Summer die-off of western pond turtle (Actinemys marmorata) along an intermittent coast range stream in central California

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deanae appears to be widely distributed throughout the MRG and its associated ditches, and has likely been established for a number of years. More research is necessary to determine what effect, if any, *O. deanae* and other nonnative crayfishes have on the MRG system.

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SUMMER DIE-OFF OF WESTERN POND TURTLE (*ACTINEMYS MARMORATA*) ALONG AN INTERMITTENT COAST RANGE STREAM IN CENTRAL CALIFORNIA

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Abstract—During late summer and fall 2014, we documented western pond turtle (*Actinemys marmorata*) mortality, as indicated by the presence of turtle shells, along a 3.7-km reach of Coyote Creek in the Diablo Range of central California. In total, we observed 39 western pond turtle shells scattered irregularly along our study reach. Shells were found in dry reaches adjacent to or close to pools containing live turtles, as well as in or adjacent to dry pools in isolated dry reaches. Ninety percent of shells observed contained no carcass, and several shells showed evidence of predation. Though the cause of mortality is unclear, our observations confirm that western pond turtles may experience high mortality during droughts, which could result in

significant population decline. The presence of live turtles in refugial pools emphasizes the importance of protecting and managing permanent pools in the face of intensified drought conditions.

Resumen—A finales del verano, y el otoño del 2014, documentamos la mortandad de tortugas del pacífico (*Actinemys marmorata*), indicada por la presencia de caparazones de tortuga a lo largo de una distancia de 3.7 km de Coyote Creek en la Diablo Range del centro de California. En total, se observaron 39 caparazones de tortuga del pacífico esparcidas irregularmente a lo largo de nuestro tramo de estudio. Las caparazones se encontraron en los tramos secos adyacentes o cerca de las charcas que contenían tortugas vivas. También se encontraron en o adyacentes a charcas resecadas en tramos secos aislados. El noventa por ciento de las caparazones observadas no contenían el cadáver adentro, y varias caparazones tenían evidencia de depredación. Aunque la causa de la mortandad no está clara, nuestras observaciones confirman que las tortugas del pacífico pueden sufrir una alta mortandad durante las sequías, lo que podría resultar en una disminución significativa de la población. La presencia de tortugas vivas en charcas permanentes enfatiza la importancia de proteger y manejar charcas permanentes frente a la sequía intensificada.

The western pond turtle (*Actinemys marmorata*) inhabits lakes, ponds, canals, wetlands, and streams (Stebbins and McGinnis, 2012). It is the only freshwater turtle native to California, where it is listed as a special status species and is believed to be vulnerable to extinction because of a restricted range and declining populations (California Natural Diversity Data Base, in litt.). Western pond turtles forage and mate in the water, but nest and often overwinter in terrestrial environments (Bury, 1986; Reese and Walsh, 1998; Rathbun et al., 2002; Bondi and Marks, 2013; Zaragoza et al., 2015).

Western pond turtles are commonly observed in intermittent streams in Mediterranean-climate California (Jennings and Hayes, 1994; Rathbun et al., 2002). As stream flow ceases and the wetted channel contracts during the dry season, turtles often congregate in remnant pools. Declining water levels in these remnant pools provide a cue for some turtles to move to upland habitats, where they overwinter or estivate until the following wet season (Rathbun et al., 2002; Bondi and Marks, 2013). Turtles in northern California streams generally leave the water by August or early September (Reese and Walsh, 1998; Bondi and Marks, 2013). However, some turtles choose to remain in persistent pools until the onset of winter rains (Rathbun et al., 2002; R. A. Leidy, pers. observ.). Late-summer movement of turtles from aquatic to terrestrial environments is thought to be an adaptation for evading the deleterious scouring effects from high stream flows in winter and spring (Reese, 1996; Rathbun et al., 2002). Movement between aquatic and terrestrial environments is not without risk, however, as turtles are subject to predation by raccoons (*Procyon lotor*) and other animals (Rathbun et al., 2002).

Coyote Creek is a large intermittent stream (830 km^2 drainage area) with headwaters in the Diablo Range of central California where the western pond turtle remains locally common. Coyote Creek typically flows for 6 to 9 months beginning in late fall and continuing through early summer, and then contracts to isolated perennial pools by midsummer and fall, a pattern that is typical of Mediterranean-climate streams in this region (United States Geological Survey, http://waterdata.usgs.gov/ca/nwis/uv/?site_no=11169800&PARAmeter_cd=00065,00060). Our study reach lies between 281 and 375 m in elevation. By late summer, this reach is characterized by long dry stretches traversing deep alluvial deposits that are interwoven with narrow canyons, underlain by near-surface bedrock, that support relatively small remnant pools. We estimated that during 2014 less than 5% of our study reach is wetted by late summer and the maximum depths of the remnant pools range from 9 to 168 cm.

On 7 days between 4 August 2014 and 11 November 2014, we walked 3.7 km of Coyote Creek (37°5.546′N, 121°28.095′W) and a tributary, Kelly Cabin Canyon (37°10.2011′N, 121°28.4639′W), to document the use of permanent pools as refuges for native aquatic invertebrates and vertebrates. During the course of this study, we documented numerous dead western pond turtles along Coyote Creek, as indicated by the presence of turtle shells within remaining pools and within dry channels and adjacent riparian areas. When we encountered a turtle shell, we noted the location and condition (e.g., size, carcass intact or not, presence of predator bite, claw, or wound marks) to avoid recounting individuals. We also assessed each turtle shell for the presence of flesh, skin, skeletal remains, and scutes, and whether the shell was bleached, decayed, or otherwise damaged from prolonged multiple-year submersion in pools or from the movement of alluvium. This allowed us to clearly determine whether turtle mortality occurred during the 2014 dry season or during previous years. Here we report the number of shells encountered during our study and observations regarding likely sources of turtle mortality.

In total, we observed 39 western pond turtle shells scattered irregularly along our study reach. Turtle shells were found in dry stretches of stream either adjacent or in proximity to permanent pools containing live turtles, as well as within and adjacent to dried pools in relatively isolated dry stretches of stream. No turtle shells were

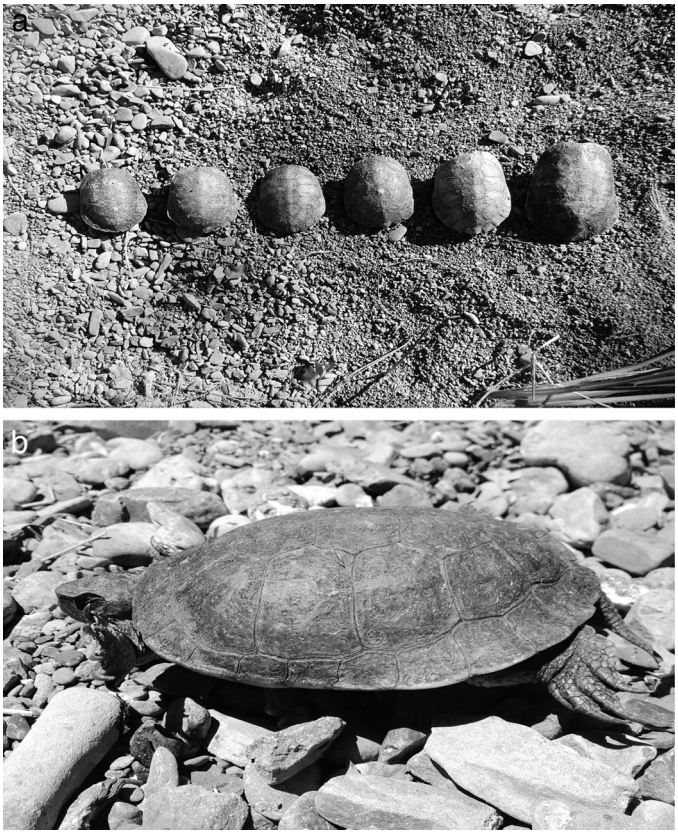

Fig. 1—a) Six of seven empty shells of western pond turtle (*Actinemys marmorata*) recorded on 12 October 2014 from a single dried pool adjacent to a permanent pool along the study reach of Coyote Creek, California. Live turtles were observed in the pool 2 weeks before drying. b) A dead western pond turtle with an intact carcass observed on 4 September 2014 in the study reach adjacent to a permanent pool containing live turtles.

observed in permanent pools. We visually estimated the range of maximum straight-line carapace lengths for all but one turtle as 14–18 cm. Approximately 90% ($n = 34$) of the shell cavities contained only small remnants of soft tissues inside, suggesting that predators or scavengers had extracted the fleshy bodies from most shells (Fig. 1a). All turtle shells exhibited evidence of 2014 dry-season mortality by the presence of remnant flesh, skin, skeletal remains, or scutes. No turtle shells exhibited bleaching, excessive decay, abrasion, or mechanical damage that would indicate prolonged immersion in water or damage from contact with moving alluvium. We observed four shells that were scarred or broken as evidenced by the presence of claw and tooth marks. The remaining 10% ($n = 5$) of carcasses were intact (Fig. 1b). In addition to dead turtles in the terrestrial environment, we also observed live turtles in perennial pools during the entire observation period.

Movement studies have revealed that western pond turtles in intermittent streams will move into remnant pools as the stream contracts and fragments, and many will later move to the upland terrestrial environment to estivate (Bondi and Marks, 2013). Intermittent streams vary in the duration of the dry period and extent of refugial pool habitat, which influences turtle movement behavior. For example, previous research at one central California intermittent stream reported that 100% of tagged turtles left the creek for upland habitats when there were no in-stream perennial refuges available, but only 50% of turtles moved upland in a neighboring stream where perennial pools were available (Rathbun et al., 2002). Furthermore, the number of in-stream perennial refuges varies among years at any given site, with more wetted habitat following wet winters than dry winters (Hwan and Carlson, 2016). Our study occurred during the 2014 water year—the third and driest year of a multiyear drought and the second driest year in the recorded history of California (Griffin and Anchukaitis, 2014)—so it is possible that the turtle mortality we observed was more extreme because of these harsh drought conditions. No turtle shells were observed within permanent pools or dry channels by RAL over previous surveys of the study reach during late September 1993 and August 1995 (R. A. Leidy, pers. obser.). Notably, the total precipitation during 1993 and 1995 was 151% and 145%, respectively, above the yearly average for the period 1976–2014 as measured at a nearby rain gauge (Henry Coe State Park, in litt.).

Although we have documented a western pond turtle die-off, the cause of mortality is unclear. In a recent paper examining temporal patterns of animal die-off events, only one die-off of a freshwater turtle (European pond turtle, *Emys orbicularis*) was reported, and it was caused by otter predation (Lanszki et al., 2006; Fey et al., 2015). Predation has also been implicated in the mortality of pond turtles in California (Rathbun et al., 2002). Specifically, these authors studied the movement of tagged pond turtles in central California from an intermittent stream to upland reaches, and found that 8 of 13 dead turtles recovered on land showed signs of predation by raccoon. Of the 39 turtle shells that we recovered, roughly 90% showed signs of predation or postmortem scavenging, but we were unable to distinguish between these two possibilities. However, the remaining 10% ($n = 5$) of intact carcasses suggest that predation was not the sole cause of mortality. Past research suggests that western pond turtle survival rates can be very high (>95%) in wet years (Ashton et al., 2011), but quite low (<20%) in severe drought years (Holland, 1991). Thus, drought likely affects western pond turtle mortality in California streams, but more research is needed to determine whether these impacts are direct (e.g., desiccation) or indirect (e.g., increased predator access in drying pools).

Our observations confirm that western pond turtle populations at Coyote Creek might experience high mortality during the dry season, at least over some portion of the total stream length in the watershed. This suggests that during droughts turtle mortality might be

significant and potentially could result in population-level declines. More important, over the course of our study, we regularly encountered live pond turtles in remnant pool habitat, which emphasizes the importance of protecting and managing refugial pools for conserving pond turtles, particularly in the face of intensified drought conditions and climate change.

We thank Henry Coe State Park for providing access to the study reach at Coyote Creek. This research was funded by the Rose Hills Innovator Award at UC-Berkeley to SMC and a Smith Postdoctoral Fellowship to MTB. This work was also supported by the USDA National Institute of Food and Agriculture, Animal Health project [1004229] to SMC. We thank S. Kelson for assistance in the field and P. L. Fiedler for review of the manuscript.

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FEEDING ECOLOGY OF NONNATIVE, INLAND *FUNDULUS GRANDIS* IN THE LOWER PECOS RIVER

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Abstract—Gulf killifish, *Fundulus grandis*, have been introduced in the Lower Pecos River and are highly abundant in reaches of the Permian Basin region. Very little is known about the ecology of nonnative, inland populations of *F. grandis*. We investigated the feeding ecology of this species in the Pecos River using stomach contents analysis and laboratory feeding trials. Inland *F. grandis* were piscivorous, consuming more fish prey