wildlife, which now manages the area. Seven native fishes, five minnows and two suckers, coexist in the pristine stream by segregating into different feeding and habitat niches. Aravaipa Creek largely has been spared from the usual problems of water diversion and introduction of exotic predatory or competing species. It is one of the few remaining examples of the complex fish communities once characteristic of Arizona streams. Two of the seven fishes in Aravaipa Creek are groups endemic (evolved in and restricted to) the Gila River System: spikedace (*Meda fulgida*) and beach minnow (*Tiaroga cobitis*). Two other Nature Conservancy preserves in Southern Arizona, Patagonia-Sonoita Creek Sanctuary and Canelo Hills-Cienega, also contain relatively undisturbed, native fish communities.



SPECKLED DACE

Rhinichthys osculus

Rhinichthys = snout fish
osculus = small mouthed



Marshes, once common but now rare, are characteristically shallow variable habitats with dense growths of emergent vegetation, which provide fish habitat similar to that of small streams. One incredibly different marsh habitat is Cottonball Marsh, lying in the barren salt pan of Death Valley at more than 260 feet below sea level. Here, one endemic fish, the Cottonball Marsh pupfish (*Cyprinodon milleri*) lives in a few permanent pools and channels. This aquatic habitat is surprisingly moderate (salinities to 45 parts per thousand and temperatures to 96.8°F), considering that air temperatures to 122°F cause salts to crystallize at the edges of the pools. Although this pupfish is considered a rare species, it is well protected by its remote location within Death Valley National Monument.

Thermal springs abound in the Death Valley System. The warm clear pools teeming with pupfish are particularly abundant in Ash Meadows, Nevada. A series of large springs contains the Ash Meadows pupfish (*Cyprinodon nevadensis mionectes*) and speckled dace. Big Spring, one of the largest and most beautiful of these springs, is part of a 397-acre Nature Conservancy preserve that also protects several rare, endemic species of wildflowers.

Isolated at a slightly higher elevation is a series of six small, warmer springs inhabited by the endangered Warm Springs pupfish (*Cyprinodon n. pectoralis*). Devils Hole, a warm, 93°F pool with no outlet, lying about 50 feet below the surface of the earth in a fault fracture on the side of a hill in central Ash Meadows, is inhabited by the endangered Devils Hole pupfish. This pupfish has evolved in probably the most restricted and isolated habitat of any fish in the world. It is the smallest of all pupfish, lacks vertical side markings, has completely lost the paired pelvic fins, is non-aggressive, and does not exhibit the characteristic pupfish breeding territoriality.

Sadly, almost all desert fishes have suffered greatly from disruption and destruction of their habitats. Twenty-one of the 23 endangered species of fishes in the United States live in desert areas. Native fish habitats have been lost because their waters have been reduced, either by diverting the surface water or by mining the groundwater. Fish populations have declined or disappeared because exotic, non-native fishes and other organisms, which are predators or competitors, have been introduced.

Diversion of surface water has taken a tremendous toll on desert fishes. Virtually every desert stream-dwelling species has been eliminated from part of its native range. Many species are listed as endangered because of this type of habitat loss. They include: Owens pupfish (*Cyprinodon radiosus*) in Owens River, California; woundfin (*Plagopterus argentissimus*) of the Virgin River; Moapa dace (*Moapa coriacea*) in Moapa River; and Colorado River squawfish and humpback chub, both of the Colorado River. Extensive loss of marsh habitat combined with predation by introduced game fishes has extirpated the Desert pupfish (*Cyprinodon macularius*) from the entire Colorado River.

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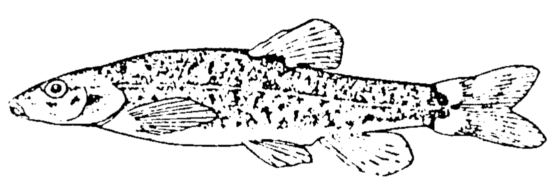
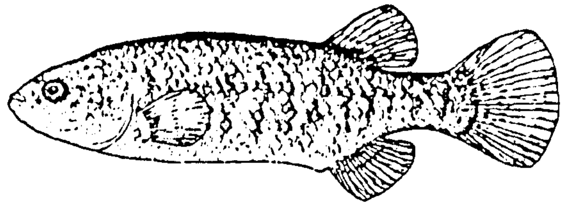


LOACH MINNOW, *Tiaroga cobitis* Girard.

PAHRUMP KILLIFISH, *Empetrichthys latos* Miller. Fig. 445. Desert water holes in Pahrump Valley, Nye County, Nevada.



The lowering of water tables by mining of groundwater can also be devastating. The endangered Pahrump killifish (*Empetrichthys latos*) no longer exists in its native Pahrump Valley where all of the springs have gone dry following attempts at residential development. Major agricultural development in Ash Meadows starting in 1969 resulted in rapid reduction of spring flows and disturbance of fish habitat. The water level in Devils Hole, the only habitat of the endangered Devils Hole pupfish, was directly lowered by pumping of wells. The shallow limestone shelf upon which the small Devils Hole pupfish population depends for food and spawning was progressively exposed. The National Park Service sued (Devils Hole has been an annexed part of Death Valley National Monument since 1952), claiming a prior federal water right that ensured the survival of this small fish. The six-year legal battle culminated with the 1976 U.S. Supreme Court decision recognizing the National Park Service's water right and guaranteeing a water level in Devils Hole that will support a stable population of pupfish.

Introduced exotic species often wreak havoc on simple desert fish communities where native fishes have had few if any predators or competitors. Competitors are sometimes less immediately threatening than predators, like the bass that have decimated the desert pupfish. Yet introduction of competitors is more common and always leads to the decline of the native fishes. The extinct Ash Meadows killifish (*Empetrichthys merriami*) was never common and was last seen by scientists in Big Spring in 1948, several years after the introduction of mollies (*Poecilia sphenops*) and mosquitofish (*Gambusia affinis*). The decline and destruction of several populations of Gila topminnow (*Poeciliopsis occidentalis*) were due to competition from introduced mosquitofish.

A different sort of threat to desert fishes occurs when closely related non-native species are introduced and crossbreeding occurs. The two native desert chubs in California, Owens chub (*Gila bicolor snyderi*) and Mojave chub (*Gila b. mohavensis*), have hybridized throughout their respective drainages with the introduced coastal chub (*Gila orcutti*). Each subspecies now exists in only one isolated, genetically pure population.

The universal decline of fishes in all desert areas is more than the tragic demise of a few species--it signals the destruction of the desert's most precious resource: aquatic ecosystems. As long as the pressure of human expansion into arid areas continues, the demand for water will rise. We must act now to preserve desert aquatic habitats of fishes whose genes contain information that has been molded in the harsh and variable desert environment and the aquatic habitats in which they survive. Neither the fishes nor the habitats can be regenerated once they are radically altered or destroyed.

The key to survival of desert fishes is the preservation of *entire* aquatic habitats with an adequate water supply. The Nature Conservancy has made an admirable beginning with four preserves supporting entire habitats of desert fishes. Such acquisitions combined with major regional recovery plans--such as one to preserve adequate habitat for survival of the large fishes native to the Colorado River--must accelerate rapidly if desert fishes and desert aquatic habitats are to remain a significant part of the natural heritage of the American Southwest.

David Soltz is Associate Professor of Biology at California State University at Los Angeles. In addition to teaching ecology and ichthyology, he researches the community structure and life history of desert fishes. Dr. Soltz recently published The Natural History of the Native Fishes in the Death Valley System *(Los Angeles County Museum of Natural History, 1978).*

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