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Locality records for Woodhouse's toad: have wet washes in a dry desert led to extralimital occurrences of an adaptable anuran?

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Woodhouse's toad (*Anaxyrus woodhousii*), also referred to as the Rocky Mountain toad, is an adaptable bufonid that disperses readily into newly disturbed habitats (Ryan et al. 2017). It has a broad geographic distribution in North America, ranging in elevation from below sea level to elevations of about 2,500 m (Storer 1925; Stebbins 1951; Sullivan 2005; Goodward and Wilcox 2019). In California, *A. woodhousii* is native to the Lower Colorado River Valley in southeastern Imperial County (Storer 1925; Appendix A). In 1905 and 1906, Colorado River waters broke through a partially constructed canal and flooded the Salton Sink (McCollom 2000; Ross 2020). As a result, *A. woodhousii* likely became established in the Imperial Valley, Imperial County; it could have arrived earlier, however, when the Colorado River overflowed its banks on previous occasions (NOAA 2010; CDWR 2013; SSA 2017; Lynch and McNeece 2020; Ross 2020) and its presence unconfirmed.

In general, amphibian movements are occasional and limited (Sinsch 1990; Blaustein et al. 1994). Long-distance dispersal by anurans may be more common than historically assumed, however, in part because logistical realities often limit the size of study areas (Smith 2003). Distances over which specific taxa can disperse are often poorly known (Smith and Green 2006), but many species of bufonids are capable of long-distance movements (Smith and Green 2005). Whatever event(s) contributed to the establishment of extralimital populations more than 70 km west of the Colorado River, *A. woodhousii* had been confirmed in the Imperial Valley by the mid-1920s (Appendix A).

By the late 1920s, the documented presence of Woodhouse's toad had expanded westward from the Imperial Valley to Harper Well, located along San Felipe Creek, and also in Imperial County (Appendix A). Additionally, Glaser (1970) described a single record of Woodhouse's toad near Mecca, Riverside County, suggesting the geographic range of *A.*

woodhousii was expanding northward into the Coachella Valley of Riverside County, and he further noted the potential for the occurrence of Woodhouse's toad near the Colorado River in the Palo Verde Valley, Riverside County. Apparently unbeknownst to Glaser (1970), at least nine specimens had been collected in the Coachella Valley (ARCTOS 2018; VertNet 2020; Appendix A) by the time he published his monograph on the amphibians and reptiles of Riverside County. Although some additional specimens were collected near Mecca from 1930 to 1970, compelling evidence that *A. woodhousii* did not become widely distributed in the Coachella Valley was provided by Goodward and Wilcox (2019) who noted, "It appears this species [Woodhouse's toad] did not get established or persist in the Coachella Valley with the 1905-06 [breach of the canal] or earlier floodwaters that created temporary wetlands in the Salton Sink."

Within five years of Glaser's (1970) publication, Woodhouse's toad was numerous in channels and ditches near Mecca in the Coachella Valley, and Keasler et al. (1975) reported that the species was encountered only where irrigation was occurring. More recently, Goodward and Wilcox (2019) described the occurrence of *A. woodhousii* as throughout the Coachella Valley, and further affirmed the close association of Woodhouse's toad with irrigated agriculture; they also noted its association with anthropogenic ponds, golf resorts, and urbanized areas. In this note, I describe the heretofore unreported presence of Woodhouse's toad in the Santa Rosa Mountains on the western edge of the Coachella Valley, and outside the range of the species depicted by Goodward and Wilcox (2019). Further, I offer comments on the probable role of extreme weather events in expanding the geographic range of *A. woodhousii* in southeastern California.

On 3 August 1977, I captured, photographed, and released a single *A. woodhousii* (Figure 1) at Upper Sumac Spring (33.4549 N, 116.2207 W, ~780 m above sea level) in the Santa Rosa Mountains, Riverside County; based on its size, I suspected the specimen was an adult male. At that time, water was present in a small (1 × 1.5 × 0.25 m) pool. Upper Sumac Spring is in Sumac Canyon, which drains a large portion of the eastern slope of the Santa Rosa Mountains, and an expansive alluvial fan is contiguous with irrigated agricultural land (~6 m above sea level) near the mouth of the canyon. I observed no toads during spring and summer 1975 and 1976 (two visits per year, respectively), when I inspected Upper Sumac Spring to ascertain the presence of surface water at that location. Available information (Jones et al. 1953, 1957; Weaver et al. 1970) indicates the spring long has been a dependable source of surface water used by desert bighorn sheep (*Ovis canadensis nelsoni*); thus, an earlier, albeit previously unreported, presence of *A. woodhousii* at Upper Sumac Spring cannot be ruled out.

In September 1976, Tropical Storm Kathleen deposited unusually high rainfall in and near the Imperial and Coachella valleys (Appendix B), and 1976 was the first of several years of above-average precipitation that increased availability of surface water in many canyons on the eastern slope of the Santa Rosa Mountains (Wehausen et al. 1987). The storm yielded 16.18 cm of rain at Deep Canyon ($\bar{x}_{\text{September}}$ = 1.40 cm) and 13.31 cm of rain at Thermal ($\bar{x}_{\text{September}}$ = 0.81 cm), located 35 km northwest and 29 km north of Upper Sumac Spring, respectively (WRCC 2020). Following that storm, water flowed almost continuously in Sumac Canyon and other major canyons on the east side of the Santa Rosa Mountains until May 1977 (V. C. Bleich, personal observation). The flow of water in Sumac Canyon had subsided by the time I visited Upper Sumac Spring in August 1977, at which time intermittent pools remained in the bottom of the drainage.

Figure 1. Dorsal (A) and lateral (B) photographs of Woodhouse's toad (*Anaxyrus woodhousii*) captured at Upper Sumac Spring, Santa Rosa Mountains, Riverside County, California, on 3 August 1977; identification confirmed by R. B. Loomis, California State University, Long Beach.

Geographic expansion of *A. woodhousii* westward from the Colorado River to the Imperial Valley and, subsequently, northward to the Coachella Valley, was facilitated by suitable habitat created as land was irrigated for agricultural purposes, and the concomitant development of canals and ditches (Goodward and Wilcox 2019; Keasler et al. 1975) and, potentially, golf courses and urbanized areas. Additionally, Goodward and Wilcox (2019) noted that Woodhouse's toad likely dispersed northward along the channelized Whitewater River during surface flows. The early presence of *A. woodhousii* at Harper Well, and more recently at Upper Sumac Spring following Tropical Storm Kathleen, however, compelled me to hypothesize that dispersal of *A. woodhousii* throughout the Imperial Valley and Coachella Valley, but particularly to extralimital locations isolated from irrigated agriculture, has been facilitated by extreme rainfall events.

Application of the Path Distance Function in Google Earth Pro yielded a distance of ~8.8 km—as measured along the canyon floor—and a mean slope of 8.7% between Upper Sumac Spring and the nearest irrigated agricultural land. The continuous flow of water in Sumac Canyon for ~8 months following Tropical Storm Kathleen likely resulted in conditions suitable for *A. woodhousii* to disperse westward into the canyon and eventually reach Upper Sumac Spring. In contrast, San Felipe Creek is an intermittent stream, the eastern terminus of which historically reached the Salton Sink, but now is contiguous with irrigated agricultural fields in the western Imperial Valley. Application of the Path Distance Function yielded a distance of ~17.0 km (mean slope = 0.21%) from Harper Well (~34 m below sea level) to the existing shoreline of the Salton Sea (~70 m below sea level)—a surrogate for the probable distance to suitable habitat following formation of the Salton Sea in 1905—and a distance of ~8.4 km (mean slope = 0.33%) from Harper Well to the nearest agricultural activity (~62 m below sea level) in the western Imperial Valley. Although the date that *A. woodhousii* first arrived at Harper Well cannot be determined definitively, Mendenhall (1909) described the presence of "good water" and an abundance of mesquite (*Prosopis* sp.) several years prior to publication of his research.

Keasler et al. (1975) did not identify extreme rainfall events as important to the dispersal of Woodhouse's toad or the subsequent increase in its geographic distribution, but Goodward and Wilcox (2019) alluded to that possibility. The severity and widespread occurrence of such events over much of the Imperial and Coachella valleys (Appendix B), however, suggests major storms have played prominent roles in the geographic distribution of the species. Since 1963—when *A. woodhousii* was first reported from the Coachella Valley—8 of 13 (62%) weather stations in the vicinity of the Coachella or Imperial valleys have recorded maximum annual rainfall ranging from 223% to 347% of mean annual rainfall on record, 6 of 13 (46%) have recorded maximum monthly rainfall ranging from 93% to 243% of mean annual rainfall on record, and 7 of 13 (54%) have recorded maximum one-

Figure 2. Flooding at Ocotillo, Imperial County, California, 40 km SSW of Harper Well, Imperial County, following Tropical Storm Kathleen. This image exemplifies the vast areas covered by flowing or standing water associated with the severe, albeit infrequent, rainfall events that likely have contributed to the dispersal of Woodhouse's toad (*Anaxyrus woodhousii*) in or adjacent to the Imperial and Coachella valleys, California (FEMA 1989).

day rainfall ranging from 68% to 196% of mean annual precipitation on record (WRCC 2020). Many of these extreme rainfall events probably yielded widespread runoff like that resulting from Tropical Storm Kathleen (Figure 2).

Periodic severe rainfall events similar to those emphasized above likely have contributed to the widespread distribution of Woodhouse's toad in the Imperial and Coachella valleys, and particularly in locations normally isolated from potentially suitable habitat by dry canyon bottoms (e.g., Upper Sumac Spring) or intermittent creeks (e.g., Harper Well). Intense weather events result in stepping-stone habitat—wherein survival of a species may be enhanced for a period of time (Bleich et al. 1990) and is analogous to the springs described by Goodward and Wilcox (2019)—that allowed, and continues to allow, *A. woodhousii* to expand in distribution and reproduce in areas otherwise unavailable in the absence of torrential rainfall. Thus, the westward expansion of *A. woodhousii* into Sumac Canyon and its presence at Upper Sumac Spring likely were results of extreme rainfall and subsequent runoff associated with a major storm event, and at least one similar event most likely explains the presence of Woodhouse's toad at Harper Well early in the 20th Century. Whether populations remain at Upper Sumac Spring or at Harper Well, or others have become established and persist at additional springs in the Santa Rosa Mountains, or at heretofore unconfirmed locations in the West Chocolate, East Chocolate, Orocopia, Chuckwalla, Little San Bernardino, or Fish Creek mountains—each of which is proximate to the Salton Sink and the Imperial or Coachella valleys—is not known.

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APPENDIX A. MUSEUM RECORDS FOR *ANAXYRUS WOODHOUSII*

Museum records (ARCTOS 2018, VertNet 2020) documenting the dispersal of *A. woodhousii* from the Lower Colorado River Valley, Imperial County, to the Imperial and Coachella valleys, Imperial (I) and Riverside (R) counties, California, respectively. Also shown are the years during which *A. woodhousii* was recorded at Harper Well, Imperial County, and at Upper Sumac Spring, Riverside County. *A. woodhousii* remains widespread in the Imperial Valley and has spread to numerous locations throughout the Coachella Valley (Goodward and Wilcox 2019).

General Location	Specific Location	Year	Institution	Specimen Number
Near Colorado River (I)	Potholes	1910	MVZ[a]	Herp 1842, 1844
	5 mi NE Yuma	1910	MVZ	Herp 1843
	Yuma Indian Reservation	1912	CAS[b]	Herp 33422
Imperial Valley (I)	Imperial	1926	UMMZ[c]	Herp 64925, 64926, 71483
	El Centro	1929	LACM[d]	Herp 12054
	SE Corner Salton Sea	1930	SDMNH[e]	Herp 14517
W of Imperial Valley (I)	Harper Well	1929	CAS	SUA 3033, 3034
		1929	SDMNH	Herp 1753, 1754
		1939[f]	MVZ	Herp 31539, 31540
Coachella Valley (R)	Indio	1930	SDNHM	Herp 14431–14437
		1966–1972	LACM	Herp 105740, 105741
	Mecca and vicinity	1963–1970	LACM	Herp 12038, 62331, 62332, 88518, 91837, 91838, 105736–105739
		1970	UCM[g]	62331, 62332
	Whitewater River Delta	1983	CCBER[h]	Herp 14838–14840
N of Coachella Valley (R)	N of Present-day I-10	1964–1969	MVZ	Herp 98624
			LACM	Herp 74562; 88509–88515; 91834–91836
		1973	AUM[i]	Herp 22728
Santa Rosa Mtns. (R)	Upper Sumac Spring	1977	This paper	

[a] Museum of Vertebrate Zoology, University of California, Berkeley
[b] California Academy of Sciences
[c] University of Michigan Museum of Zoology
[d] Natural History Museum of Los Angeles County
[e] San Diego Museum of Natural History
[f] Erroneously reported by Goodward and Wilcox (2019) as the date *A. woodhousii* initially was collected at Harper Well
[g] University of Colorado Museum of Natural History
[h] Cheadle Center for Biodiversity and Ecological Restoration, University of California, Santa Barbara
[i] Auburn University Museum of Natural History

APPENDIX B. EXTREME ANNUAL, MONTHLY, AND DAILY RAINFALL IN AND PROXIMATE TO THE IMPERIAL AND COACHELLA VALLEYS

Available records of maximum rainfall amounts (in cm) recorded at 13 weather stations in or near the Imperial and Coachella valleys, Imperial County (I) and Riverside County (R), California (WRCC 2020). For each station, the year, month, and day with maximum rainfall are reported, respectively. This summary of extreme precipitation events also includes the mean annual rainfall at each station, and the percent of mean annual rainfall accounted for by each annual, monthly, and daily maximum on record. The extreme rainfall events associated with these records (e.g., tropical storms, monsoonal thunderstorms, etc.) likely have played, and continue to play, a role in the dispersal of *Anaxyrus woodhousii* in southeastern California, and particularly to areas isolated for extended periods by vast expanses of dry land, such as Sumac Canyon, Riverside County and Harper Well, Imperial County.

Station	Mean Annual Rainfall	Maximum Annual Rainfall (Year)	Percent of Mean Annual Rainfall	Maximum Monthly Rainfall (Month Year)	Mean Rainfall Same Month	Percent of Mean Annual Rainfall	Maximum Single-day Rainfall (Month Year)	Percent of Mean Annual Rainfall	Years on Record
Gold Rock Ranch (I)	9.91	19.15 (1992)	193	9.27 (Jan 1995)	1.65	94	6.73 Aug 1971)	68	1964–1996
Calexico (I)	6.83	23.70 (1905)	347	9.60 (Aug 1977)	1.04	141	7.14 (Dec 1982)	105	1904–2010
El Centro 2 SW (I)	6.45	18.64 (1992)	289	13.03 (Sep 1933)	0.66	202	6.50 (Sep 1939)	101	1932–2012
Imperial Coop (I)	7.21	17.98 (1906)	249	15.54 (Feb 1905)	1.22	216	10.36 (Sep 1939)	144	1901–2012
Imperial Airport (I)	5.97	13.34 (1977)	223	9.53 (Aug 1977)	0.71	160	5.64 (Sep 1976)	94	1962–2012
Brawley 2 SW (I)	6.73	20.78 (1939)	309	17.14 (Sep 1939)	0.64	255	9.91 (Oct 1932)	147	1910–2007
Yuma Date Orchard (I)	8.99	24.26 (1926)	270	16.18 (Aug 1909)	1.75	180	9.19 (Aug 1909)	102	1905–1929
Niland (I)	6.63	20.52 (1983)	310	10.03 (Jul 1968)	0.46	151	6.73 (Jul 1968)	102	1914–2012
Mecca 2 SE (R)	7.92	25.81 (1983)	326	14.40 (Sep 1976)[a]	0.74	182	10.76 (Sep 1976)[a]	136	1905–2012
Thermal Airport (R)	7.52	22.02 (1976)[a]	293	13.31 (Sep 1976)[a]	0.81	177	8.20 (Sep 1976)[a]	109	1950–2012
Indio Fire Station (R)	8.36	27.56 (1939)	330	22.76 (Sep 1939)	0.79	272	16.38 (Sep 1939)	196	1894–2012
Deep Canyon (R)	14.45	47.80 (1983)	331	22.23 (Sep 1983)	1.75	154	9.09 (Sep 1982)	63	1963–2016
Palm Springs (R)	13.94	34.85 (1983)	250	21.41 (Jan 1943)	2.87	154	11.61 (Jan 1943)	83	1906–2012

[a] Tropical Storm Kathleen