SALT CREEK PUPFISH
***Cyprinodon salinus salinus* (Miller)**

Status: High Concern. While Salt Creek pupfish seem fairly secure, given their restricted distribution in the protected lands of Death Valley National Park, the threat of extinction is elevated due to their isolation and dependence upon a single water source.

Description: Salt Creek pupfish are slender bodied compared to most other pupfishes. They can reach 63 mm but rarely get longer than 50mm TL. The scales are small, oval to circular in shape, with reticulated interspaces between the circuli; they are intermediate to *Cyprinodon nevadensis* and *C. macularius* in the number of radii (15-22, usually 18). There are 28-29 scales in the lateral series. The preorbital region of the head lacks scales. Lateral line pores, especially the preopercular pores, are well developed. The mouth is slightly supraterminal and has tricuspid teeth with prominent median ridges. The dorsal fin is set behind the midpoint of the body. The pelvic fins are reduced and may even be absent. There are 8-11 dorsal fin rays (usually 9-10); 9-11 anal fin rays (usually 10); 14-17 pectoral fin rays (usually 15-16); 15-19 caudal fin rays (usually 16-17); 0-6 pelvic fin rays (the pelvic fin may be absent); gill rakers number 18-22 (usually 19-21) and are shorter and more compressed than in other pupfishes.

The back of reproductive males is purple and the sides are deep blue with 5-8 broad black bands that may be continuous or interrupted. The caudal fin has a prominent black terminal band and the anterior profile of males is noticeably arched (Miller 1943b). Females have 4-8 vertical lateral bars that are, except during spawning, less intense than the barring pattern of males. Females are more slender bodied than males and less conspicuously colored, being brownish with a silvery sheen.

Taxonomic Relationships: The Salt Creek pupfish was first described by Miller (1943b) from Salt Creek in Death Valley. Similarity of morphological characteristics to the Amargosa pupfish, such as reduced or absent pelvic fins, posterior position of the dorsal fin, short head, small eyes, and low fin-ray counts, indicate the two species are closely related (Miller 1943b). Mitochondrial DNA analysis confirms this close relationship but suggests that they began diverging before the desiccation of Lake Manly in the late Pleistocene (Echelle and Dowling 1992). *Cyprinodon salinus* is divided into two subspecies, *C. s. salinus* from Salt Creek and *C. s. milleri* from Cottonball Marsh, into which Salt Creek overflows.

Life History: While Salt Creek pupfish usually live one year or less, they become sexually mature at 30-40mm TL and have a generation time of 2-3 months, enabling them to reproduce several times a year (Sigler and Sigler 1987). Such a short generation time allows large populations to build rapidly during favorable high water conditions, resulting in colonization of areas beyond the limits of permanent water. During these periods, pupfish numbers have been estimated in the millions (Miller 1943b). While this estimate is likely high, densities of 527 fish per square meter have been measured (Sada and Deacon 1995). When flood waters recede, many fish are trapped in side pools or on drying flood plains and perish. Flash flooding also results in population losses, as fish become isolated in downstream pools that eventually dry (Williams and Bolster 1989).

Like other desert pupfishes, Salt Creek pupfish largely subsist on cyanobacteria and algae but will also feed on aquatic insects, crustaceans, and snails that share their habitats (Moyle 2002). Reproductive behavior and other aspects of their life history are similar to the riverine Amargosa pupfish (*Cyprinodon nevadensis ssp.)*.

Habitat Requirements: Salt Creek is located 49 m below sea level in North America's driest desert, where summer air temperatures can be greater than 50˚C, so it is among the most severe habitats inhabited by any fish. Beginning as a series of seepages on the floor of Death Valley, upper Salt Creek contains surface water only during winter and spring. This upper section is fishless and traverses Mesquite Flat for 2 km before abruptly entering a narrow, shallow canyon. Augmented by inflow from Mclean Springs, flow within the canyon provides 1.5 km of year-round habitat for pupfish. Within the canyon, the stream channel incised 3-7 m into the alkaline mud substrate and created a series of large (10 x 25 m by 2 m deep), interconnected pools which form the core of Salt Creek pupfish habitat. Canyon pools contain heavy growths of aquatic plants and are protected by overhanging salt grass, pickleweed, and saltbush, making them ideal refuges for pupfish. Below this canyon section the stream becomes shallow and exposed, quickly disappearing into the floor of Death Valley during normal water years. During periods of high flow, when surface water in Salt Creek expands downstream from the canyon, Salt Creek pupfish may inhabit as much as 5 km of stream habitat. However, most fish in this reach perish as high waters on the floodplain recede and downstream pools dry.

Water temperatures in Salt Creek fluctuate from near freezing in the winter to greater than 40°C in the summer. However, the temperature in deeper pools seldom exceeds 28°C and may provide temperature refuges, especially for reproduction. Salinity is also high, in summer approaching that of sea water (LaBounty and Deacon 1972). The levels of boron (39 ppm) and total dissolved solids (23,600 ppm) are remarkably high for any inland fish habitat (Miller 1943b).

Given the extreme conditions found in Salt Creek, it is not surprising that these fish are physiologically adapted to tolerate wide temperature and salinity fluctuations. Under experimental conditions, Salt Creek pupfish tolerate temperatures of 38˚C and can survive short-term exposure up to 43°C. They also survived salinities of up to 67 ppt, but died at 79 ppt (LaBounty and Deacon 1972).

Distribution: The Salt Creek pupfish is naturally restricted to Salt Creek, Death Valley National Park, Inyo County. However, they were introduced into Soda Lake, San Bernardino County, and into River Springs, Mono County (Miller 1968). The Soda Lake population no longer exists and the pupfish in River Springs have apparently hybridized with *Cyprinodon nevadensis amargosae,* which were introduced into the same spring. Thus, genetically pure *C. s. salinus* are restricted to Salt Creek and its associated marshes, about 1.5-6 km below McLean Springs. Their actual range varies by water year (Swift et al. 1993).

Trends in Abundance: The numbers of Salt Creek pupfish fluctuate widely based on season and water year, but there is no indication that they are less abundant now than they were in the past.

Nature and Degree of Threats: In spite of protections afforded by Salt Creek's relatively pristine state and location within Death Valley National Park, the Salt Creek pupfish population still faces potential threats, especially given their extremely restricted distribution. The springs which feed Salt Creek may be connected to the aquifer that provides water to Furnace Creek, the center of Death Valley's tourism, so potential for excessive pumping and reduced stream flow exists. Public access to their only known habitat increases risk of contamination and introduction of exotic species and novel pathogens, although these risks are small given the severity of the environment.

	Rating	Explanation
Major dams	n/a	
Agriculture	n/a	
Grazing	n/a	
Rural Residential	Low	Groundwater pumping by Furnace Creek, the town center of Death Valley, could reduce base flows in Salt Creek
Urbanization	n/a	
Instream mining	n/a	
Mining	Low	Present in basin but no known impact
Transportation	n/a	
Logging	n/a	
Fire	n/a	
Estuary alteration	n/a	
Recreation	Low	Limited potential for source of invasive species or pathogens
Harvest	n/a	
Hatcheries	n/a	
Alien species	Low	Harsh conditions favor Salt Creek pupfish and limit opportunities for colonization by alien species

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Salt Creek pupfish. 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: The predicted effects of climate change pose a particular threat to the continued existence of Salt Creek pupfish and their unique desert habitat. As an oasis species, Salt Creek pupfish are remarkably well adapted to widely varying salinity and temperature characterized by their habitat; however, they also exist at the edge of their thermal tolerances, so slight increases in water temperature during summer could impact reproduction and survival.

Isolated desert springs and rivers fed by subsurface flow systems are precarious ecosystems, vulnerable to geologic and anthropogenic disruption. Fed by rain and snow melt at high elevations in desert mountain ranges (Riggs and Deacon 2002), desert aquifers in the Death Valley region will likely receive less recharge as the regions warms. For the reasons described above, Moyle et al. (2013) considered Salt Creek pupfish to be "critically vulnerable" to extinction as the result of climate change effects.

Status Determination Score = 2.7 – High Concern (see Methods section Table 2). While this pupfish seems fairly secure in its isolated setting within a national park, its single, isolated, population is particularly vulnerable to stochastic events and anthropogenic threats, especially aquifer depletion, along with predicted impacts associated with climate change (Table 2).

Metric	Score	Justification
Area occupied	1	Confined to Salt Creek
Estimated adult abundance	3	Population fluctuates widely
Intervention dependence	4	Protection afforded within Death Valley National Park
Tolerance	2	Adapted to extreme temperatures and salinities that would kill most other fishes but exist at the very edge of their tolerances; could be threatened by small changes, esp. increased water temperatures or decreased surface flow
Genetic risk	2	Frequent population fluctuations increase the risk of genetic bottlenecks and may reduce heterozygosity
Climate change	1	Threatened by potential water temperature increases and reduction in aquifer recharge
Anthropogenic threats	5	See Table 1
Average	2.6	18/7
Certainty (1-4)	3	Population has been studied in the past; no recent data available

Table 2. Metrics for determining the status of the Salt Creek 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 explanation of scoring procedures.

In 1992, E. L. Rothfuss, then superintendent of Death Valley National Monument, recommended that the Salt Creek pupfish be listed as a threatened species for the following reasons: "During spring the population expands and disperses throughout the braided stream system, but by mid-summer habitat has contracted due to seasonal evaporation of water, and the fish are confined to several source pools south of MacLean Spring. We believe listing is warranted in light of the restricted extent of the habitat during this portion of the year. While restricted to these pools, the fish are vulnerable to intentional contamination, introduction of exotic competitors, and stochastic events," (letter to B. Bolster, CDFW, June 1, 1992). These threats have not changed in the

intervening 20+ years. The Salt Creek pupfish is considered to be Vulnerable by the American Fisheries Society and "Critically Imperiled" by NatureServe (Jelks et al. 2008). The Cottonball Marsh subspecies is listed as Threatened by the State of California.

Management Recommendations: Present management by Death Valley National Park is adequate to maintain Salt Creek pupfish populations, as well as the entire unique Salt Creek ecosystem. However, potential refuge sites should be located and contingency plans developed in case reductions in Salt Creek pupfish abundance drop below minimum viable levels. Given their restricted range and limited perennial habitat, Salt Creek pupfish should remain a Species of Special Concern with a status review every 5-10 years to document abundance trends and habitat quality and quantity.

Figure 1. Distribution of Salt Creek pupfish, *Cyprinodon salinus salinus* (Miller), in Salt Creek, Inyo County, California.