California Fish and Game 104(3): 129-147; 2018

Biodiversity of amphibians and reptiles at the Camp Cady Wildlife Area, Mojave Desert, California and comparisons with other desert locations

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We examined the biodiversity of amphibian and reptile species living in and near constructed ponds in the riparian area at the Camp Cady Wildlife Area (CCWA) in the Mojave Desert of San Bernardino County, California, based on field work from 1998-1999, 2016-2017, review of the literature, and searches for museum specimens using VertNet.org. A total of 11 species (201 captures), including two frogs and toads (one non-native frog), one turtle, three snakes, and five lizards were captured at terrestrial drift fences with pitfall traps encircling two ponds (0.5 hectares total) on the property in 1999. Four additional species (one frog, one lizard, and two snakes) were previously reported in 1978 from a ranch 1.6 km southwest from CCWA for a total of 15 species in the local area. The southwestern pond turtle (*Actinemys pallida*), was commonly observed at CCWA from 1998 to 1999 and documented as a breeding population. However, the species was extirpated at CCWA sometime after 2014 when the last individuals were photographed, and none have been detected since then despite significant efforts to do so. Biodiversity of amphibians and reptiles at CCWA is relatively low compared with sites elsewhere in the

Mojave Desert with more elevational diversity. The 14 native species documented at CCWA accounts for approximately 21% of the native reptile and amphibian species reported by Stewart (1994) for the entire Mojave Desert, including peripheral species. Our smaller sample likely represents a group of easily detected species and is biased toward those found in or near water, especially amphibians. However, the relative proportion of amphibians vs. reptiles that inhabited CCWA in the last 40 years is not significantly different from the recently compiled proportions at five military installations in the California deserts. The herpetofauna inhabiting CCWA is notable for including riparian obligates like the western toad (*Anaxyrus boreas*), Northern Baja California treefrog (*Pseudacris h. hypochondriaca*), and *A. pallida* that are otherwise absent from large portions of the Mojave Desert. Other species are typical of those that are expected in the low-elevation creosote scrub-dominated ecosystem in the area.

Key words: amphibians, California, Camp Cady Wildlife Area, herpetofauna, Mojave Desert, Mojave River, reptiles

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Species richness is a fundamental metric of ecosystems and has long been proposed as a criterion for directing conservation efforts (Myers et al. 2000, Gotelli and Colwell 2001). There is little doubt that biotic inventories aimed at documenting species composition are essential for effective management of natural resources. Biodiversity surveys can provide valuable baseline data on species occurrences and distribution over varying spatial and temporal scales (Gibbons et al. 1997, Hillebrand et al. 2017, Schmeller et al. 2017) that can reveal the effects of sampling bias as well as the effects of natural or anthropogenic stressors on community structure.

Large areas of the Mojave Desert in California have been heavily impacted by human activities for centuries (Lovich and Bainbridge 1999), especially in the western portion where urbanization continues (Hunter et al. 2003). In particular, the Mojave River corridor has been heavily impacted by anthropogenic changes over time resulting in significant changes from pre-colonization times (Lines 1996, Webb et al. 2001, Laity 2003). Increases in municipal and agricultural water use since the 1980s have eliminated or dramatically reduced surface water availability, especially along the middle and lower reaches of the Mojave River (Izbicki and Michel 2004, Todd Engineers 2013). Climate simulations for the near future (2021-2040) project continuing declines in surface water availability across the southwest USA including reduced soil moisture and runoff in California (Seager et al. 2012). De-watering the Mojave River presents challenges for wildlife conservation, especially for riparian obligates and associates that have few other water sources in this otherwise arid landscape.

The Camp Cady Wildlife Area (CCWA) is a state-managed facility along the lower reach of the Mojave River that supports a variety of wildlife species, including several that are dependent on riparian habitat. Only one previous survey of amphibians and reptiles (herpetofauna) was conducted in the vicinity of the Camp Cady Wildlife Area (CCWA), but that was 40 years ago (Brown 1978). In contrast, numerous studies have been published discussing various aspects of the hydrology, geology, and vegetation along the river (e.g., Pluhar et al. 1991, Lines and Bilhorn 1996, Webb et al. 2001, Todd Engineers 2013). This study provides an assessment of the biodiversity of amphibians and reptiles at CCWA with emphasis on those found in or near water. A wide variety of species were expected, espe-

cially riparian obligates, due to the presence of permanent water at this otherwise arid site. In addition, we compare and contrast the herpetofauna of Camp Cady with data from other parts of the California deserts, including several military installations that have recently assembled checklists.

Materials and Methods

Study area.—The Camp Cady Wildlife Area (34° 56.187' N, 116° 36.650' W) is an approximately 770-ha area (Figure 1) in the Mojave Desert managed by the California Department of Fish and Wildlife for bird watching, wildlife viewing, hiking, and hunting (birds and rabbits). The site is located 32 km east of Barstow, in San Bernardino County, California. Elevation ranges from 512 to 536 m. Using the Westmap (https://cefa.dri.edu/Westmap/) pixel function to calculate average climate conditions from yearly averages for the period 1999-2017, summers are hot and dry with an average high temperature of 40.5˚C,

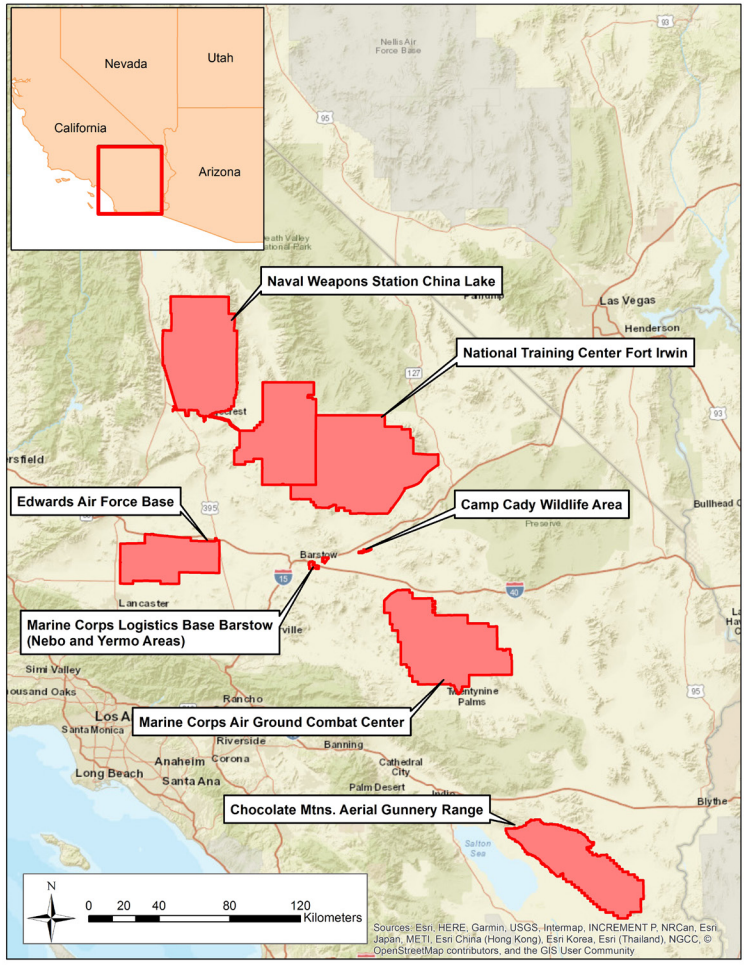

Figure 1.— Map showing the location and boundaries of Camp Cady Wildlife Area and the Department of Defense military installations for which data on amphibian and reptile diversity are available.

winters are cool with average low temperatures of 2.2˚C, and average annual precipitation is 8.1 cm. Plant species in the riparian area include: mesquite (*Prosopis* spp.), tamarisk (*Tamarix ramosissima*), willow (*Salix* spp.), cottonwood (*Populus fremontii*), saltgrass (*Distichlis spicata*), saltbush (*Atriplex* spp.), and cattails (*Typha domingensis*).

Three artificial ponds, less than 2 m in depth, are maintained at CCWA through groundwater pumping (Figure 2). The ponds are adjacent to the Mojave River and its floodplain (Lovich and Meyer 2002). The ponds were constructed between 1983 and 1984 to maintain an assurance population of endangered Mojave tui chubs (*Siphateles bicolor mohavensis*). "Bud's Pond," the central pond (hereafter Pond 2), is approximately 0.25 ha and surrounded primarily by cattails. The easternmost pond (Pond 3), also approximately 0.25 ha, is surrounded by cattails and honey mesquite and has a small island in the center. Pond 1, the westernmost pond, was originally created as a plastic-lined fire suppression pond (approximately 0.1 ha). It was not sampled in this study due to its small size and lack of natural vegetation or habitat. The Mojave River in this area once included dense stands of riparian vegetation (Todd Engineers 2013) and a small lake (the latter shown on U.S. Geological Survey topographic maps as recently as 1993) but neither the river nor the lake held water during the time of our sampling.

From May 1998 through October 1999 and April 2016 through July 2017, we set baited hoop traps (Gibbons 1988) in the riparian area at CCWA to sample for southwestern pond turtles (*Actinemys pallida*) as detailed in Lovich and Meyer (2002). From 12 May 1999 to 12 July 1999, we installed drift fences and pitfall traps (Gibbons and Semlitsch 1981) on berms around the perimeters of Ponds 2 and 3 to intercept nesting female *A. pallida*, but we recorded any amphibians or reptiles observed or captured incidentally. We installed pitfall traps (19-L plastic buckets) on both sides of the drift fence (Lovich and Meyer 2002) and checked them periodically during daylight hours. After identifying species, we released all

Figure 2.— Satellite image of the Camp Cady Wildlife Area study site, San Bernardino County, California, USA. Photo modified from ©2018 Google Earth Pro.

animals on the opposite side of the fence from where they were captured. Daytime water temperatures averaged 19° C during field sampling in 1999. Rainfall was only observed on one day during the study period while we were present (2 June 1999).

We obtained other records of species found in the immediate vicinity of Camp Cady from Brown (1978) and VertNet.org (Table 1), the latter for museum specimens. Brown (1978) conducted his three-month study (21 April-9 July 1978) on private property, 1.6 km southwest of our study site, along the south floodplain of the Mojave River. He used eight 19-L pitfall bucket traps along the dry edges of the river, along with hand captures and nooses, to sample the terrestrial herpetofauna. He used seines and dip nets in areas with water. The pitfall traps were checked every two weeks. We compiled records for the greater California desert region from other literature sources as cited below. We obtained records for Department of Defense military installations in the California desert from Peterson et al. (2017; *in press*) and the associated database they compiled. Common and scientific names of herpetofauna follow Crother et al. (2017).

We compared the relative proportion of amphibian vs. reptile species at CCWA to those same proportions for five military installations in the California deserts (Figure 1). We hypothesized that species diversity at CCWA would be disproportionately weighted toward amphibians due to the concentration of our sampling near ponds along the Mojave River channel. We tested proportions across sites with a contingency table analysis. We also analyzed comparable data on reptile species richness and abundance from ongoing research at the California Desert Studies Center (Zzyzx, near Baker, California) spanning 27 years (June 1991-May 1993, January 2000-December 2001, January 2008-June 2018), as described, in part, by Wallace (2003, Jason Wallace, CSU, Fullerton, unpublished data). That study used an array of 129 19-L bucket pitfall traps without drift fences on a creosote bush (*Larrea tridentata*)-dominated alluvial fan (288-358 m ASL) in the Soda Mountains approximately 50 km northeast of CCWA. We used the Shannon Index where

$$H' = \sum_{i=1}^{R} p_i \log p_i$$

and an Equitability Index where

$H'/H_{max} = H'$/natural log of the total number of species observed

to compare data collected at Camp Cady in 1998-1999 with those of Wallace (2003, Jason Wallace, CSU, Fullerton, unpublished data). Equitability Indices range from 0 to 1 with higher values reflecting more similar numbers of individuals among species. Although there are vastly different timescales involved between our study and that of Wallace, his are the only comprehensive reptile data available in the region for comparisons of species richness and evenness. Our conclusions on these comparisons are tempered accordingly by not conducting statistical tests of differences between indices.

Results

We captured 201 amphibians and reptiles in our drift fence in 1999 (Table 1). No *A. pallida* were captured or observed in the period from 2016 to 2017 despite significant effort. Since the only species marked for individual recognition during our studies was *A.*

Table 1.—List of all species reported in this study, an earlier study by Brown (1978), and museum specimens recorded over time in and near the Camp Cady Wildlife Area. MVZ = Museum of Vertebrate Zoology, UCMP = University of California Museum of Paleontology.

Scientific name	Location	Captures	Capture Method	Year	Months Found	Collector	Comments
Anaxyrus boreas (western toad)	Camp Cady	98	Drift Fence	1999	May-July	this study	Brown reported as "*Bufo boreas*"
	Camp Cady	5	Can trap	1978	April-July	Brown, 1978	Museum specimen MVZ Amphibian and reptile specimens #172757
Actinemys pallida (southwestern pond turtle)	Camp Cady	27	Drift Fence	1999	May-July	this study	Brown reported sightings by other people at Camp Cady
"Emydidae" (assumed *Actinemys pallida*)	Camp Cady	1	Visual	1965	N/A	Daily & Hutchison	Carapace fragments, Museum specimen # UCMP V 74679
Aspidoscelis tigris (tiger whiptail)	Camp Cady	14	Drift Fence	1999	May-July	this study	
	Camp Cady	1	Can trap	1978	April-July	Brown, 1978	Brown reported as "*Cnemidophorus tigris*"
Coluber flagellum (coachwhip)	Camp Cady	1	Drift Fence	1999	June	this study	
	Camp Cady	2	Can trap	1978	April-July	Brown,1978	Brown reported as "*Masticophis flagellum*"
Crotalus cerastes (sidewinder)	Camp Cady	1	Can trap	1978	April-July	Brown, 1978	
Hypsiglena chlorophaea (desert nightsnake)	Camp Cady	1	Drift fence	1999	June	this study	
Lampropeltis californiae (California kingsnake)	Camp Cady	4	Drift Fence	1999	May-June	this study	Brown reported as *"Lampropeltis getulus californiae*"
Lithobates catesbeianus (American bullfrog)	Camp Cady	16	Drift Fence	1999	June-July	this study	Brown reported as "*Rana catesbeiana*"
	Camp Cady	18	Can trap	1978	April-July	Brown, L.T. Findley	Museum specimen MVZ Amphibian and reptile specimens #172783
Pituophis catenifer deserticola (Great Basin gophersnake)	Camp Cady	-	-	1978	–	Brown, 1978	Brown reported sightings by other people at Camp Cady
Pseudacris h. hypochondriaca (Northern Baja California treefrog)	Camp Cady	15	Can trap	1978	April-July	Brown, 1978	Brown reported as "*Hyla regilla*"
	Camp Cady	10	Hand	1978	May	Brown, L.T. Findley	Lot of 10 tadpoles, Museum specimen MVZ Amphibian and reptile specimens #172766
Sceloporus occidentalis (western fence lizard)	Camp Cady	28	Can trap	1978	April-July	Brown, 1978	Museum Specimen MVZ Amphibian and reptile specimens #172897
	Camp Cady	10	Drift Fence	1999	June	this study	
	Camp Cady	2	Hand	1978	May	Brown, L.T. Findley	Museum specimen MVZ Amphibian and reptile specimens # 172895 & 172896
Sceloporus magister (desert spiny lizard)	Camp Cady	12	Can trap	1978	April-July	Brown, 1978	Museum specimen MVZ Amphibian and reptile specimens #172869
Urosaurus graciosus (long-tailed brush lizard)	Camp Cady	1	Drift Fence	1999	June	this study	
Uta stansburiana (common side-blotched lizard)	Camp Cady	17	Drift Fence	1999	May-July	this study	
	Camp Cady	4	Can trap	1978	April-July	Brown, 1978	
Xantusia vigilis (desert night lizard)	Camp Cady	9	Drift Fence	1999	May-June	this study	

pallida, it is unknown how many individuals of other species were captured. Captures and recaptures included 114 frogs and toads, 27 turtles, 6 snakes, and 54 lizards for a total of 87 reptile and 114 amphibian captures (including 3 lizards captured but not identified to species by field technicians). At Pond 3 there were 112 amphibian captures and 63 reptile captures, while Pond 2 only had 2 amphibian and 20 reptile captures (four reptiles caught were not associated with any pond). Eleven species were identified from captures in 1998 and 1999 (Figure 3), including two species of frogs and toads, one turtle, three snakes, and five lizard species. Four additional species [Northern Baja California treefrog (*Pseudacris h. hypochondriaca*), desert spiny lizard (*Sceloporus magister*), Great Basin gopher snake (*Pituophis catenifer deserticola*), and sidewinder (*Crotalus cerastes*)] were reported by Brown (1978) bringing the total herpetofauna in the CCWA area to 15 species. Brief species accounts of the recorded herpetofauna are given below with records of museum specimens, if available.

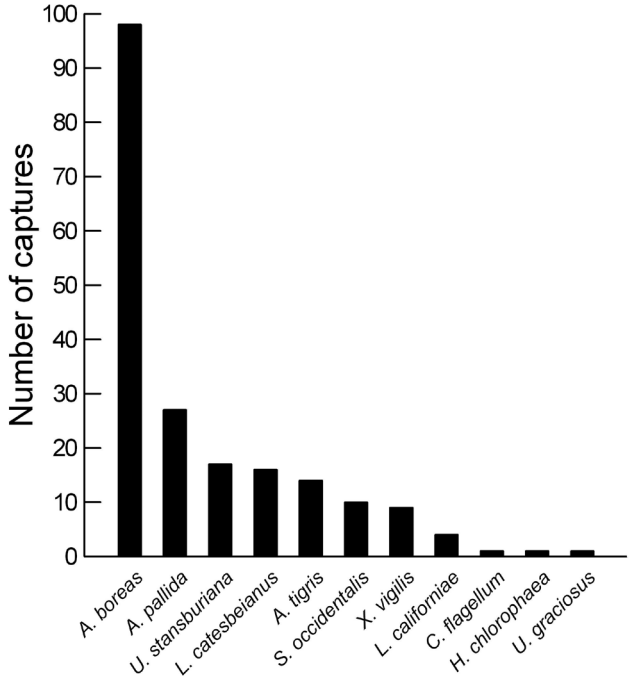

Figure 3.—Number of captures of amphibians and reptiles by species from 1998 to 1999 at the Camp Cady Wildlife Area (not including 3 unidentified lizards).

In the ongoing study of Wallace (2003, Jason Wallace, CSU, Fullerton, unpublished data) at Zzyzx, California, 3,027 captures of 20 reptile species were recorded as of June 2018 (Table 2). The Shannon Index was 1.50, H_{max} was 3.00, and the Equitability Index was 0.50. By comparison, CCWA data from 1998 to 1999 had a Shannon Index of 1.67, H_{max} was 2.40, and the Equitability Index was 0.70. Since Wallace's data do not include amphibians, we removed the two amphibian species from the same CCWA data resulting in a Shannon Index of 1.12, an H_{max} of 2.20, and an Equitability Index of 0.51. The data of Brown (1978) including amphibians (Table 1) had a Shannon Index of 1.73, an H_{max} of 2.20, and an Equitability Index of 0.79.

Table 2.—List of all reptile species reported in the ongoing study of Wallace (2003, Jason Wallace, CSU, Fullerton, unpublished data) at Zzyzx, California. Data collected monthly June 1991-May 1993, January 2000-December 2001, and January 2008-June 2018.

SCIENTIFIC NAME	COMMON NAME	CAPTURES
Uta stansburiana	common side-blotched lizard	1,529
Aspidoscelis tigris	tiger whiptail	809
Urosaurus graciosus	long-tailed brush lizard	187
Chionactis occipitalis	western shovel-nosed snake	117
Coleonyx variegatus	western banded gecko	108
Callisaurus draconoides	zebra-tailed lizard	92
Dipsosaurus dorsalis	desert iguana	68
Phrynosoma (Doliosaurus) platyrhinos	desert horned lizard	54
Phyllorhynchus decurtatus	spotted leaf-nosed snake	29
Rena humilis	western threadsnake	8
Xantusia vigilis	desert night lizard	5
Gambelia wislizenii	long-nosed leopard lizard	4
Hypsiglena chlorophaea	desert nightsnake	4
Arizona elegans	glossy snake	3
Sauromalus ater	common chuckwalla	3
Crotalus cerastes	sidewinder	2
Crotaphytus bicinctores	Great Basin collared lizard	2
Uma scoparia	Mojave fringe-toed lizard	1
Coluber flagellum	coachwhip	1
Pituophis catenifer deserticola	Great Basin gophersnake	1

The relative proportion of native amphibian vs. reptile species at CCWA and five military installations in the California deserts (Naval Air Weapons Station China Lake, Edwards Air Force Base, National Training Center [Ft. Irwin], Logistics Base Barstow, and Chocolate Mountains Aerial Gunnery Range) listed in Tables 3 and 4 were not statistically different when tested with contingency table analysis ($X^2 = 4.66$, $df = 5$, $P = 0.46$).

Frogs and toads.—American bullfrog (*Lithobates catesbeianus*). 16 captures. This species is native to eastern and central North America but is introduced all over the world (Behler and King 1979, Kupferberg 1997, Stebbins 2003). Kupferberg (1997) stated this

Table 3.—List of amphibians and reptiles at six military bases in the Mojave and Sonoran deserts of California for comparison with data on amphibian and reptile diversity at Camp Cady Wildlife Area. Data are from Petersen et al. (2017, in press) as tabulated in the associated database that they provided to us. Species occurrence is listed as X = confirmed on site or P = potentially on site but unconfirmed. Although their compilation included various subspecies we condensed the table to include only species-level taxonomy.

Species	Naval Weapons Station China Lake	Edwards Air Force Base	National Training Center Ft. Irwin	Marine Corps Air Ground Combat Center	Marine Corps Logistics Base Barstow	Chocolate Mtns. Aerial Gunnery Range
Actinemys pallida (western pond turtle)		X			P	
Anaxyrus boreas (western toad)	X	X		X	X	
Anaxyrus punctatus (red-spotted toad)	X	X		X	P	P
Anaxyrus woodhousii (Woodhouse's toad)						P
Arizona elegans (glossy snake)	X	X	X	X	P	P
Aspidoscelis tigris (tiger whiptail)	X	X	X	X	X	X
Batrachoseps robustus (Kern Plateau salamander)	P					
Callisaurus draconoides (zebra-tailed lizard)	X	X	X	X	X	X
Chelydra serpentina (snapping turtle)		X				
Chilomeniscus stramineus (variable sandsnake)		X				
Chionactis occipitalis (western shovel-nosed snake)	X	X	X	X	P	P
Chrysemys picta (painted turtle)		X				
Coleonyx variegatus (western banded gecko)	X	X	X	X	X	P
Coluber flagellum (coachwhip)	X	X	X	X	X	P
Coluber taeniatus (striped whipsnake)	X					
Crotalus atrox (western diamond-backed rattlesnake)						X
Crotalus cerastes (sidewinder)	X	X	X	X	X	X
Crotalus pyrrhus (southwestern speckled rattlesnake)		P	X	X	X	P
Crotalus oreganus (western rattlesnake)	X					
Crotalus scutulatus (Mohave rattlesnake)	X	X	X	X	X	
Crotalus stephensi (Panamint rattlesnake)	X					
Crotaphytus bicinctores (Great Basin collared lizard)	X	X	X	X	X	P
Diadophis punctatus (ring-necked snake)	X					
Dipsosaurus dorsalis (desert iguana)	X	X	X	X	X	X
Elgaria panamintina (Panamint alligator lizard)	X					
Gambelia wislizenii (long-nosed leopard lizard)	X	X	X	X	X	X
Gopherus agassizii (Mohave desert tortoise)	X	X	X	X	X	X
Heloderma suspectum (Gila monster)						P
Hemidactylus turcicus (Mediterranean gecko)		P			P	P
Hypsiglena chlorophaea (desert nightsnake)	X	X	X	P	X	P
Lampropeltis californiae (California kingsnake)	X	X	X	X	P	P
Lichanura orcutti (rosy boa)	X	X				
Lichanura trivirgata (three-lined boa)			X			P
Lithobates berlandieri (Rio Grande leopard frog)						P
Lithobates catesbeianus (American bullfrog)	X	X		P	X	
Phrynosoma (Doliosaurus) platyrhinos (desert horned lizard)	X	X	X	X	X	X
Phyllorhynchus decurtatus (spotted leaf-nosed snake)	X	X	X	X	X	P
Pituophis catenifer (gopher snake)	X	X	X	X	X	
Plestiodon gilberti (Gilbert's skink)	X	P				
Pseudacris hypochondriaca (Baja California treefrog)		X			X	
Pseudacris sierra (Sierran treefrog)	X					
Rena humilis (western threadsnake)	P	P	X	P	P	P
Rhinocheilus lecontei (long-nosed snake)	X	X	X	X	X	P
Salvadora hexalepis (western patch-nosed snake)	X	X	X	X	X	P
Sauromalus ater (common chuckwalla)	X	X	X	X	P	X
Sceloporus graciosus (common sagebrush lizard)	X		P			
Sceloporus magister (desert spiny lizard)			X			
Sceloporus occidentalis (western fence lizard)	X	X	X	X	X	P
Sceloporus uniformis (yellow-backed spiny lizard)	X	X	P	P	P	
Sonora semiannulata (western groundsnake)	X	X	X			
Tantilla hobartsmithi (Smith's black-headed snake)	P			X	P	P
Thamnophis hammondii (two-striped gartersnake)		X				
Trachemys scripta (pond slider)		X				
Trimorphodon lambda (Sonoran lyresnake)		X				
Trimorphodon lyrophanes (California lyresnake)	X		P			
Uma scoparia (Mohave fringe-toed lizard)	P	P	X	X	P	P
Urosaurus graciosus (long-tailed brush lizard)	P	X	X	X	X	
Urosaurus ornatus (ornate tree lizard)			P	X	X	P
Uta stansburiana (common side-blotched lizard)	X	X	X			
Xantusia vigilis (desert night lizard)	X	X	X	X	X	X
Xenopus laevis (African clawed frog)		X		X	X	

Table 4.—Number of amphibian and reptile species reported from various localities within the California deserts. Non-native species numbers are in parenthesis. Camp Cady Wildlife Area (CCWA) totals include our study (1998-1999, 2016-2017), Brown (1978) records, and museum specimens. The data for Brown (1978) include only those species reported near CCWA by him at that time. Department of Defense (DoD) (Petersen et al. 2017) records include confirmed and potential species for the military installations listed. Non-natives were not included in the Stebbins (1995) report. Wallace data includes Wallace (2003) and Jason Wallace, CSU, unpublished data, collected at California Desert Studies Center (Zzyzx, near Baker California). Neither Wallace nor Stebbins included amphibians in their study.

	Number of Species		
	Amphibian	**Reptile**	**Total**
CCWA	2(1)	12	14(1)
Brown (1978)	2(1)	9	11(1)
DoD-Naval Air Weapons Station China Lake	4(1)	38	42(1)
DoD-Edwards Air Force Base	3(2)	35(4)	38(6)
DoD-National Training Center Ft. Irwin	0	34	34
DoD-Marine Corps Air Ground Combat Center	3(1)	29	32(1)
DoD-Logistics Base Barstow	4(1)	30(1)	34(2)
DoD-Chocolate Mtns. Aerial Gunnery Range	2(1)	28(1)	30(2)
Stebbins (1995)a	–	24	24
Stebbins (1995)b	–	56	56
Stewart (1994)c	2(1)	35	37(1)
Wallace-California Desert Studies Center	–	20	20

[a] Only includes species from Pisgah Lava Flow approximately 31 km southeast of CCWA

[b] Entire California desert including Mojave, Sonoran, and Great Basin deserts

[c] Not including peripheral species (occurs in the habitat peripheral to the Mojave Desert)

invasive species was first introduced into California in 1896, and Brown (1978) stated that bullfrogs were introduced to the Mojave River at CCWA in 1927 and 1969. Bullfrogs are a known predator of several different frog, fish, turtle, bird, and snake species (Jancowski and Orchard 2013, Rockney 2015), causing declines in some native species (Stebbins 2003, Pearl et al. 2004). Brown (1978) observed 18 specimens 1.6-4.82 km west/southwest of Camp Cady.

L. catesbeianus museum specimens: Museum of Vertebrate Zoology 172783

Northern Baja California treefrog (*Pseudacris h. hypochondriaca*). No captures in 1999; however, Brown (1978) had 15 captures 1.6 km southwest of Camp Cady Ranch. Formerly recognized as *P. regilla*, this widespread species group was recently split into several taxa ranging from Canada to Baja California, Mexico (Recuero et al 2006). *P. h. hypochondriaca* is considered by some to be the most abundant and ubiquitous amphibian

in western North America (Recuero et al 2006). The species is found in widely scattered oases and other water sources in the Mojave Desert, as well in more mesic coastal locations.
P. h. hypochondriaca museum specimens: Museum of Vertebrate Zoology 172766

Western toad (*Anaxyrus boreas*). 98 captures adults and juveniles (no tadpoles were observed). Distributed from Alaska to Baja California, Montana, and Colorado, with wide elevational range from sea level to 3.0 km ASL (Stebbins 2003). *A. boreas* can endure both hot and freezing temperatures through the use of burrows (Mullally 1952). There is one previous capture record of the species (five specimens) 1.6 km southwest of CCWA (Brown 1978). The taxonomy of this species complex is still undergoing changes in western USA deserts (Gordon et al. 2017).
A. boreas museum specimens: Museum of Vertebrate Zoology 172757

Turtles.—Southwestern pond turtle (*Actinemys pallida*). We intercepted *A. pallida* 27 times at drift fences. Lovich and Meyer (2002) estimated a population size of 25 (± SE 3.28) turtles in 1999. *A. pallida* inhabits aquatic and sometimes surrounding terrestrial habitats at different times of the year (Bury 2012). It is the only extant, native, freshwater turtle in California (Lovich and Beaman 2008) where it is a species of special concern (Thompson et al. 2016). Records show a historical and prehistorical presence of *Actinemys* at various points along the Mojave River (Jefferson 1987, Ernst and Lovich 2009), including CCWA. The species became extirpated at CCWA after April or May of 2014 based on observations by the preserve manager and substantiated by our inability to trap or observe turtles from 2016 to 2017. The species was not included in the list for CCWA produced by Brown (1978): however, he noted that *A. pallida* was sighted in the area during that time by others.
A. pallida museum specimens: University of California Museum of Paleontology 74679 (carapace fragments).

Lizards.—Common side-blotched lizard (*Uta stansburiana*). 17 captures. Distributed throughout western North America, *U. stansburiana* prefers arid or semi-arid habitats (Wilson 1991, Stebbins 2003). Another local record of four captures was noted 1.6 km southwest of Camp Cady (Brown 1978).
U. stansburiana museum specimens: none

Desert night lizard (*Xantusia vigilis*). Nine captures. This small, nocturnal, secretive species lives under rocks and fallen trees primarily in California but extending into surrounding desert states and Mexico (Stebbins 2003). *X. vigilis* has somewhat specialized habitat needs that frequently include fallen yucca (*Yucca schidigera*) or Joshua tree (*Yucca brevifolia*) limbs and trunks (Marlow et al. 1988, Stebbins 2003). However, at CCWA they used dead cottonwood logs since yucca and Joshua tree are absent from the site.
X. vigilis museum specimens: none

Desert spiny lizard (*Sceloporus magister*). No captures in 1999; however, Brown (1978) lists 12 captures 1.6 km southwest of Camp Cady. Widely distributed throughout the deserts of the western United States and Mexico, this species inhabits both terrestrial and arboreal microhabitats (Parker and Pianka 1973, Leaché and Mulcahy 2007).
S. magister museum specimens: Museum of Vertebrate Zoology 172869

Long-tailed brush lizard (*Urosaurus graciosus*). One capture. This mostly arboreal species is distributed in the western United States but is common in California (including the Mojave Desert) and Arizona (Vitt and Ohmart 1975, Stebbins 2003). *U. graciosus* spends very little time terrestrially, preferring tree limbs, which may explain why only one was captured, despite their abundance in some locations (Vitt et al. 1978). It may have fallen

from one of the many mesquite or tamarisk trees fringing the margins of Pond 3.
U. graciosus museum specimens: none

Tiger whiptail (*Aspidoscelis tigris*). 14 captures. *A. tigris* prefers desert habitats with sparse plants and plenty of open space in the western United States (Pianka 1970, Stebbins 2003). One specimen is known from 1.6 km southwest of Camp Cady (Brown 1978).
A. tigris museum specimens: none

Western fence lizard (*Sceloporus occidentalis*). 10 captures. *S. occidentalis* prefers arid, open spaces with plenty of perch sites as a terrestrial and arboreal species in the western United States (Adolph 1990, Stebbins 2003). Twenty-eight specimens were previously reported 1.6-4.82 km southwest of Camp Cady (Brown 1978).
S. occidentalis museum specimens: Museum of Vertebrate Zoology 172895, 172896, 172897

Snakes.—California kingsnake (*Lampropeltis californiae*). Four captures. This wide-ranging snake is distributed throughout the western United States and is common in California; therefore, our capture of *L. californiae* was not unexpected (Stebbins 2003, Pyron and Burbrink 2009).
L. californiae museum specimens: none

Coachwhip (*Coluber flagellum*). One capture. *C. flagellum* ranges widely throughout the southern United States and northern Mexico (Stebbins 2003). They prefer xeric, sandy environments, use rodent holes for shelter from the elements, and sometimes occur around water where prey are abundant (Palermo et. al 1988). Two captures were documented 1.6 km southwest of CCWA (Brown 1978).
C. flagellum museum specimens: none

Great Basin gophersnake (*Pituophis catenifer deserticola*). No captures in 1999; however, Brown (1978) reported sightings in the Camp Cady area. This species is widespread across the western United States and slightly into Canada, occupying a wide variety of habitats (Stebbins 2003). *P. catenifer*, while mostly terrestrial, are excellent climbers (Eichholz and Koenig 1992) and good swimmers (Rodríguez-Robles 2003).
P. c. deserticola museum specimens: none

Desert nightsnake (*Hypsiglena chlorophaea*). One capture. This small, nocturnal snake is rarely seen, yet widely distributed, and inhabits most of the western United States (Stebbins 2003). *Uta stansburiana* is a common prey item for this snake (Stebbins 2003).
H. chlorophaea museum specimens: none

Sidewinder (*Crotalus cerastes*). No captures in 1999; however, Brown (1978) had one capture 1.6 km southwest of Camp Cady Ranch. *C. cerastes* is one of the most commonly seen snakes in the Mojave and Sonoran deserts, preferring sandy habitats (Secor 1994, Persons and Nowak 2007). This species was expected but not encountered during our study.
C. cerastes museum specimens: none

Discussion

We captured 11 different species of herpetofauna, consisting of 201 captures at CCWA in 1999, using drift fences with pitfall traps. Four additional species were reported from near CCWA (Brown 1978) bringing the total documented herpetofauna in the local area to 15 species. Amphibian drift fence captures were greater than that of reptiles at CCWA (114 amphibians and 87 reptiles), even though there was greater species diversity in reptiles (nine species) than amphibians (two species). Brown (1978) reported three species of amphibians

and nine species of reptiles 1.6 km southwest of our study site, several of which we did not encounter in our later surveys (including *C. cerastes*, *P. h. hypochondriaca*, *S. magister,* and *P. c. deserticola*). In total, 3 species of amphibians and 12 reptile species have been reported at CCWA. Stebbins (1995) reported 10 lizard species, 13 snake species, and the desert tortoise (*Gopherus agassizii*) at the Pisgah Lava flow (approximately 31 km southeast of CCWA), while (Stewart 1994) reported 3 anuran species, 1 turtle species, 16 lizard species, and 18 snake species with another 28 peripheral species in the entirety of the Mojave Desert (Table 4). Stebbins (1995) did not include amphibians in his survey. More recently, Mittermeier et al. (2002) tallied 14 amphibian species and 45 reptile species in the entirety of the Mojave Desert. We observed far fewer Mojave reptile species than Stebbins (1995), Stewart (1994), or Mittermeier et al. (2002) due to the short duration of our study, limited capture techniques, and the small area we sampled. More species are doubtless present in the greater 770-ha CCWA, away from the ponds where our sampling was concentrated.

Amphibians dominated our captures with the largest number being 98 for the native species *Anaxyrus boreas*. In contrast, we only captured 16 of the invasive species *Lithobates catesbeianus*. This is surprising due to the hardy nature and wide-ranging habitat of the latter. *L. catesbeianus* is a gape-limited predator, consuming a wide variety of prey items (Cook and Currylow 2014). It is possible that the large size, semi-terrestrial niche, and toxic skin secretions of *A. boreas* provide some protection from predation by the mostly aquatic *L. catesbeianus* (Olson 1989, Benard and Fordyce 2003, Pearl et al. 2004). Our data contrast with those of Brown (1978), who observed a reverse proportional abundance of these species: 18 *L. catesbeianus* and 5 *A. boreas*, 1.6 km southwest of Camp Cady (Brown 1978). None of the frogs and toads we captured were tadpoles, whereas Brown (1978) captured both adults and tadpoles.

Short-term studies like ours and Brown (1978) had relatively high Shannon Indices compared to the long-term study of Wallace (2003, Jason Wallace, CSU, Fullerton, unpublished data). The latter detected more rare species and larger numbers of common species, resulting in a lower Equitability Index, compared to the short-term studies with fewer species and a more even distribution of numbers of individuals per species. Predictably, our 1998-1999 CCWA data excluding amphibians resulted in a lower Shannon Index than Wallace (2003, Jason Wallace, CSU, Fullerton, unpublished data), but the Equitability Indices were almost identical. The ratio of native amphibians to reptiles at CCWA was 16.6%; however, that ratio was not statistically different from the amphibian/reptile ratio (0-10.5%) for five other military installations in the California deserts.

Other species were notable for their absence in our survey. The red-spotted toad (*Anaxyrus punctatus*) has a wide California desert distribution, a need for permanent water sources (due to limited migration patterns), and an affinity for dried, ephemeral stream beds (Weintraub 1974, Stewart 1994). However, unexpectedly, we found none in this study. Brown (1978) also noted the unexpected absence of *A. punctatus* in the Camp Cady area. *A. punctatus* may not have colonized the CCWA ponds, due to their relatively recent creation, lack of rocky substrate, and great distance from other permanent water sources (Bradford et al. 2003). CCWA combines a xeric environment with permanent lentic water sources to create a rare desert oasis for amphibians, allowing consistent resources to meet the demands of reproduction and hydration for continued survival that would otherwise be impossible (Mayhew 1995).

Of the 11 species of reptiles reported from CCWA, including four snakes, all are

common to this area, yet only a few specimens of each species were caught, in contrast to the large number of lizards captured (perhaps because we sampled in the summer, during the hottest part of the year, instead of during the spring). Since there were six different species of lizards (52 captures), comprising most of the reptiles, it is surprising that more snake species were not represented since lizards (and some amphibians) are a prey source to many snakes, including those captured in this study (Arnold 1972, Ferguson et al. 1982, Rodríguez-Robles et al. 1999). *Crotalus cerastes* and other congeners have been found in Camp Cady and surrounding areas (Brown 1978; Reynolds 2004; Persons and Nowak 2007; Petersen et al. 2017, *in press*; Jason Wallace, CSU, Fullerton, unpublished data) but were not captured or observed in our study. Large snakes in particular are difficult to capture in buckets of the size we used (Gibbons and Semlitsch 1981).

Only one species of turtle was caught at the site. *A. pallida* is a species known to occur along the Mojave River with previous historical and prehistorical records of occurrence (Lovich and Meyer 2002). Camp Cady provides adequate habitat for *A. pallida*; however, they may have been adversely affected by predators, including *L. catesbeianus* (Rockney 2015), and decreasing water supplies that diminish suitable habitat in the river channel (Spinks et al. 2003). The reason for their disappearance at CCWA after 2014 is unknown, but predation of hatchlings by bullfrogs and predation on juveniles and adults from a host of mammalian carnivores (Ernst and Lovich 2009; Vander Haegen et al. 2009) are possible explanations, especially for such a small, potentially vulnerable population. The disappearance of *A. pallida* represents a 6% decrease in biodiversity of the herpetofauna reported in this paper over the last 40 years. However, if we used drift fences and pitfall traps during the 2016-2017 trap sessions, we may have detected additional changes in the herpetofauna.

Site-specific inventories for amphibians and reptiles in the California desert are often scattered and fragmentary; however, systematic efforts to census biodiversity on Department of Defense installations recently became available (Petersen et al. 2017, 2018; Table 3). Due to increased urbanization and a changing climate, reptiles and amphibians are forced to perish or adjust, whether it is by location, elevation, lifestyle, prey selection, or through evolutionary adaptation (Gibbons et al. 2000, Urban et al. 2014). Since this study was largely conducted in 1999, anthropogenic influences and persistent drought (Griffin and Anchukaitis 2014, Mann and Gleick 2015) have had continued impacts on the Mojave River and the CCWA. Future monitoring of amphibians and reptiles at CCWA are needed to evaluate continued changes in biodiversity.

Acknowledgments

Thanks to B. Kenyon for providing access to housing while on site. Research on southwestern pond turtles from 2016-2018 was supported by funding from the Bureau of Land Management and the California Department of Fish and Wildlife through the Mojave Desert Resource Conservation District. Special thanks to Chris Tracy for reviewing an earlier version of the manuscript, and A. Ellsworth, J. Gannon, C. Otahal, D. Raponi, and R. Scofield for assistance and support during our studies. Permits (SC-1639) were obtained from the California Department of Fish and Wildlife for our earlier and later research. Their protocols were followed. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Submitted 5 March 2018
Accepted 29 May 2018
Associate Editor was L. Patterson