

FINDING AND PHOTOGRAPHING THE FABLED FIVE PUPFISHES OF THE MOJAVE AND COLORADO DESERTS IN CALIFORNIA AND NEVADA



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INTRODUCTION

Pupfishes of the genus *Cyprinodon* comprise 45 extant and three extinct species of small, short-lived fishes that range from California and Massachusetts in the US southward through Central America and the Caribbean islands to Colombia and Venezuela (Esmaili et al. 2018). They are renowned for tolerating environmental extremes, with temperatures ranging from below freezing (-1.9°C) to about 46°C (Bennett and Beiting 1997; Clark 2014), and salinities ranging from fresh water to four times (142 ppt) that of sea water (35 ppt) (Simpson and Gunter 1956). But despite their uncanny ability to adapt to harsh environments, many species are restricted to only one or a few small pools of water, with some having the smallest habitats of any animal species. Two of the extant species are extinct in the wild (the Potosi Pupfish *C. alvarezii* and La Palma Pupfish *C. longidorsalis* in Mexico) and more than a third are classified by the International Union for the Conservation of Nature (IUCN) as either Critically Endangered or Endangered (Esmaili et al. 2018).

The topography of both the Mojave Desert in eastern California and western Nevada and the Colorado Desert of southeastern California is punctuated by rugged mountain ranges and dusty basins. Few people driving on highways through these parched desert landscapes are aware that some of the world's rarest and most interesting fishes thrive in nearby desert oases, some only a few minutes' walk from a parked car. These include five species of *Cyprinodon* pupfishes: the Devils Hole Pupfish *C. diabolis*, Desert Pupfish *C. macularius*, Amargosa Pupfish *C. nevadensis*, Owens Pupfish *C. radiosus*, and Death Valley Pupfish *C. salinus*. Today's populations of these

species are relicts of those that inhabited the large pluvial lakes and rivers that once filled deep basins of western North America during the Pleistocene and subsequently receded as the glaciers retreated and vanished. The IUCN classifies the Devils Hole Pupfish as Critically Endangered, the Owens Pupfish and Death Valley Pupfish as Endangered, and the Desert Pupfish and Amargosa Pupfish as Vulnerable (Esmaili et al. 2018). The ecology of four of these species in the northern Mojave Desert and the history of the heroic efforts of biologists to protect them are eloquently described in a hefty tome by biologist Christopher Norment (2014).

Few people can name the five pupfish species of California and Nevada's deserts and even fewer have managed to see them all. In this article, I hope to inspire others to search for them by describing my quest to find and photograph all five species, and I hope to increase public awareness and demand for protecting their populations from the threats of introduced species and increased water consumption due to the growing demands of agriculture and urban/residential development.

AMARGOSA PUPFISH

The Amargosa Pupfish comprises five extant and one extinct subspecies in scattered springs and streams in the northern Mojave Desert of eastern California and western Nevada. The Tecopa subspecies, *C. n. calidae*, occurred in two small streams at Tecopa Hot Springs, California, until extensive habitat alteration to accommodate more tourists caused its extinction in the 1970s (Miller et al. 1989). Ignominiously, it became the first federally endangered animal declared extinct. Fortunately, the populations of the other five subspecies are reasonably well protected (Norment 2014).

As a biology professor most familiar with birds, I often visited the deserts of southeastern California while studying for two university degrees in southern California in the mid-1980s and early 1990s and less frequently while teaching at a college in northwestern California since 2003. Yet I knew very little about the region's pupfishes and had never seen one until a memorable day, 8 January 2012. After spending a long weekend with my wife, Marta, in Las Vegas, we were driving home when I saw a sign for Ash Meadows National Wildlife Refuge in western Nevada and decided to check it out. We parked at a trailhead and began hiking on

Photos by the author.

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Figure 1. Kings Pool, a large spring inhabited by the Amargosa Pupfish at Ash Meadows National Wildlife Refuge, Nevada.



Figure 2. An Amargosa Pupfish of the Ash Meadows subspecies.



Figure 3. An Amargosa Pupfish of the Shoshone subspecies at Shoshone Spring, California.

a boardwalk beside a stream, Crystal Spring, where I encountered a sign with information about the Ash Meadows subspecies of the Amargosa Pupfish, *C. n. mionectes*. Pupfish! Suddenly excited by the prospect of seeing my first pupfish, I diligently scanned the crystal-clear water of the hot spring, especially at the aqua blue Crystal Pool at the end of the boardwalk, but disappointingly I was unable to spot one, although I saw some introduced Western Mosquitofish *Gambusia affinis* and managed to photograph one.

Not willing to give up, we visited the Visitor's Center and inquired where we could see a pupfish. After a naturalist provided directions, we drove to the Point of Rocks parking lot and hiked along a short boardwalk crisscrossing a small stream until we arrived at another large spring, Kings Pool (Figure 1), where we were thrilled to see many blue-tinged male and brown-barred fe-



Figure 4. Salt Creek, a small stream inhabited by the Death Valley Pupfish in Death Valley National Park, California.

male pupfish swimming amidst gobs of green algae and swarms of Western Mosquitofish. Having left my underwater camera case at home, I was unable to take any underwater photos, but I managed to get a few grainy photos with the telephoto lens I use to photograph birds, and I vowed to return one day to get better photos.

Five years later, on 29 March 2017, I returned to Ash Meadows National Wildlife Refuge with a student. We hiked to Kings Pool and spent a half hour watching the antics of the pupfish. I spent a long time on my belly with an arm extended underwater, striving to obtain photos of the Amargosa Pupfish with an underwater camera, and this time I was happier with the results. But I obtained my best photos four years later when I returned with five students on 22 March 2021 (Figure 2). The following day we drove through the dusty town of Shoshone in the Mojave Desert of California where we encountered a roadside interpretive sign with information about the Shoshone subspecies of the Amargosa Pupfish, *C. n. shoshone*. More pupfish! We followed a short trail winding around the margins of several pools emanating from the Shoshone Spring and saw dozens of pupfish up close, which were easy to photograph with a telephoto lens (Figure 3). The private landowner of the spring is committed to protecting the pupfish and welcoming tourists to see them.

DEATH VALLEY PUPFISH

Death Valley lies at the bottom of a basin once filled by a large pluvial lake, Lake Manly, that once covered a surface area of about 1,600 km² in the Mojave Desert of eastern California. With the lowest elevation (86 m below sea level) and the hottest temperatures (max 56.7° C) in North America, it is a desolate and potentially dangerous place to visit on a hot summer day, but it is a delightful place to visit when the temperatures are cooler, especially in spring when the flowers are blooming. Two populations of the Death Valley Pupfish occur in the basin: the Salt Creek subspecies, *C. s. salinus*, and the Cottonball Marsh subspecies, *C. s. milleri*. Both subspecies are well protected within the boundaries of Death Valley National Park (Normont 2014).

Although I had visited Death Valley several times, I did not search for its iconic pupfish until 28 March 2017, when I took two students with me on a camping trip in the California deserts during spring break. By this time, I had searched online for information about the pupfish and knew where to look for it, so we drove to Salt Creek (Figure 4) and began hiking along a boardwalk beside



Figure 5. A Death Valley Pupfish of the Salt Creek subspecies.

the stream. Small schools of pupfish darted back and forth in the shallow water, frequently chasing each other and some were even spawning. All were brown, but a few males had blue tinges. Within the next month the males would turn deeper blue as the breeding season progressed. I was able to get some decent photos with my telephoto lens (Figure 5), and got even more photos when I returned with five students on 21 March 2021. I have not visited Cottonball Marsh to see its subspecies, which is in a remote area accessible only by a long and arduous hike.

DEVILS HOLE PUPFISH

Devils Hole is a narrow geothermal pool about 22 m long and 3.5 m wide, deep within a rocky cleft in a detached unit of Death Valley National Park in the northern Mojave Desert of western Nevada; it is adjacent to Ash Meadows National Wildlife Refuge. Despite its small surface area, the pool is only a small tip of a large aquifer that branches into numerous subterranean caverns, and it is so deep—divers have descended to 130 m—that its bottom has never been found. The pool is extremely sensitive to seismic activity, with disturbances in the water resulting from earthquakes as far away as Japan, Indonesia, and Chile. Stunning videos of miniature tsunamis caused by large earthquakes can be found online.

Devils Hole is the only natural home of the Devils Hole Pupfish, and it may be the smallest habitat containing the entire natural population of a vertebrate species. When the hole's water level dropped in the 1960s and 1970s due to farmers pumping groundwater to irrigate their crops, the pupfish became the center of acrimonious legal and public relations battles between farmers who demanded more groundwater and conservationists who realized the fish would likely become extinct if the water level receded below a shallow, submerged rock at one end of the pool that provided critical habitat for foraging and spawning. Eventually the conflict was settled by the US Supreme Court, which ruled in favor of the pupfish in 1976. The pupfish population is censused by biologists each spring and fall and is usually much larger in the fall. The population gradually declined from more than 500 individuals in the 1990s to only 35 individuals in 2013 (Brown 2021; Wilson et al. 2021), but it subsequently rebounded to 263 individuals by fall 2022. Several attempts to establish a second population elsewhere failed until a replica of the upper portion of Devils Hole was built at the Ash Meadows Fish Conservation Facility in 2013 (Brown 2021; Wilson et al. 2021). This facility now protects a captive population and provides a refuge in case the wild population is wiped out by a catastrophic event.

I first read about the plight of the Devils Hole Pupfish in my primary school's library while growing up in Maryland in the 1970s,



Figure 6. Dylan Turner searching for Devils Hole Pupfish at Devils Hole, Nevada.



Figure 7. A Devils Hole Pupfish swimming above a small white carpet, which provides a favored substrate for spawning.



Figure 8. Biologists collecting eggs from two white carpets at the shallow end of Devils Hole.

but I never imagined I would ever get to see one until another memorable day, 29 March 2017. After a student and I watched the antics of Amargosa Pupfish at Kings Pool in Ash Meadows National Wildlife Refuge, we searched for Bighorn Sheep *Ovis canadensis* in the nearby hills at Point of Rocks but were unable to find any. Still hoping to find the sheep, we decided to explore the refuge's roads. As we drove up a winding dirt road in the rugged hills, we came across a sign for Devils Hole beside the road. On the slope above us we spotted a chain-link fence, topped by barbed wire, surrounding a large area. Eureka! Surely the fence protected the home of the fabled Devils Hole Pupfish. We parked our car and enthusiastically hiked a short distance up a dirt service road to the fence. A sign guided us to the entrance of an observation platform partially spanning the narrow canyon from which we gazed downward at Devils Hole. An interpretative sign provided information about the iconic pupfish. Eager to see one, I scanned through binoculars for about five minutes until I saw a small fish swimming in shallow water at the near end of the pool. Yipppee! I was elated to see one. Next, student Dylan Turner scanned the pool with the binoculars (Figure 6) until he, too, spotted a pupfish.

I returned to Devils Hole with five students taking a Desert Biology class on 22 March 2021. This time I brought along a telescope, so we took turns staring through it as several pupfish swam slowly and sometimes chased each other in the shallows at the closest end of the pool. Two mysterious white squares were present in the shallow water, which made it easier to see the fish whenever they swam above one, and I was able to photograph a distant pupfish swimming above a square (Figure 7) with my telephoto lens, but I wished I had a bigger lens! Serendipitously, two vehicles drove up the service road and parked just outside of the fence. Four biologists emerged from the vehicles and carried loads of gear to the pool. While the biologists spanned the pool with metal beams and platforms (Figure 8), one of them, Jennifer Gumm, explained to us that the white squares were carpets providing a soft substrate preferred by the pupfish for spawning. The biologists removed the two carpets, placed them into a container, and transported them to their research lab where the eggs would be removed and incubated in an aquarium. The carpets would be returned to Devils Hole to collect more eggs, and the young, captive-reared fish would be added to the captive population in the replica of Devils Hole at Ash Meadows. Meeting the biologists and observing them in action was a terrific educational experience for my students and me.

DESERT PUPFISH

The Desert Pupfish formerly occupied many springs and streams in several large drainage basins in southeastern California, southern Arizona, and northwestern Mexico. Natural populations currently survive in only three drainage basins: the Salton Sink in southeastern California, the Laguna Salada in Baja California, and the Colorado River Delta in Baja California. However, small populations have been introduced to numerous refugia, some of which have failed, in southern California, southern Arizona, and northwestern Mexico (Bonham 2021; Echelle and Echelle 2021).

In the Colorado Desert of southeastern California, both natural and introduced populations of the pupfish occur in tributaries and agricultural drainage ditches along the shores of the Salton Sea, a large body of water that formed in 1905 when water diverted

from the Colorado River burst through an irrigation canal and flowed into the Salton Sink for two years before the canal was repaired. Water levels in the Salton Sea were subsequently maintained by irrigation runoff in the Imperial Valley, but because the "sea" is about 70 m below sea level and has no outlet, the water has gradually become hypersaline (currently about 1.8 times greater than seawater). The Desert Pupfish has an uncanny ability for colonizing irrigation drainage ditches and impoundments along the shores of the Salton Sea, but its ability to do so is increasingly impeded by increasing salinity, toxic chemicals, and frequent algal blooms that have killed most of the introduced fish (Oglesby 2005; Bradley et al. 2022).

When I visited the Salton Sea with a group of five students on 26 March 2021, I was aware that the pupfish occurred in two tributaries, Salt Creek on the east bank and San Felipe Creek on the southwest bank, but I didn't think we would have the time to search for them. My twin brother, William Hayes, is a biology professor at Loma Linda University in southern California, and he had told me about the Cleveland Street Drain, an irrigation drainage ditch at the north end of the Salton Sea, where we could look for amphibians and reptiles. So, I drove there, parked on



Figure 9. Cleveland Street Drain, an agricultural ditch inhabited by the Desert Pupfish at the north end of the Salton Sea.



Figure 10. A school of Desert Pupfish. (Note: Photo adjusted by editors.)

the dirt road, and scrambled about 5 m down the bank to examine the ditch. Although I didn't see any amphibians or reptiles, there were several introduced Sailfin Mollies *Poecilia latipinna*. I drove a short distance to another spot along the road and again scrambled down the bank of the ditch (Figure 9) to see what more I could find. This time there were plenty of fish, including more Sailfin Mollies and introduced Mozambique Tilapia *Oreochromis mossambicus*, plus an unexpected school of several hundred Desert Pupfish with blue-tinged males and brown-barred females (Figure 10). Finding the Desert Pupfish proved much easier than anticipated, requiring no more than 15 minutes of searching! The pupfish remained in the drainage ditch when I checked again with another group of five students on 3 January 2023, and later that day I found several more pupfish in a pool where they had been introduced at the nearby Dos Palmas Preserve.

OWENS PUPFISH

Owens Valley is a deep basin at the northern edge of the Mojave Desert, sandwiched between the Sierra Nevada Mountains to the west and the White Mountains and Inyo Mountains to the east. Situated within the rain shadow of the tallest peaks of the Sierra Nevada range, the valley's natural aridity is exacerbated by a long and sordid history of surface water diversions by the Los Angeles Department of Water and Power. As a consequence of the water diversions and the introduction of predaceous Largemouth Bass *Micropterus nigricans*, the formerly abundant Owens Pupfish, which is endemic to the valley, was considered extinct by 1942. Fortuitously, a few were rediscovered in 1956 followed by the discovery of about 200 individuals in 1964. The pupfish were reintroduced in several places, but one by one the reintroduced populations died out until the fateful day of 18 August 1969, when the last 400 individuals—the entire population of the species—were scooped out of the water in a drying pool, placed in two buckets, and carried by hand across uneven terrain to a nearby spring (Miller and Pister 1971; Pister 1993). Subsequently, the pupfish were reintroduced to several other sites and are now carefully managed (Norment 2014).

After considerable online sleuthing to determine where I could see the pupfish, I arrived at Fish Slough with a group of five students in my Desert Biology class on 20 March 2021. After parking our motor home, we hiked nearly three miles along a dirt road to BLM Spring (Figure 11). We gazed into the depths of the spring as dozens of Western Mosquitofish darted in and out of the profuse tangles of green algae, but disappointingly I couldn't see any fish that resembled pupfish. However, I noticed that some of the fish in deeper water had blue tinges and thought they might be the pupfish. Later, when I downloaded the photos on my laptop and examined them more closely, I realized they were just mosquitofish with blue tinges caused by a quirk of lighting in the green algae (Figure 12). Disappointed by my failure to see a pupfish, I vowed to return for another try.

More than two years passed before I returned to Fish Slough with a student on 20 November 2023. This time we quickly spotted more than a dozen pupfish, which appeared to be more timid than the other species. When we approached the edge of the spring, they quickly fled from the edge into the green algal jungle in deeper water, but as we lay on our bellies and patiently watched, one by one they returned to shallower water where I managed to



Figure 11. BLM Spring, inhabited by the Owens Pupfish at Fish Slough, California.

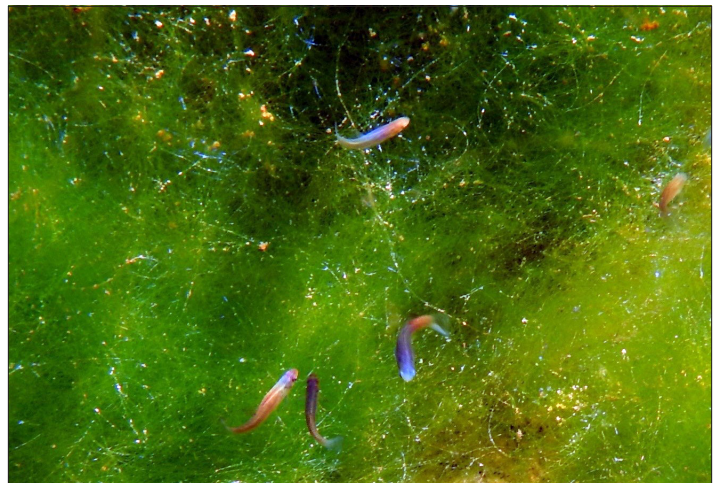


Figure 12. Western Mosquitofish with blue tinges caused by a quirk of lighting. (Note: Photo adjusted by editors.)



Figure 13. An Owens Pupfish. (Note: Photo adjusted by editors.)

obtain some photos with my underwater camera (Figure 13). Although it took me more than a decade, I was immensely pleased to have finally found and photographed my fifth and final species of California and Nevada's fabled pupfishes.

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