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RESEARCH NOTE

An endemic anuran and a horny toad: distributional histories, the potential for sympatry, and implications for conservation

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The Amargosa toad (*Anaxyrus nelsoni*) is one of five bufonid species with highly restricted distributions in the Great Basin of California and Nevada (Gordon et al. 2017, 2020), and was described as *Bufo boreas nelsoni* by Stejneger (1893). The holotype (USNM 18742) and 7 paratypes were collected in Oasis Valley, Nye County, Nevada. Two paratypes (USNM 18744 and USNM 18745) originally ascribed to that taxon were collected in the Amargosa River drainage at Resting Springs, Inyo Co., California, but the taxonomic status of the Resting Springs paratypes appears uncertain (Storer 1925). The Amargosa toad is restricted in distribution to Oasis Valley (Burroughs 1999; Dodd 2013; IUCN 2019) where it occupies wetlands along or adjacent to a 15-km reach of the Amargosa River between Springdale and Beatty (Fig. 1). The taxon may be declining in number (Simandle 2006, IUCN 2019), but is not protected under the federal endangered species act (USFWS 2010). Following population assessments (Altig and Dodd 1987; Heinrich 1995; Stein et al. 2000), which generated concern about conservation of the taxon, a multi-party agreement (NDOW 2000) was developed. The most recent status assessments of the Amargosa toad (Hammerson 2004; USFWS 2010), however, were completed more than a decade ago. In this paper I do not advocate for endangered or threatened status for Amargosa toad but, rather, offer a cautionary note in the context of the potential for sympatry between *A. nelsoni* and a non-native congener, Woodhouse's toad (*Anaxyrus woodhousii*), and the consequences thereof.

Woodhouse's toad is well-adapted to a variety of ecological conditions (Bradford et al. 2005; Ryan et al. 2017), and occurs widely throughout the United States (Conant 1958; Stebbins 2003). In California, its historical range was restricted to the Lower Colorado River Valley, Imperial County (Storer 1925), and historical range in Nevada encompassed the floodplains of the Muddy, Virgin, and Colorado rivers in Clark County (Bradford et al. 2005). This generalist bufonid is highly successful at exploiting newly available habitat and, over the past century, this ability has led to a substantial expansion of its distribution in California and Nevada (Bradford et al. 2005; Goodward and Wilcox 2019; Bleich 2020).

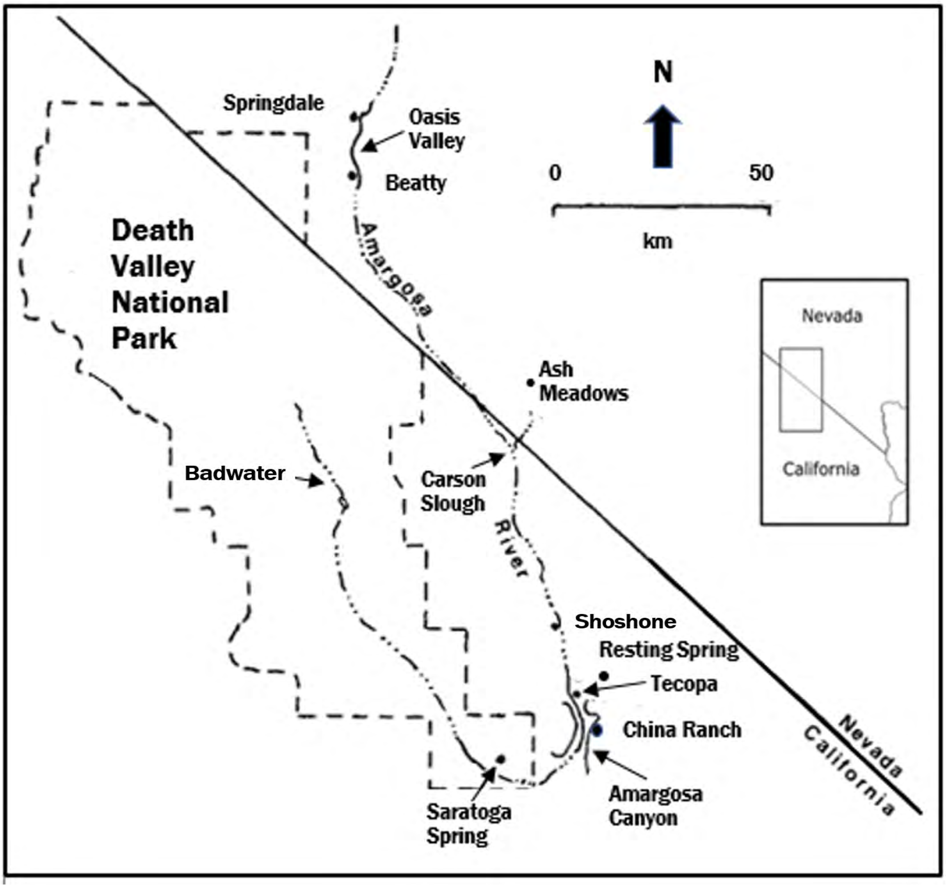

Figure 1. The Amargosa River has its origin at an elevation of 1,200 m on Pahute Mesa, about 20 km north of Beatty, Nye County, Nevada. The river flows southward, westward, and then northward over a distance of 185 km, reaching its terminus near Badwater in Death Valley, Inyo County, California. Sections of the Amargosa River that do not support perennial surface flows in the absence of substantial rainfall events are indicated by the broken line; those sections normally supporting surface water occur primarily in Oasis Valley, in the vicinity of the Amargosa River Canyon, and near Saratoga Spring, and are indicated by a solid line; adapted from Williams et al. (1984).

In general, amphibian movements are occasional and limited (Sinsch 1990; Blaustein et al. 1994), but long-distance dispersal by anurans may be more common than historically assumed, in part because logistical realities often limit the size of study areas (Smith 2003). Further, the distances over which specific taxa can disperse often are poorly known (Smith and Green 2006), but long-distance movements by many species of bufonids have been described, and *A. woodhousii*—as well as a number of other congenerics—is capable of such movements (Smith and Green 2005, 2006; Palmeri-Miles 2012; Bleich 2020; Myers 2020). Expansion of the distribution of *A. woodhousii* in California and Nevada can be explained in large part by anthropogenic introductions, or other anthropogenic actions that have created suitable habitat (Bradford et al. 2005; Goodward and Wilcox 2019). In addition, severe precipitation events likely have provided opportunities for *A. woodhousii* to move long distances along intermittent waterways and colonize areas not contiguous with extant populations (Bleich 2020). Rainfall events similar in severity to those described by Bleich (2020) occur within the historical range of *A. nelsoni*, and further south along the Amargosa River (Tanko and Glancy 2001; WRCC 2020). Water flows above ground in and adjacent to the Amargosa River (Fig. 1, Fig. 2) for extended periods following such events (Tanko and Glancy 2001) and, although some sections dry spatially and temporally, other stretches remain wet year-round (Dodd 2013; Humphrey et al. 2017).

Numerous records of *A. woodhousii* recently have been confirmed along the Amargosa River, and elsewhere in the Amargosa River drainage basin, in Inyo and San Bernardino counties, California and Nye County, Nevada. In 2012, *A. woodhousii* was reported from an undisclosed location along the Amargosa River "south of Death Valley" (California Herps 2020a), and the species later was reported from wetlands along the Amargosa River ~5 km south of Tecopa, Inyo County (Greene and Branston 2013). Information provided initially by California Herps (2020a) was revised (California Herps 2020b) after the location was confirmed (G. Nafis, *in litt.*, 20 July 2020) to be that reported by Greene and Branston (2013). Observations (iNaturalist 2020) or museum specimens obtained in 2017 (VertNet 2020) confirmed persistence of the population described by Greene and Branston (2013), as well as additional locations along the Amargosa River. Further, *A. woodhousii* has become established in a reservoir and in wetlands along Willow Creek, a tributary to the Amargosa River near the China Ranch, in northern San Bernardino County and southern Inyo County (Appendix A). Greene and Branston (2013) estimated the Euclidean distance from their

Figure 2. Extreme precipitation events in the Amargosa River drainage basin frequently result in temporary wetlands that can serve as 'stepping-stone' habitat and facilitate dispersal by *Anaxyrus woodhousii*. This image depicts flooding on State Line Road at Carson Slough near Death Valley Junction, Inyo County, California, on 25 February 1998; adapted from Tanko and Glancy (2001).

recently discovered population of *A. woodhousii* to the nearest population of *A. nelsoni* to be 130 km. As of 2017, the Path Distance Function in Google Earth Pro indicated the distance between the nearest population of *A. woodhousii* on the Amargosa River to that of *A. nelsoni* in Oasis Valley was approximately 150 km as measured along the river channel. Nevertheless, in 2016, 2019, and 2020, Woodhouse's toad was confirmed at Ash Meadows National Wildlife Refuge (AMNWR), Nye County, an area supporting numerous springs and wetlands (Kodric-Brown and Brown 2007) and proximate to the Amargosa River. Confirmation of *A. woodhousii* at AMNWR increases the potential of its presence in the main channel of the Amargosa River at the same latitude, thereby placing it within a Euclidian distance of ~70 km (~100 km as measured along the river channel) of populations of *A. nelsoni*.

Neither date(s) nor source(s) of origin of these recently confirmed populations of *A. woodhousii* can be determined with certainty. A herpetofaunal survey of the Death Valley region that included portions of California and Nevada (Stejneger 1893) yielded no records of *A. woodhousii* (described at the time as *Bufo lentiginosus woodhousii*) in the vicinity of the Amargosa River, including Saratoga Spring—a perennial source of surface water separated from the river by a damp salt flat and thin layer of water (Bradley 1970)—or elsewhere along the Amargosa River, including Oasis Valley. Norris (1949:46) confirmed the presence of treefrogs (*Pseudacris regilla*), and Turner and Wauer (1963) confirmed the presence of *P. regilla* and red-spotted toads (*Anaxyrus punctatus*) at Saratoga Spring, but neither party reported *A. woodhousii* at that location. Norris (1950:117–118) also reported the presence of treefrogs and of introduced bullfrogs (*Lithobates catesbeianus*) at Fairbanks Ranch and at Fairbank's Springs—both within AMNW and having abundant water, mesquite trees, cottonwoods, tamarisk, and grass (Norris 1950:117–118; McCracken 1990:22). Neither Norris (1950) nor McCracken (1990) mentioned the presence of toads at either of those locations. It is certain, however, that *Anaxyrus* sp. was collected at Resting Springs in Chicago Valley, Inyo County, in 1891 (Stejneger 1893); Resting Springs is connected to the Amargosa River by a normally dry watercourse (Hershler and Pratt 1990) of ~5 km in length (Fig. 1).

Nearly 80 years following Stejneger's (1893) report, Bezy and Wright (1972) reported *A. punctatus*, but not Woodhouse's toad, during their herpetological survey of the Amargosa River Canyon. Additionally, I did not encounter Woodhouse's toad during extensive fieldwork along the Amargosa River between Willow Creek and Shoshone (Bleich 1972, 1974, 1979, 1980; Gould and Bleich 1977). Further, F. A. Gomez (*in litt.*, 7 September 2020), a resident of Tecopa from 1961 to 1985, does not recall observing any toads during countless hours spent recreating along the Amargosa River. Moreover, and roughly a century after Stejneger's (1893) report, neither Pratt and Hoff (1992) nor Persons and Nowak (2006) reported *A. woodhousii* in the Amargosa River drainage. Thus, available evidence suggests that Woodhouse's toad had not become established in that region prior to the work of Persons and Nowak (2006).

Whether the current distribution of *A. woodhousii* in the Amargosa River drainage represents multiple anthropogenic introductions, or is the result of range expansion from a single introduction, is not known. It is possible that Woodhouse's toad was present at one or more of these sites (Appendix A) prior to 2012, but the initial date(s) of any such appearance(s) cannot be ascertained, and the presence of *A. woodhousii* in the Amargosa River drainage is most apt to be a recent phenomenon. The ability of Woodhouse's toad to disperse along normally dry streambeds confirms it can move substantial distances when surface flows create suitable, albeit perhaps temporary, 'stepping stone' habitat (Bleich 2020), and such may contribute to an expanding distribution of *A. woodhousii* in the Amargosa River drainage and elsewhere. Stepping-stone habitat enhances the probability of dispersal into areas of noncontiguous—albeit otherwise suitable—habitat that can arise as a result of stochastic occurrences, among which are extreme rainfall events. Further, these habitat patches have allowed expansion of *A. woodhousii* (and other anurans) into previously unoccupied areas (Goodward and Wilcox 2019). Stepping-stone habitat also has the potential to promote gene flow among isolated populations, potentially enhancing persistence of recently established, but noncontiguous, demographic units (Bleich et al. 1990).

Anaxyrus spp. are especially vulnerable to congeneric hybridization, and interbreeding between Woodhouse's toad—a highly successful species capable of rapid or long-distance dispersal under suitable conditions—and ≥10 other bufonids has posed a conservation risk to several taxa (Hillis et al. 1984; Sullivan and Lamb 1988; Gergus et al. 1999; Lannoo 2005). If Woodhouse's toad becomes sympatric with *A. nelsoni*, the ramifications for disease transmission, ecological relationships (i.e., competition), hybridization and resultant genetic introgression (Fig. 3), or behavioral modifications, singly or in combination, bode poorly for the future of Amargosa toad as a viable taxon (Carey et al. 2003; Sullivan 2005).

Figure 3. Woodhouse's toad (*Anaxyrus woodhousii*) has hybridized with at least 10 other species in the western United States as summarized by Sullivan (2005), and readily breeds with other members of the family Bufonidae as demonstrated here with a red-spotted toad (*Anaxyrus punctatus*). If Woodhouse's toad attains sympatry with Amargosa toad (*Anaxyrus nelsoni*), the potential for genetic introgression will become a primary conservation concern. Photograph © B. J. Putman, 6 April 2017, China Ranch, San Bernardino County, California; used with permission.

The recent and continuing de-emphasis of natural history as a respectable scientific discipline by many colleges and universities (Noss 1996; Kessler and Booth 1998; Bleich and Oehler 2000; Bleich 2018) has yielded decreased interest in the relevance of descriptive ecology or distributional records. Citizen science, however, is beginning to fill that void, and increasingly is recognized as a valued and valid source of information (Gura 2013; Ballard et al. 2017; Spear et al. 2017; Parker et al. 2018b). It is through such efforts that shifts in the distribution of *A. woodhousii* along the Amargosa River (iNaturalist 2020) and elsewhere (Goodward and Wilcox 2019), or documentation of the western toad (*Anaxyrus boreas*) in the Amargosa River drainage (iNaturalist 2020) recently have become available or are tractable, but shortcomings do exist. For example, while emphasizing the value of the riparian ecosystem associated with the Amargosa River and its importance to a variety of taxa, Parker et al. (2018a) failed to note that *A. woodhousii* is not native to that system or to call attention to the ramifications of its presence.

Proximity of Woodhouse's toad to the distribution of *A. nelsoni* was noted by Greene and Branston (2013). More recently, *A. woodhousii* has been confirmed at multiple locations along the Amargosa River, and potentially within 100 km of Oasis Valley. The dispersal ability of Woodhouse's toad and the occurrence of multiple disjunct populations of this highly adaptable bufonid in the same river drainage occupied by a vulnerable congeneric raise concern and suggest additional efforts are necessary to understand the current distribution of *A. woodhousii*. Demonstrating the potential impact of an exotic or invasive species, however, need not require conclusive proof (Carey et al. 2003) before action is taken to prevent development of an egregious, and perhaps irreversible, situation. As emphasized by Bradford et al. (2005), doing so is a tremendous challenge, but fear-of-failure to preclude development of sympatry between an endemic species of limited distribution and a widespread and highly adaptable invasive species should not prevent efforts to ensure the persistence of *A. nelsoni* as a viable taxon (Meek et al. 2015). I suggest conservation agencies and interested parties—including citizen-scientists (Bass 2016)—work collaboratively to record shifts in the distribution of Woodhouse's toad along the Amargosa River and that actions to prevent the northward dispersal of *A. woodhousii*—and the potential for sympatry with *A. nelsoni*—be initiated immediately.

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APPENDIX A. RECORDS OF *ANAXYRUS WOODHOUSII* IN THE AMARGOSA RIVER DRAINAGE

The Amargosa River drains a watershed of 15,540 km^2 (Menges 2008). The river extends ~198 km from its origin on Pahute Mesa, Nye County, Nevada, through a portion of southern Inyo and northern San Bernardino counties, California, and reaches is terminus in Death Valley, Inyo County. Within the drainage basin, and as of the date of this publication, *Anaxyrus woodhousii* has been confirmed in that portion of Amargosa River near Tecopa, California, and at Ash Meadows National Wildlife Refuge, Nye County, Nevada.

Date	General Location	County	Latitude	Longitude	Source
Apr 2012	Amargosa River, ~4 km SSE of Tecopa	Inyo [a]	35.815919	-116.214778	LACM PC 1602, 1603 [d, e]
Mar 2016	Ash Meadows National Wildlife Refuge	Nye [b]	36.401367	116.274716	iNaturalist 10173429 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.804388	-116.183839	iNaturalist 5633718 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.805131	-116.183450	iNaturalist 5633759 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.804388	-116.183839	iNaturalist 5633770 [f]
Apr 2017	China Ranch, adjacent to main parking area	Inyo	35.799762	-116.194764	iNaturalist 5645084 [f]
Apr 2017	China Ranch downstream from main parking area	Inyo	35.799008	-116.195107	iNaturalist 5645092 [f]
Apr 2017	Amargosa River, S confluence with Willow Creek	SB [c]	35.783139	-116.201470	iNaturalist 5645123 [f]
Apr 2017	Amargosa River, 4.2 km S Old Spanish Trail Hwy	Inyo	35.814089	-116.210463	iNaturalist 5712521 [f]
Apr 2017	Amargosa River, 4.0 km S Old Spanish Trail Hwy	Inyo	35.815352	-116.21093	iNaturalist 5633669 [f]
Apr 2017	China Ranch, adjacent to main parking area	Inyo	35.799733	-116.194892	iNaturalist 5648539 [f]
Apr 2017	Amargosa River, 3.7 km S Old Spanish Trail Hwy	Inyo	35.817289	-116.21411	iNaturalist 5645134 [f]
Apr 2017	Amargosa River, 3.7 km S Old Spanish Trail Hwy	Inyo	35.817325	-116.214076	iNaturalist 5645137 [f]
Apr 2017	Amargosa River, 4.4 km S Old Spanish Trail Hwy	Inyo	35.810046	-116.211608	iNaturalist 5645143 [f]
Apr 2017	Amargosa River, 1.4 km S Old Spanish Trail Hwy	Inyo	35.836011	-116.222668	iNaturalist 5645177 [f]
Apr 2017	Amargosa River, 750 m S Old Spanish Trail Hwy	Inyo	35.841682	-116.225401	iNaturalist 5645175 [f]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.80505	-116.18379	LACM Herps 188785 [e]
Apr 2017	China Ranch Reservoir, China Ranch	Inyo	35.80505	-116.18379	LACM Herps 188786 [e]
Apr 2017	Amargosa River, 4.0 km S Old Spanish Trail Hwy	Inyo	35.81580	-116.21164	LACM Herps 188789 [e]

APPENDIX A. CONTINUED

Date	General Location	County	Latitude	Longitude	Source
Apr 2017	Willow Creek, downstream of China Ranch [g]	SB	35.789746	-116.199901	iNaturalist 5633649 [f]
May 2017	Ash Meadows National Wildlife Refuge	Nye	36.401093	-116.274748	iNaturalist 6409166 [f]
Apr 2019	Ash Meadows National Wildlife Refuge	Nye	36.432697	-116.310188	iNaturalist 22147290 [f]
Mar 2020	Ash Meadows National Wildlife Refuge	Nye	36.401542	-116.273897	iNaturalist 40312776 [f]

[a] Inyo Co., California
[b] Nye Co., Nevada
[c] San Bernardino Co., California
[d] Greene and Branston (2013)
[e] Los Angeles County Museum of Natural History specimen number
[f] Locations associated with iNaturalist records are available at https://www.inaturalist.org/observations
[g] Location at which image in Fig. 2 was obtained