California Fish and Game 103(3): 91-95; 2017

Distribution of Amargosa River pupfish *(Cyprinodon nevadensis amargosae*) in Death Valley National Park, CA

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Key words: Amargosa River pupfish, Death Valley National Park, distribution, endangered species, monitoring, intermittent streams, range

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Amargosa River pupfish (*Cyprinodon nevadensis amargosae*), is one of six recognized subspecies of Amargosa pupfish (Miller 1948) and survives in waters embedded in a uniquely harsh environment, the arid and hot Mojave Desert (Jaeger 1957). All are endemic to the Amargosa River basin of southern California and Nevada (Moyle 2002). Differing from other spring-dwelling subspecies of Amargosa pupfish (*Cyprinodon nevadensis*), Amargosa River pupfish is riverine and the most widely distributed, the extent of which has been underrepresented prior to this study (Moyle et al. 2015). Originating on Pahute Mesa, Nye County, Nevada, the Amargosa River flows intermittently, often underground, south past the towns of Beatty, Shoshone, and Tecopa and through the Amargosa River Canyon before turning north into Death Valley National Park and terminating at Badwater Basin (Figure 1). Amargosa River pupfish is data deficient with a distribution range that is largely unknown. The species has been documented in Tecopa Bore near Tecopa, Inyo County, CA (Naiman 1976) and in the Amargosa River Canyon, Inyo and San Bernardino Counties, CA (Williams-Deacon et al. 1982, Scoppettone et al. 2011). In the lower Amargosa River, pupfish were documented in the southeastern corner of Death Valley National Park south of the Inyo-San Bernardino County line (Miller 1948) and in the vicinity of Valley Springs (Sada et al. 1997; see Figure 1). These data represent occurrence of pupfish in waters flowing approximately 1.6 km northwest of Saratoga Springs (Soltz and Naiman 1978). This study identifies further downstream habitat and reports presence of Amargosa River pupfish 18 river km upstream of Badwater Basin. Though locally known to occur, Amargosa River pupfish have not previously been documented this far downstream in the lower Amargosa River.

During 2016, an extensive survey of the lower Amargosa River drainage within Death Valley National Park was conducted in the spring (April – May), prior to dry season, and in October, after dry season. The purpose was to determine the distribution of Amargosa River pupfish within Death Valley National Park and to identify suitable locations at which to establish long-term monitoring sites. Survey area was determined by identifying wetted habitat (an underestimate of actual available habitat) using 2010 Bing maps and 2010 or 2014 Google Earth aerial imagery and incorporated into Esri® ArcMAP Version

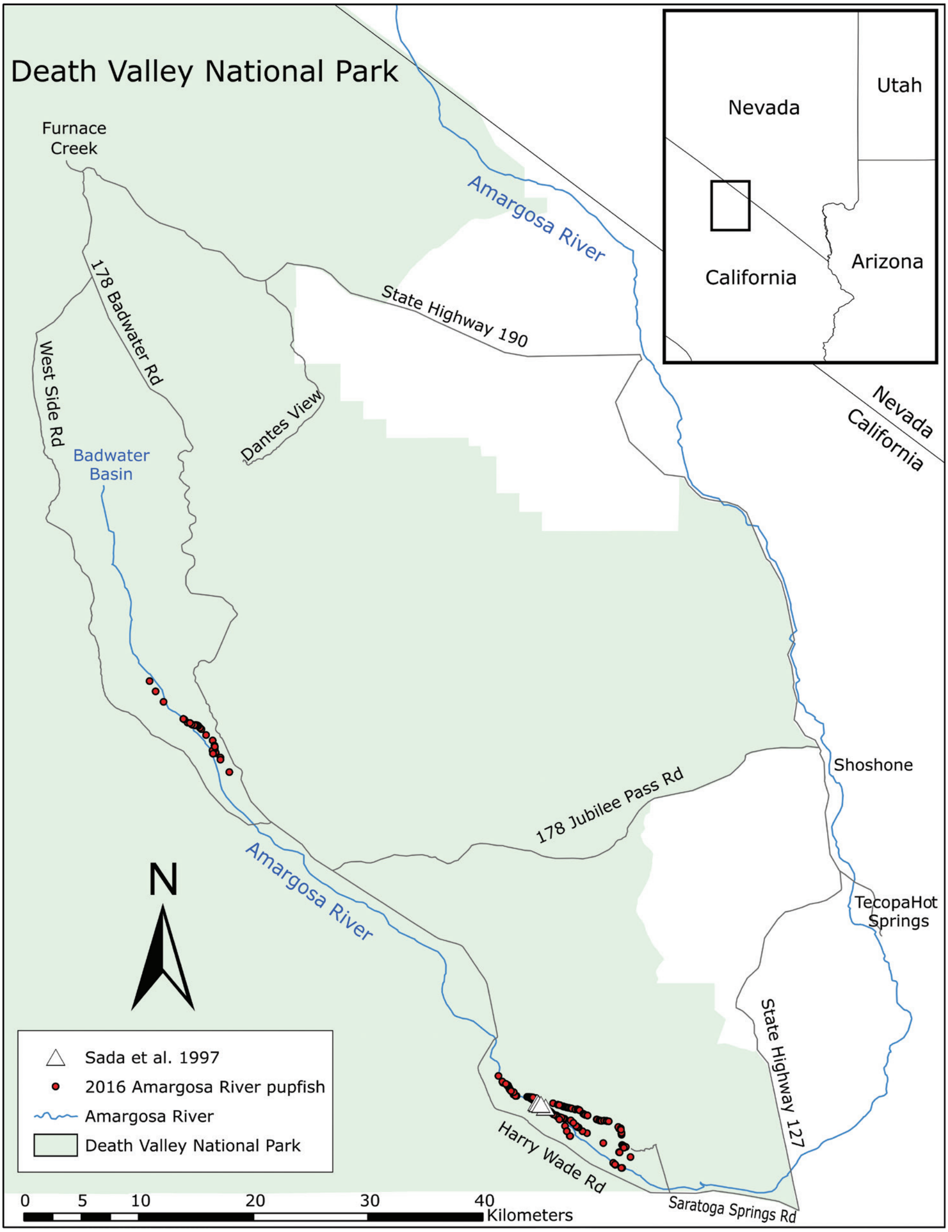

FIGURE 1.—Map of Amargosa River and drainage with wetted and ephemeral sites, upper and lower reaches, Amargosa River pupfish occurrence, and previous record of Amargosa River pupfish (Sada et al. 1997), Death Valley National Park, California, spring and autumn 2016.

10.1. In spring 2016, ground surveys of 508 pre-determined sites were conducted and 213 were sampled for Amargosa River pupfish, the latter selected based on water volume, proximity to other sample sites, and safety of accessibility. A set of three criteria, developed to target sample sites with potential for perennial water following dry season and ease of access, included minimum mean water depth of 0.2 m, minimum area of 100 m^2, and a maximum distance of 2.5 km to the nearest road. Based on these criteria, as well as supplemental pools chosen based on water volume and/or visual observation of pupfish, 53 sites were sampled for Amargosa River pupfish in autumn 2016. During all sampling events, one to three Gee minnow traps (3-mm mesh) were baited with dog food and deployed at sample sites. Water temperature, dissolved oxygen, and pH were measured with Hanna Instruments, Inc., HI9829 portable multiparameter probe. Depth was visually estimated. Biologists were selective towards vegetation and narrow channels when possible while deploying traps. Additionally, Weasel traps (3 mm mesh, 76 mm radius), constructed in-house following a U.S. Geological Survey protocol (S. Madill, U.S. Geological Survey, unpublished report), were used to target pools too shallow for a standard Gee trap. Traps were fished for 2 hr to 7.5 hr and never fished overnight to avoid potential stress to fish. Amargosa River pupfish were processed and returned to the water within 3 m of the trap deployment site. Individuals were categorized and enumerated as male, blue hue with a dark stripe along the caudal and/or anal fin distal edge; female, olive-brown with darker pigmented diamond bars laterally (Figure 2); juvenile, breeding colors not displayed; or age-0, approximate total length less than 1 cm. Other fish species encountered during site visits were identified to species, counted, and photographed.

The downstream-most location of Amargosa pupfish captured in this study extends the previously recorded geographic range approximately 49 river km to 36^{o} 2' 53.448" N, 116^{o} 47' 59.244" W. Totals of 3,738 and 3,424 Amargosa River pupfish were captured in spring and autumn, respectively, and one western mosquitofish (*Gambusia affinis*) was captured in spring. Mean catch per unit trap was comparable between males and females in spring, but most pupfish captured in autumn were female (78% of total catch). All age-0 fish observed in spring were recorded after 6 April 2016, suggesting an approximate spawning time. Across sample sites and seasons, temperature ranged from 13.3 to 30^{o}C, dissolved oxygen ranged from 0.03 to 11.5 mg/L, pH ranged from 7.3 to 9.9, and depth ranged from 0.01 to 2.00 m.

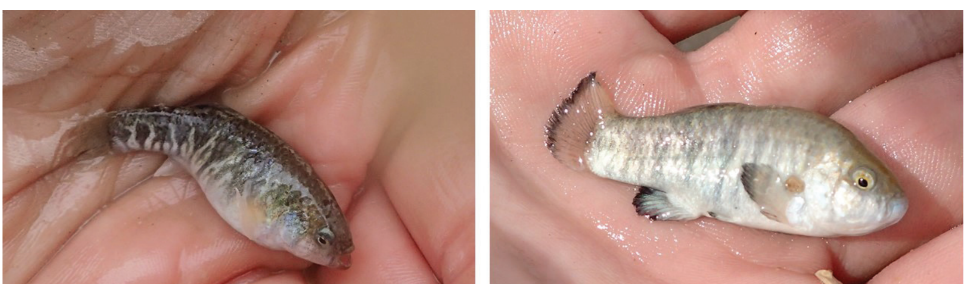

FIGURE 2.—Adult female (left) and male (right) Amargosa River pupfish displaying breeding colors, Death Valley National Park, California, 8 April, 2016 and 11 March 2016, respectively.

Water flow was intermittent overall throughout the drainage system but two stretches of river, defined as the upper and lower reach and delineated by Harry Wade and West Side road crossings (see Figure 1), were consistently wetted in spring. These reaches were separated by approximately 32 km of dry or underground flowing river, offering no pupfish habitat. In contrast to spring surveys, largely dry conditions were noted during autumn with some persistent, isolated pools in both reaches and greater connectedness among pools in the lower compared to upper reach. Catch per unit trap was greater in the lower than upper reach in spring (26.3, 12.1; respectively) and opposite in autumn (3.1, 84; respectively), presumably influenced by drying conditions through summer, increasing capture probability by concentrating fish within the upper reach. Across both spring and autumn, the six sites with the largest catch rates had a mean depth of 0.5 m, both factors indicating these sites have potential for perennial water. Of the sites sampled in spring, pupfish were captured and/or observed at most sites (137; 64%) and at slightly less than half of sites sampled in autumn (25; 46%) indicating Amargosa River pupfish persist in water available to them.

An extreme flooding event in October 2015 dramatically altered normal flow conditions to the Amargosa River basin by increasing discharge two orders of magnitude compared to mean recorded October measurements from 1961 to 2014 (2.42 m^3/s, 0.04 m^3/s) in Tecopa, California (US Geological Survey 2016) and temporarily flooding Badwater Basin. Higher flows resulted in greater water connectivity and persistence through spring 2016 compared to normal intermittent flows not associated with flood events. Continuous water may facilitate dispersal of Amargosa River pupfish throughout the river though overall impacts of the flood event remain unknown. Under normal precipitation conditions, total wetted area is expected to decrease, diminishing connectivity and isolating habitats.

Amargosa River pupfish survival is dependent on availability of perennial pools and short reaches of flowing water, the distribution and abundance of which has been largely unknown within Death Valley National Park. In addition to aerial imagery and site surveys, these observations of pupfish occurrence provide a baseline spatial database of occupied and potential Amargosa River pupfish habitat. Such baseline data allow for comparison with future conditions in the context of stochastic factors, anthropogenic impacts, and climate change induced alterations of flora and fauna distribution patterns. Dewatering of the Amargosa Aquifer for human use alters surface water levels and may threaten Amargosa River habitat availability (Deacon 2011). Scoppettone et al. (2011) suggested that invasive saltcedar (*Tamarix sp.*), red-swamp crayfish (*Procambarus clarkii*), and western mosquitofish present in the Amargosa River Canyon may negatively impact pupfish populations. Two of the Amargosa pupfish subspecies, Tecopa (*C. n. calidae*) and Shoshone (*C. n. shoshone*) are considered extinct and Amargosa River pupfish is a Species of Special Concern in California (Moyle et al. 2015).

Acknowledgments

This work was funded and permitted by the National Park Service and we would like to thank Dr. K. Wilson and all biologists at Death Valley National Park for their cooperation and commitment to conservation. We also thank the rest of the Marsh & Associates team for their enthusiasm searching for pupfish through a very harsh environment.

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Received: 12 May 2017
Accepted: 25 September 2017
Associate Editor was D. Lentz