AMARGOSA RIVER PUPFISH
Cyprinodon nevadensis amargosae (Miller)

Status: High Concern. The Amargosa River pupfish needs to be monitored closely because its status could change quickly if river flows are further reduced or new non-native species invade.

Description: All Amargosa pupfish (*Cyprinodon nevadensis)* subspecies are small fish that rarely exceed 50 mm TL. The body is deep, especially in reproductive males. The head is blunt and slopes steeply to a small, terminal, oblique mouth. There is one row of tricuspid teeth on each jaw, with the central cusps being truncated or pointed. *C. nevadensis* is a variable species, but can be distinguished from other pupfishes by the following characteristics: (1) the scales are large, the circuli lack spine-like projections, and the interspaces are reticulated; (2) there are 23-28 scales (usually 25-26) along the lateral line and 15-24 scales (usually 16-18) anterior to the dorsal fin; (3) the pelvic fins are reduced and may even be absent; (4) there are 8-11 anal fin rays (usually 10), 11-18 pectoral fin rays (usually 15-17), 0-9 pelvic fin rays (usually 6), and 14-22 caudal fin rays (usually 16-19); (5) gill rakers range from 14-22 (usually 15-17) and preopercular pores from 7-17 (usually 12-14). Reproductive males in breeding colors are bright blue with a black band at the posterior edge of the caudal fin. Reproductive females are drab olive-brown and develop 6-10 vertical bars along their sides which may be distinct or faint. An ocellus (eyespot) is typically present on the posterior base of the dorsal fin of females.

The Amargosa River subspecies is similar to *Cyprinodon n. nevadensis* but has more scales around the body and fewer scale radii than other subspecies (see Table 1).

Taxonomic Relationships: *C. nevadensis amargosae* is one of three extant subspecies of *C. nevadensis* found in California. The fossil record and past geologic events suggest that the *Cyprinodon* species differentiated relatively recently, with most differentiation occurring during the pluvial-interpluvial fluctuations of the early to mid-Pleistocene (Miller 1981). Some differentiation may have even occurred in the last 10,000 years, following the final recession of pluvial waters. As water table height receded in the Great Basin during the Pleistocene, numerous scattered lakes and streams shrank, isolating remnant populations of pupfishes which led to allopatric speciation of *C. nevadensis*.

C. nevadensis is a complex of subspecies commonly (and confusingly) referred to as Amargosa pupfish. The species was first described from Saratoga Springs by Eigenmann and Eigenmann (1889) but, following the initial description, it was lumped with the desert pupfish (*Cyprinodon macularius)* until Miller (1943a) separated it again. In subsequent studies, Miller (1948) recognized and described six subspecies of *C. nevadensis*, four of which occurred in California: Saratoga Springs pupfish (*C. n. nevadensis)*, Amargosa River pupfish (*C. n. amargosae)*, Shoshone Springs pupfish (*C. n. shoshone)*, and Tecopa pupfish (*C. n. calidae*). Two more subspecies occur in Nevada: Ash Meadows pupfish (*C. n. mionectes)* and Warm Springs pupfish (*C. n. pectoralis*). *Cyprinodon n. calidae* is now extinct (Moyle 2002).

Measure/ Count	*C. n. amargosae*		*C. n. nevadensis*		*C. n. shoshone*	
	male	female	male	female	male	female
	ALL		ALL		ALL	
Standard length (mm)	36		40		34	
*Body width	256	265	274	269	231	229
*Head length	305		312		307	
*Head depth	330	304	367	343	331	311
*Head width	240	259	257	256	233	231
*Snout length	101		97		89	
*Mouth width	117		115		114	
*Mandible length	198		95		93	
*Anal origin to caudle base	338	346	394	362	371	355
*Caudle peduncle length	264	237	277	253	263	251
*Anal fin base length	116	105	111	105	108	101
*Anal fin length	330	304	227	195	217	190
*Pelvic fin length	98	89	95	87	90	77
Anal fin ray count	10		10		10	
Dorsal fin ray count	10		10		10	
Pelvic fin ray count	6		6		4	
Pectoral fin ray count	16		16		16	
Caudal fin ray count	18		17		18	
Lateral line scales	26		26		26	
Predorsal scale count	19		18		18	
Dorsal fin to pelvic fin scale count	11		10		9	
Caudal peduncle circumference scale count	16		16		15	
Body circumference scale count	27		25		23	

*Expressed as percent of standard length x 1000.

Table 1. Comparative average morphometrics and meristics of three *Cyprinodon nevadensis* subspecies. Adapted from Miller (1948).

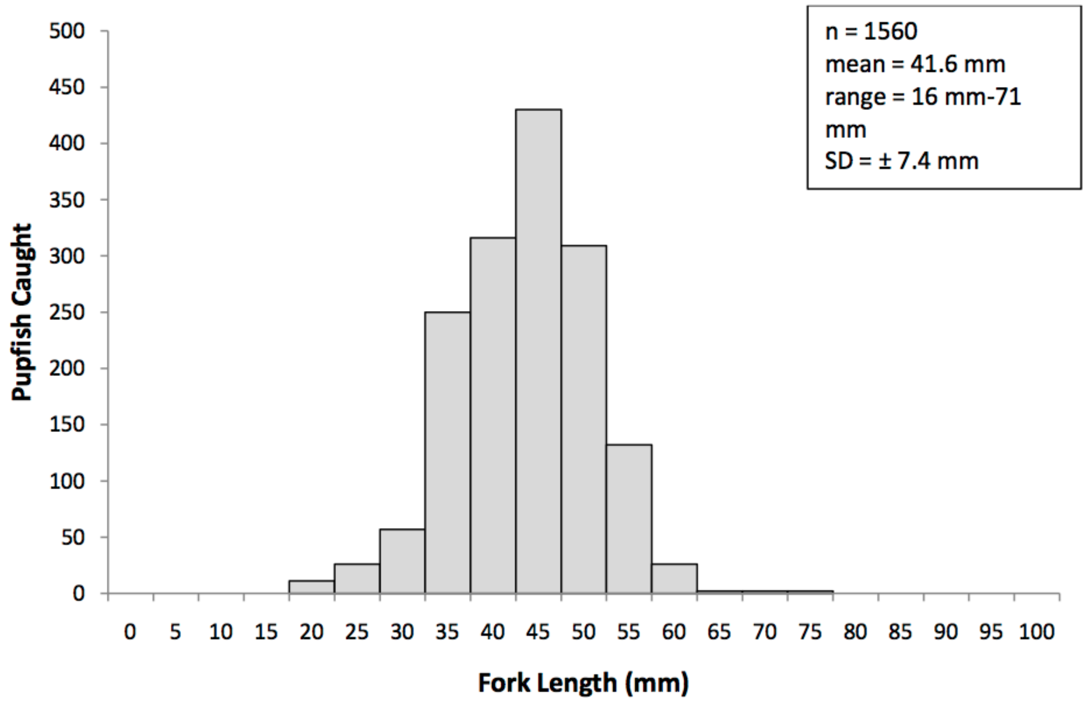

Figure 1. Length frequency of Amargosa River pupfish (*Cyprinodon nevadensis amargosae*) captured during a summer, 2010 survey of the Amargosa River Canyon, California. Figure from Scoppettone et al. 2011.

Life History: The life history of Amargosa River pupfish is similar to that of Saratoga Springs pupfish. Being riverine, however, its reproductive strategies differ from spring-dwelling pupfishes. Males do not establish and defend territories in leks, as do males of spring-dwelling subspecies. Instead, they are group spawners (Kodric-Brown 1981). Spawning may take place in the center of the group but, most often, a reproductive male will direct a receptive female to the periphery of the group to spawn. Highest densities and peak breeding season occur during summer, when water temperatures are higher and food is abundant (Kodric-Brown 1977). However, breeding may occur year-round in thermally stable habitat.

Pupfish feed primarily on blue-green cyanobacteria and algae, but they also feed seasonally on lesser quantities of small invertebrates, mostly chironomid larvae, ostracods, and copepods (Naiman 1975, 1976). They can also be effective predators of mosquito larvae in heavy vegetation (Danielsen 1968). They forage continuously throughout the day but are less active at night.

Few Amargosa River pupfish live longer than a year in the wild and they rarely exceed 65 mm FL; most are less than 50 mm FL (Figure 1). However, these pupfish can reach sexual maturity in a few months at 30 mm FL, so are capable of multiple generations in a year (Moyle 2002).

Habitat Requirements: The Amargosa River is an intermittent desert stream. For most of its course, the river flows underground except after infrequent rain events. Pupfish habitat in the lower Amargosa River is divided into two distinct reaches of perennial flow separated by 16 km of dry riverbed. The upstream reach, near Tecopa, is itself divided into two sections, the first being characterized by broad marshes fed by hot springs and the second by a narrow, steep-sided canyon where the river is only 2 m wide but reaches depths of 2.5 m. In the canyon, flows are swift between pools and substrates consist of gravel and sand, with some boulder and rubble (Miller 1948, Williams et al. 1982). Pools are numerous, both within the river and on the flood plain, the largest being about 8 x 5 m. Substrates in pools are primarily mud and clay and shoreline vegetation is abundant. Gravel riffles are not preferred habitat (Williams et al. 1982). Pupfish seem to prefer depths between 10-35 cm (Williams et al. 1982). A 2010 BLM survey of Amargosa Canyon found that pupfish were most abundant in habitat reaches associated with native vegetation and scarce where salt cedar dominated the riparian corridor (Scoppottone et al. 2011). The water during this survey was clear and saline, with pH ranging from 8.2-8.7 and dissolved oxygen ranging from 7.3-11.6 mg l^{-1}. Total dissolved solids were fairly high and variable at 1,390-3,890 ppm.

In the Tecopa area, this subspecies also inhabits the torrid outflows of hot springs, habitats formerly occupied by *C. n. calidae* (extinct). One of the most unusual habitats is Tecopa Bore, an outflow of an artesian well. Water temperature at the head of the bore is 47.5˚C; in winter it can cool to nearly freezing only 1 km downstream. In the bore, pupfish tend to congregate at water temperatures near their thermal maxima of 42˚C because cyanobacteria abundance is greater in the warmer water (J.H. Brown 1971). Pupfish follow cooler water blown upstream by winds into ungrazed areas otherwise outside their thermal tolerances. When the wind dies, pupfish caught in hot water (> 42˚C) will die unless they are washed downstream into cooler water.

The downstream reach is in Death Valley National Park at an elevation of 33 m (Miller 1948). Here, the river bottom consists of fine silt, clay, mud, and sand; there are no macrophyte beds. The current is moderate to swift between pools, which are 0.75-1.25 m deep. Water temperature varies seasonally from 10 to 38 °C, except during severe winters when temperatures may approach freezing. Younger fish tolerate higher water temperatures than adults (Shrode 1975) and are commonly found in the warmer, shallower (ca. 5 cm) water close to shore. Habitats along the shore may serve as refuge from predation or competition for food (Miller 1948). This reach is characterized by large diel variation in water temperature and by vertical temperature stratification.

Distribution: *C. n. amargosae* is the most widely distributed subspecies of *C. nevadensis*, inhabiting two perennial sections of the lower Amargosa River and Tecopa Bore, Inyo County. The upper section begins upstream of Tecopa and flows through Amargosa Canyon for about 11 km until it approaches Sperry, where it dries, except after rare periods of heavy rainfall upstream. The second, lower, section flows through Death Valley northwest of Saratoga Springs, approximately 32 km downstream of Sperry, and continues for about 3 km. Differences in meristic characteristics between the two populations suggest that they are effectively isolated from each other (Miller 1948), except, perhaps, in times of floods. In 1940, R. R. Miller planted 350 Amargosa pupfish in River Springs, Adobe Valley, Mono County. This population was extant and flourishing; however, because *C. s. salinus* was planted at the same time, studies are needed to determine whether, and to what extent, hybridization between the two taxa may have occurred (E. Pister, CDFW, pers. comm. 1999).

Trends in Abundance: The Amargosa River pupfish is the most widespread of any *C. nevadensis* subspecies and is fairly common in the lower Amargosa River, particularly around Tecopa (unpublished data, the authors) and in Amargosa Canyon (Scopppottone et al. 2011). Pupfish populations in Amargosa Canyon appear relatively stable between surveys in 1982 (Williams et al. 1982) and 2010 (Scoppettone et al. 2011). The Amargosa River pupfish also occurs in an isolated downstream reach of river in Death Valley National Park. Historic abundance records are lacking but Amargosa River pupfish may be less abundant now than formerly because water diversions have long reduced Amargosa River flows.

Nature and Degree of Threats: The major threat to Amargosa River pupfish is potential dewatering of its unique habitats, the Amargosa River and tributaries, by a combination of local surface water diversions and groundwater withdrawals. The Amargosa Aquifer, which supplies springs in Ash Meadows, Nevada and the Amargosa River, receives much of its recharge flow from areas on the northern and northeastern slopes of nearby Spring Mountains (Riggs and Deacon 2004), but is also dependent on regional groundwater movement through large, ancient aquifers that extend into western Utah and central Nevada (Dettinger and Cayan 1995, Deacon et al. 2007).

Agriculture. In the late 1970s and early 1980s, substantial groundwater development reduced spring discharge in Ash Meadows, causing a dramatic decline in water levels at Devils Hole, habitat of the endangered Devils Hole pupfish, *C. diabolis*. After a Supreme Court decision halted pumping, spring discharge in Ash Meadows recovered and the groundwater table rose steadily until 1987. However, a slow decline began in 1988 and continues to the present (Riggs and Deacon 2004). Analysis by Bedinger and Harrill (2006) indicates that the decline is not correlated to climate but, instead, is due to agricultural water withdrawal from as far as 30 km away.

Grazing. Livestock grazing is prohibited within Death Valley National Park but may be an issue on private lands around Tecopa. Even small herds can significantly alter habitat required by pupfish by trampling springs or eliminating native riparian vegetation.

Urbanization. In 2004, the Southern Nevada Water Authority (SNWA) proposed to mine large quantities of water from several different valleys that lie within the Ash Meadows groundwater basin (Breen 2004, Southern Nevada Water Authority 2004, Vogel 2004). If the Amargosa region withdrawals continue to increase and if Las Vegas proceeds with its planned withdrawals, it is highly likely that the springs which feed the Amargosa River could be greatly reduced or even dry completely, especially during drought periods (Deacon 2011). As the increasing human population of Tecopa and the upper Amargosa Valley seek protection from episodic flood events, potential flood control modifications to the basin can pose a threat to Amargosa River aquatic habitats.

Recreation. Unrestricted public access to the entire limited range of Amargosa River pupfish increases risks of introduction of alien species, contamination, and novel pathogens. Off-road vehicles can damage stream habitats and negatively affect water quality.

Alien species. Western mosquitofish (*Gambusia affinis*), associated with declines of other pupfish species, are abundant in Amargosa Canyon, yet Amargosa River pupfish appear able to coexist with them (Williams et al. 1982). Flash floods periodically reduce mosquitofish populations, to the advantage of pupfish. If flood control measures were implemented upstream, this natural purging of exotics would be reduced. Maintaining natural disturbance regimes has been shown to be of prime importance for the persistence of desert aquatic ecosystems (Kodric-Brown and Brown 2007) and every effort should be made to ensure that periodic flood flows continue in the Amargosa River. The possibility of additional introductions of alien fishes into the Amargosa River also exists. The Amargosa River is highly accessible to the public and, as such, there is an increased threat of the introduction of competitors, predators, and pathogens. Of particular concern are largemouth bass (*Micropterus salmoides),* which are easily moved, handle warm temperatures well, and are voracious predators. Even a few individuals can quickly consume a pupfish population. Pupfish have no effective defense against such predation (Moyle 2002).

Other alien species also represent a threat. Although historic data are lacking, it is assumed that native fishes were likely found in greater abundance in the Amargosa River prior to the invasion of saltcedar (*Tamarisk*), crayfish and mosquitofish, all of which have been found to negatively impact native fish populations (Scoppettone et al. 2011). Similar to many other desert aquatic habitats in the American Southwest, saltcedar is proliferating and altering habitats in Amargosa Canyon. Historically, stochastic events such as fire and flood periodically removed substantial amounts of riparian vegetation, keeping the stream channel open and dynamic (Benda et al. 2003; Kozlowski et al. 2010). Today, these same processes serve as agents for the spread of saltcedar (Wiesenborn 1996), threatening to form a saltcedar monoculture throughout the floodplain (Scoppettone et al. 2011). Because saltcedar has a substantially greater water demand than native vegetation, increases in saltcedar density in the riparian zone lead to corresponding increases in water lost to transpiration (Duncan and McDaniel 1998).

	Rating	Explanation
Major dams	n/a	
Agriculture	High	Ground water pumping and surface diversions threaten Amargosa River base flows
Grazing	Medium	Limited but even small herds can damage sensitive aquatic desert habitats
Rural residential	Low	Local surface flow diversion and groundwater pumping has the potential to reduce Amargosa River flows
Urbanization	High	Groundwater pumping by the city of Las Vegas has the potential to intercept aquifer water flowing to Amargosa River
	n/a	
Instream mining	n/a	
Mining	Low	Present in region but no known impact
Transportation	Low	Roads run along or across riparian or instream habitats in some areas, potentially increasing sediment and pollutant input
Logging	n/a	
Fire	n/a	
Estuary alteration	n/a	
Recreation	Medium	Entire limited range publicly accessible; off-road vehicle use popular in area
Harvest	n/a	
Hatcheries	n/a	
Alien species	High	Alien species are diverse and widespread

Table 2. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Amargosa River pupfish in California. Factors were rated on a five-level ordinal scale where a factor rated "critical" could push a species to extinction in 3 generations or 10 years, whichever is less; a factor rated "high" could push the species to extinction in 10 generations or 50 years whichever is less; a factor rated "medium" is unlikely to drive a species to extinction by itself but contributes to increased extinction risk; a factor rated "low" may reduce populations but extinction is unlikely as a result. A factor rated "n/a" has no known negative impact. Certainty of these judgments is high. See methods section for descriptions of the factors and explanation of the rating protocol.

Effects of Climate Change: Isolated desert springs and rivers fed by subsurface flow systems are precarious ecosystems that are particularly vulnerable to geologic and anthropogenic disruption. Climate change, therefore, poses a direct threat to the continued existence of Amargosa River pupfish. Fed by rain and snow melt at high elevation in the desert mountain ranges, desert aquifers in the Death Valley region will likely receive less recharge as the region warms (Riggs and Deacon 2002). This decline in regional water supply will be compounded by growing human demand for water in southern Nevada, which will only increase as the climate gets hotter and more arid. Although well-adapted to extreme salinity and temperature fluctuations characterized by its desert habitats, the Amargosa River pupfish exists at the limit of it thermal tolerances and is, therefore, remarkably vulnerable to small increases in temperature. Moyle et al. (2013) rated this pupfish as “highly vulnerable” to extinction as the result of the added impacts of climate change.

Status Determination Score = 2.3 – High Concern (see Methods section Table 2). The Amargosa River pupfish may be at risk of extinction because of its limited distribution in an extreme environment. Its status could change quickly if river flows are further reduced or new non-native species invade (Tables 2, 3). The Amargosa River pupfish is considered a Sensitive Species by the Bureau of Land Management, while the American Fisheries Society lists it as Vulnerable because of its limited distribution and threats to habitat (Jelks et al. 2008). NatureServe ranks this subspecies as Critically Imperiled (G2T1, http://www.natureserve.org/publications/NEscor2006.pdf). The Superintendent of Death Valley National Monument once recommended that Amargosa River pupfish be listed as a threatened species (E. L. Rothfuss, Superintendent of Death Valley National Monument, letter to B. Bolster of CDFG, May 27, 1992). This recommendation was endorsed by the Desert Fishes Council (E. P. Pister, pers. comm. 2008).

Metric	Score	Justification
Area occupied	1	Occupies only three areas in one watershed in its native range
Estimated adult abundance	3	Fluctuates highly with season and flow
Intervention dependence	3	Requires protection of habitats and water sources
Tolerance	3	Although remarkably adapted to high temperatures and salinities, they exist at the edge of their tolerances
Genetic risk	3	Flood waters likely connect Amargosa River populations periodically
Anthropogenic threats	1	Groundwater pumping and alien species could change status rapidly (see Table 1)
Climate change	2	Long-term natural and anthropogenic reductions in aquifer discharges plus increases in temperature will affect viability
Average	2.3	16/7
Certainty (1-4)	3	Well-documented biology

Table 3. Metrics for determining the status of Amargosa River pupfish, where 1 is a major negative factor contributing to status, 5 is a factor with no or positive effects on status, and 2-4 are intermediate values. See methods section for further explanation.

Management Recommendations: Efforts should be made to maintain natural flows in the Amargosa River, including periodic flood flows that reduce populations of introduced fishes and the abundance and distribution of invasive riparian vegetation. Management strategies should focus on protecing populations in both the upstream segment (Tecopa area and Amargosa Canyon) and the downstream segment (Death Valley) to maintain genetic diversity. Fortunately, the Bureau of Land Management has designated 21,552 acres surrounding Amargosa River from just south of Shoshone to Sperry as an Area of Critical Environmental Concern. In addition, The Nature Conservancy has acquired much of the canyon not administered by the BLM. Fences and barriers need to be properly maintained since vehicle trespass is a common problem. The downstream section in Death Valley is managed by the National Park Service but is dependent on water availability from upstream.

The greatest management concern is current and likely increasing levels of water removal from the aquifer that feeds the river. The U.S. Supreme Court decision (United States v. Cappaert 1977), which protected Devils Hole pupfish from water withdrawals, set a precedent for the extension of federal water rights from surface waters to include groundwater. Known as the Winters Doctrine (established in Winters vs. United States 1908), the ruling states that when the federal government reserves land, such as Death Valley National Park, by implication, it also reserves sufficient water rights to accomplish the purposes of that reservation. In the case of the Devils Hole ruling, the "purposes of the reservation" was the continued existence of the Devils Hole Pupfish. However, the application of the Winters Doctrine to ground water resources on a regional basis remains uncertain. The proposed, massive, groundwater pumping by Las Vegas should be rigorously evaluated to determine whether or not the Amargosa River depends on the aquifer and how surface flows would be reduced by pumping. Protection of the pupfish could, thus, help to protect an entire unique desert ecosystem.

Given the uncertainties of persistent flow in the Amargosa River, a contingency plan should be developed that would include the identification of habitats or facilities to temporarily hold pupfish from both upstream and downstream populations in the event population loss appears imminent (captive rearing and/or establishment of one or more refuge populations).

Figure 2. Distribution of Amargosa River pupfish, *Cyprinodon nevadensis amargosae*, in the lower Amargosa River, California.