Herpetological Conservation and Biology 17(2):278–289.
Submitted: 15 October 2021; Accepted: 5 May 2022; Published 31 August 2022.

EFFICACY OF LOW-SPEED ROAD CRUISING FOR LIZARD DETECTION AT TWO SITES IN ARIZONA, USA

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***Abstract*.—Numerous references suggest road cruising is effective for detecting many lizard taxa, yet standard inventory and monitoring publications invariably emphasize the technique to target snakes, turtles, and amphibians, with little to no mention of its use for lizards. Instead, the most commonly employed methods to detect surface-active lizard species are various visual surveys on foot. At two study sites in Arizona, USA, we used very low-speed, diurnal road cruising to detect surface-active lizards from a vehicle. To determine the efficacy of the method compared to a more conventional one, we compared our results to those of adjacent walking surveys. Between the two studies and two methods, we detected 16 lizard species. Both approaches were generally effective at targeting the same heliothermic species, although there were some differences in encounter rates. Individuals of all species were more likely to flee from an observer on foot than one in a car. Because of this differential flight response, the proportion of unidentifiable species was significantly higher from foot searches than from a vehicle.**

Key Words.—detection; encounter; inventory; lizard; method; road searches; visual searches

INTRODUCTION

Road cruising (RC) or road riding (sometimes called night cruising) has been a primary tool for surveying herpetofauna ever since Klauber (1931) quantified the method for finding snakes on roads from a vehicle. Inventory and monitoring (I&M) handbooks for herpetofauna invariably include RC as a standard method to detect snakes, turtles, and amphibians (Cooperrider et al. 1986; Heyer et al. 1994; McDiarmid et al. 2012; Graeter et al. 2013; Dodd 2016), but there is little mention of its utility for detecting lizards, except for a few specific taxa (Sullivan 2012). This is surprising, as published reports of finding lizards along roads have been available for more than a century. For example, Ditmars (1907) stated that North American teiids frequent dry, sandy places and the borders of unpaved roads. Stebbins (1954) stated that collecting lizards by automobile made it possible to sample a large area in a short time and greatly improved the chances of finding certain kinds of lizards during the day and night. More recently, in the viewing tips section of an edited field guide (Jones and Lovich 2009), 23 authors recommended looking along roadways to observe 25 lizard species in the American Southwest. Persons and Nowak (2006) used diurnal and nocturnal RC as an inventory method in Death Valley, California, USA, and detected 13 of 16 species of lizards among all methods used. Perhaps the method is generally overlooked by inventory and methods handbooks because published accounts are largely anecdotal or because most authors of the handbooks are from the eastern USA, where the diversity of native lizards is low. More commonly reported methods to detect lizards are those highlighted by the inventory and methods handbooks, including visual surveying by foot, trapping, patch sampling, and cover object searching.

Since 2003, we have used diurnal RC to inventory a highly diverse lizard community of diurnal, surface-detectable lizards at one site in southeastern Arizona (Jones 2009, 2013). A second study site was added in 2020. We refer to our particular RC approach as a very low-speed road transect (LSRT). We used RC/LSRT rather than a more conventional Visual Encounter Survey (VES) method because we felt we were effectively detecting the expected species, lizards seemed less likely to flee a vehicle than someone on foot (hence, greater confidence in identification), and driving a vehicle on a road seemed safer than walking in hazardous terrain. Also, our method was standardized and repeatable for monitoring; however, we had never statisticaly compared RC/LSRT with VES. In 2020, we compared the efficacy of the RC/LSRT method for lizard detection with off-road walking surveys (WS) near the RC routes. The WS method is a form of VES, but does not employ the recommended time-constrained restriction (Crump and Scott 1994; Glaudas 2013) or cover object searches (Guyer and Donnelly 2012; Willson 2016).

Our objectives were: (1) comparing lizard species detection between RC and WS at our study sites; (2) determining if there are differences in flight responses of lizards to low-speed vehicle approach (RC) versus walking approach (WS), and by extension, if lizards are more identifiable by either method; and (3) discussing the advantages and disadvantages of RC and WS for detection in similar habitats. Although we suspect there is a road edge effect and bias (e.g., Brehme 2003; García et al. 2007; Brehme et al. 2013), our study was not designed to address that issue. Also, edge effect is not generally a concern when building a species list or seeking out specific taxa for research. For example, presence/absence studies (e.g., environmental impact assessments) only require a species being found at a site, which may be accomplished by RC.

MATERIALS AND METHODS

Study sites.—Our studies were conducted at two sites in southern Arizona, USA (Fig. 1). One study area was the Marijilda site, in the foothills of the Pinaleño Mountains, Graham County (Jones 2009, 2013). Marijilda is primarily in a disclimax Semidesert Grassland or Chihuahuan Desertscrub transition biotic community (Brown 1994), characterized by bunchgrasses, shrubs, and small trees. It is in the Cochise Filter Barrier area (Morafka 1977), near the convergence of the Sonoran and Chihuahuan deserts (Brown and Lowe 1980). The elevational range is 1,150–1,220 m. The RC route was along a 4.2-km stretch of rough unpaved road (Marijilda Road), beginning at the junction of the Swift Trail paved road and ending at Marijilda Creek. Marijilda Road is boulder strewn along the edge and in the adjacent uplands, and the road edge lacks a well-defined berm. There are no maintained trails nearby, so the WS routes were conducted off-trail, more-or-less parallel to Marijilda Road on both sides.

The second study area was the Bajada site in Saguaro National Park (Tucson Mountains District) west of Tucson, Pima County, Arizona. The biotic community is the middle bajada (Jones 2020) of the Arizona Upland subdivision of the Sonoran Desert (Brown and Lowe 1980). The elevational range is about 700–820 m. The 5.3-km RC route is along the unpaved Bajada Scenic Loop. Unlike Marijilda, there were few boulders present along the RC route, as the primary substrate is sand and gravel, overlain with scattered cobbles. There is a well-developed berm over most of its length. The WS routes were along adjacent trails, as walking off-trail is discouraged in the national park system for

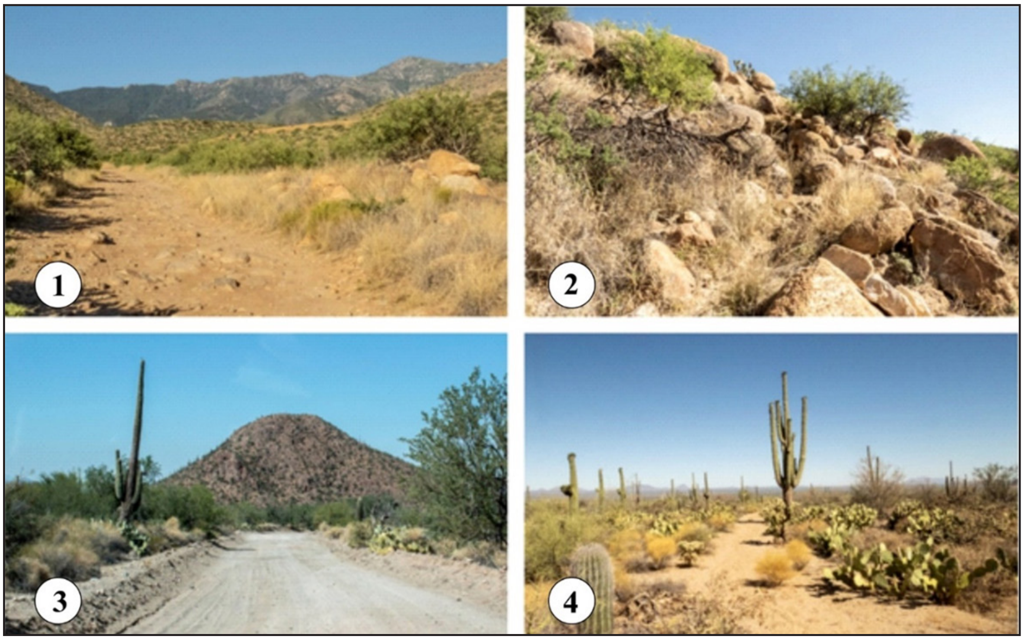

FIGURE 1. (1) Marijilda Road in Arizona, USA, is a rough, low-speed, high clearance road. (2) Marijilda pedestrian survey route, Arizona, had treacherous topography. (3) Bajada Loop driving route: note the sandy, well-developed berms. (4) Trails in the Bajada site were easy for pedestrians to navigate. (Photographed by Lawrence L.C. Jones).

resource protection (https://www.nps.gov/articles/hikingetiquette.htm) and because trails are often used as visual survey routes when available (Doan 2016). The trails used were Cactus Wren (4.5 km), Encinas (5.3 km), Sendero-Esperanza (3.2 km), and Wild Dog (3.7 km). These trails were biotically and topographically similar to the Bajada Scenic Drive.

Description of comparison techniques.—Materials needed for RC were minimal: an automobile, binoculars (essential for species identification), cell phone (navigation, environmental information, and most importantly, a safety asset), camera (for documentation and photographic vouchers), data form, food and water, and miscellaneous additional field equipment as needed. The materials for WS were similar, except that we were on foot with a backpack, so supplies were more limited. Road cruising for lizards is fairly straight forward. It is similar to the method used for other reptiles (e.g., Sullivan 2012), but there are some differences in approach to target diurnal lizards. We only surveyed unpaved roads during the day. Unlike conducting RC for snakes, it was important to scan the adjacent roadside habitat rather than just the road surface and immediate shoulder. At our two study areas, we standardized our RC approach to detect a variety of species of all sizes and allow comparison with WS. For consistency, we: (1) recorded animals only seen out to about 5 m beyond the edge of the road; (2) only allowed the driver to observe and record lizards; (3) drove at < 10 kph; and (4) surveyed when it was mostly sunny, warm, and calm. The time window for appropriate weather conditions differed between the two sites and changed with time of year at each site. At Marijilda, we began surveys during the summer usually at about 0800, when temperatures were 24°–27° C. At the Bajada site, due to a lower elevation and presence of heat-tolerant species, we started surveys in the summer at about 0900 when temperatures were 26°–29° C. Lizards were usually first detected ahead of the vehicle, and the driver often stopped briefly to confirm the identity through binoculars and the record the data.

We imposed similar restrictions during WS to be consistent with RC. For the WS, we also surveyed out about 5 m from the trail edge or route, only one person detected lizards, the pace was < 10 kph, and the environmental parameters were the same as RC. Both WS and RC were systematic and repeatable, with effort recorded as encounters per km (i.e., the encounter rate). The WS at Marijilda and Bajada were similar, except for the differences in using trails (Bajada) or not (Marijilda); at Marijilda, we followed established GPS routes recorded on a Gaia GPS application for cell phones.

There are anecdotal observations that lizards are more likely to flee from someone on foot than in a vehicle (e.g., Smith 1946; McPeak 2000; Lemm 2009). We could not find quantified data to support those observations but we think it is an important consideration for inventories. To test and quantify flight response, we documented flight (running after approach) or no flight (staying still) for the RC and WS comparison. With RC, most lizards were first seen while basking, so were either stationary or fled upon approach. If lizards only moved a short distance (< 1 m), we did not consider that they fled. Whiptail lizards (Teiidae) and Gila Monsters (*Heloderma suspectum*) differ from other taxa because they were usually detected while moving (e.g., actively foraging). Nevertheless, it was simple to ascertain if they were in flight or just foraging. To determine flight response while driving, we noted if the animal fled before or just when the front of the car passed it. Similarly, during WS, we recorded the response as flight if they ran off before or just as the observer passed.

There is only one assumption we required for RC and WS during inventory or target species survey, common to all such methods: correct species identification (Crump and Scott 1994; Guyer and Donnelly 2012). Although these and other references often include several additional assumptions, such as repeatability, thoroughness of search, recording of effort, and observer bias, these are not essential to document presence. Nevertheless, we feel it is important to include additional information on effort and other assumptions specific to the survey, as applicable, because repeating methods for future studies could be instrumental for determining trends. For example, accumulation curves are usually tied to effort (e.g., latency to first encounter of each species by person-hours). To ensure correct species identification, we trained our observers and collected vouchers (Foster et al. 2012). We took diagnostic voucher photographs rather than collecting the specimens, which was a requisite for studying animals in Saguaro National Park. Also, photographing a lizard *in situ* is less stressful to the animal than capturing it.

Data and analysis.—To measure the success of detecting expected species during our comparative studies, we compiled species lists from various sources for both of our study sites, then determined which species occurred in the appropriate habitat types within those areas. We were cognizant that additional species could have previously gone undetected. Species lists were updated to generally reflect the taxonomy and nomenclature of de Quieroz et al. (2017) and subsequent publications. For Marijilda, references included Nickerson and Mays (1969), VertNet, and previous reports from our surveys (Jones 2009, 2013). Nickerson and Mays (1969) used Marijilda Road as a basecamp for a herpetological inventory of the Pinaleño Mountains. Jones (2009, 2013) discussed the species list, taxonomy, and nomenclature. Since that time, we have updated the taxonomy: the Gila Spotted Whiptail (*Aspidoscelis flagellicaudus*) is now considered a junior synonym of the Sonoran Spotted Whiptail (*A. sonorae*; Taylor et al. 2018). We concur with Leaché and Mulcahy (2007) and Leaché et al. (2016) that the only member of the Desert Spiny Lizard (*Sceloporus magister*) complex at Marijilda is *S. magister*, rather than also including the Twin-spotted Spiny Lizard (*S. bimaculosus*) and hybrids. The only nomenclatural update from the Bajada area is that the Common Lesser Earless Lizard (*Holbrookia maculata*) is now generally considered to be the Elegant Lesser Earless Lizard (*H. elegans*) at that location (Bezy 2010; Jones 2010).

Our Marijilda RC study occurred in 2003 and in 2010–2021, but we reference our two most relevant data subsets. First, 2011–2014 comprised our most complete surveys because we surveyed weekly during the most active period for lizards (April through September, as determined by year-round surveys during those times). This more extensive data set is included here to establish an accumulation curve and a species-presence baseline. Second, for comparing WS and RC within sites, we only use data from 2020, when we conducted WS. The 2011–2014 dataset was a better baseline for the RC/LSRT technique because 2020 had the hottest, driest summer on record (Jones 2020). Despite the summer drought, there was sufficient winter/spring rain during 2019/2020 to warrant analysis in 2020. We decided to limit Marijilda WS to eight surveys due to safety concerns.

Our datasets for the Bajada study were from early May through mid-September 2020. Because WS transects were of variable length, we used encounter rate as our basic unit of comparison for both methods at Marijilda and Bajada. We entered data into Predictive Analytics Software (PASW, Version 17.0; a version of Statistical Package for the Social Sciences, SPSS, Chicago, Illinois, USA) or Excel (Microsoft 365, MSO Version 16.0) and analyzed with PASW. Our main comparisons were encounter rate for each species, total species, and unknowns (unidentifiable) within study areas. We compared differences by species between RC and WS using a Mann-Whitney U test, with adjustments to *P*-values by the methiod of Legendre and Legendre (1998) to conservatively protect against type II errors. We compared the flight responses of lizards (irrespective of species) using a 2 × 2 Contingency Table at each site. Due to the low numbers of observations for some species, we could not analyze the data by species (Zar 1984; Kinnear and Gray 2010). For all tests, we used $\alpha = 0.05$.

RESULTS

We detected 15 species during 105 visits for the Marijilda RC surveys of 2011–2014 (Table 1), including all expected species. We observed 8,498 lizards (mean

TABLE 1. Detections of lizards (n = number of encounters) from road cruising (RC) at the Marijilda study site, Arizona, USA, April-September 2011–2014. The abbreviations Enc/Visit = mean encounters per site-visit and ER = encounter rate (n/km).

Species	n	Enc/Visit	ER	Percentage of Detections
Aspidoscelis sonorae (Sonoran Spotted Whiptail)	7	0.07	0.02	0.1
Aspidoscelis tigris (Tiger Whiptail)	486	4.63	1.11	5.7
Aspidoscelis uniparens (Desert Grassland Whiptail)	50	0.50	0.11	0.6
Callisaurus draconoides (Zebra-tailed Lizard)	8	0.08	0.01	0.1
Cophosaurus texanus (Greater Earless Lizard)	590	5.62	1.34	6.9
Crotaphytus collaris (Eastern Collared Lizard)	364	3.47	0.83	4.3
Gambelia wislizenii (Long-nosed Leopard Lizard)	4	0.04	0.01	< 0.1
Heloderma suspectum (Gila Monster)	3	0.03	0.01	< 0.1
Phrynosoma modestum (Round-tailed Horned Lizard)	5	0.05	0.01	0.1
Phrynosoma solare (Regal Horned Lizard)	22	0.21	0.05	0.3
Plestiodon obsoletus (Great Plains Skink)	1	0.01	< 0.01	< 0.1
Sceloporus clarkii (Clark’s Spiny Lizard)	414	3.94	0.94	4.9
Sceloporus magister (Desert Spiny Lizard)	1,096	10.43	2.50	12.9
Urosaurus ornatus (Ornate Tree Lizard)	4,129	39.32	9.40	48.6
Uta stansburiana (Common Side-blotched Lizard)	1,212	11.54	2.76	14.3
Unknown	107	1.02	0.24	1.2
Totals	8,498	80.93	19.30	100

= 80.9 encounters/visit ± 31.1 standard deviation; range, 32–219 encounters/visit), or 19.3 encounters/km ± 7.4 (range, 7.7–52.3 encounters/km). Only eight species were commonly observed (i.e., average ≥ 1 individual/visit), plus the Desert Grassland Whiptail (*A. uniparens*), which was only frequently encountered after the start of the North American monsoon (summer rainy period). Commonly detected species were Tiger Whiptails (*Aspidoscelis tigris*), *A. uniparens*, Greater Earless Lizards (*Cophosaurus texanus*), Eastern Collared Lizards (*Crotaphytus collaris*), Clark's Spiny Lizards (*Sceloporus clarkii*), *S. magister*, Ornate Tree Lizards (*Urosaurus ornatus*), and Common Side-blotched Lizards (*Uta stansburiana*). We most frequently observed *U. ornatus*, which comprised nearly half (48.6%) of all encounters, followed by *U. stansburiana* (14.3%) and *S. magister* (12.9%). We encountered all seven of the commonly detected species active in the spring during visit 1, with *A. uniparens* detected on visit 3 (Fig. 2). After that, other species trickled in, and we did not detect the final three expected species until spring 2012 (Fig. 2). The last species we detected was *Heloderma suspectum*, on visit 53 on 4 September 2012 (Fig. 2).

At Marijilda in 2020, we had 318 lizard encounters for RC and 186 for WS during eight equal-distance visits each (Table 2). We detected 10 species during RC and eight during WS (Table 2). *Crotaphytus collaris* was the only species that was commonly detected by RC (observed during 63% of the surveys) that was not detected by WS. Significantly higher encounter rates using RC compared to WS were for *C. collaris*, *C. texanus*, *S. magister*, and *U. stansburiana* (Table 2). Only unidentifiable lizards were encountered significantly more often for WS than RC.

The Bajada site had a larger sample of surveys in 2020 (59 visits) than Marijilda (16 visits) because logistics and safety concerns were not sampling issues. We made 1,388 lizard encounters with RC and 680 encounters with WS. We detected eight species among the two methods at Bajada, with each method recording seven (Table 3). Both methods registered the same six commonly detected species. *Aspidoscelis tigris* and unidentified lizards were encountered significantly more often by WS than RC, while Desert Iguana (*Dipsosaurus dorsalis*) and *S. magister* were encountered more frequently by RC than WS (Table 3).

For all species at both sites, RC had a smaller proportion of individuals that fled from cars than surveyors on foot (Fig. 3). Overall, only 16.0% of the individuals fled from vehicles at Marijilda, while 82.2% of the individuals fled from human approach. Bajada was similar, with 17.3% fleeing from vehicles but 77.6% fleeing from observers on foot. The flight response of lizards was significantly different between RC and WS at the Marijilda site (χ^2 = 206.3, $P < 0.001$) and at the Bajada site ($\chi 2$ = 614.6, $P < 0.001$). *Urosaurus ornatus* and *U. stansburiana* were less likely to flee than other lizards during WS. At Bajada, where we also recorded where lizards were distributed along the road-associated

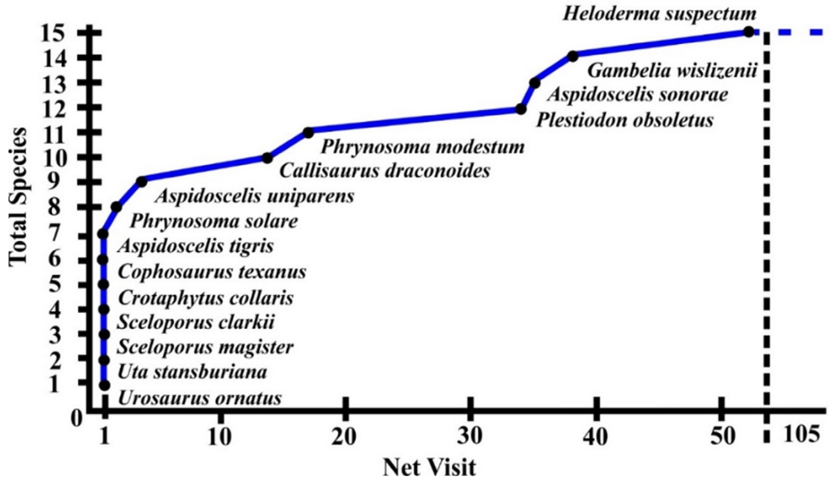

Figure 2. Species accumulation curve for Marijilda, Arizona, USA. Net visit number refers to the 2011–2014 dataset for number of surveys to first detection. Visits occurred from April through September. Net visit 1 = 1 April 2011. Visits do not represent person-days or person-hours, as is usually done for accumulation curves; our visits (daily surveys by one person) were only about 1.5–2.5 h long rather than the entire period of daily lizard activity. Standard English names, bottom to top are Ornate Tree Lizard (*U. ornatus*), Common Side-blotched Lizard (*U. stansburiana*), Desert Spiny Lizard (*S. magister*), Clark's Spiny Lizard (*S. clarkii*), Eastern Collared Lizard (*C. collaris*), Greater Earless Lizard (*C. texanus*), Tiger Whiptail (*A. tigris*), Regal Horned Lizard (*P. solare*), Desert Grassland Whiptail (*A. uniparens*), Zebra-tailed Lizard (*C. draconoides*), Round-tailed Horned Lizard (*P. modestum*), Great Plains Skink (*P. obsoletus*), Sonoran Spotted Whiptail (*A. sonorae*), Long-nosed Leopard Lizard (*G. wislizenii*), and Gila Monster (*H. suspectum*).

Table 2. Comparison of lizard detections during road cruising (RC) and walking surveys (WS), Marijilda study site, Arizona, USA, April-September 2020. Abbreviations are n = total number of individuals encountered by species by method, ER = encounter rate (n / km), P Vis = proportion of visits in which the species was detected, ND = not detected, and N/A = not applicable. Significant differences of ER in bold from adjusted Mann Whitney U test by species (*P*-values for unidentifiable and total are not adjusted).

	RC (eight surveys)			WS (eight surveys)			
Species	n	ER	P Vis	n	ER	P Vis	*P*
Aspidoscelis tigris (Tiger Whiptail)	20	0.60	0.88	32	0.97	0.88	0.896
Aspidoscelis uniparens (Desert Grassland Whiptail)	20	0.60	0.75	9	0.27	0.75	0.944
Callisaurus draconoides (Zebra-tailed Lizard)	1	0.03	0.13	ND	ND	ND	0.951
Cophosaurus texanus (Greater Earless Lizard)	20	0.60	0.88	3	0.09	0.25	**0.008**
Crotaphytus collaris (Eastern Collared Lizard)	9	0.27	0.63	ND	ND	ND	**0.008**
Gambelia wislizenii (Long-nosed Leopard Lizard)	2	0.06	0.25	ND	ND	ND	0.858
Phrynosoma solare (Regal Horned Lizard)	ND	ND	ND	1	0.03	0.13	0.951
Sceloporus clarkii (Clark's Spiny Lizard)	19	0.57	0.88	19	0.58	1.00	0.912
Sceloporus magister (Desert Spiny Lizard)	24	0.72	1.00	1	0.03	0.13	**0.011**
Urosaurus ornatus (Ornate Tree Lizard)	95	2.84	1.00	46	1.39	1.00	0.225
Uta stansburiana (Common Side-blotched Lizard)	89	2.66	1.00	23	0.70	0.88	**0.040**
Unidentifiable	19	0.57	0.63	52	1.57	1.00	**0.026**
Total	318	9.50	N/A	186	5.63	N/A	0.092

topography (Jones 2020), only 7.7% were detected on the road surface. Of these, 93.2% were moving or fled as the vehicle approached. Hence, at our RC sites, the few lizards on the roadway mostly fled from the vehicle, while lizards adjacent to the road did not.

Discussion

Relatively low travel speed is a basic requirement of RC in I&M handbooks for amphibians and reptiles. Road cruising is usually done at 16–64 kph for most reptiles (Sullivan 2012) and 20–35 kph for amphibians (Shaffer and Juterbock 1994); however, several studies suggest that small, cryptic species may go undetected at typical RC speeds (Enge and Wood 2002; Sullivan 2012; Andrews 2013), especially on unpaved roads (Klauber 1939). The faster one travels, the less visual perception and cognizance one has, so the less likely one can detect and decipher an object (Rumar 1990; Enge and Wood 2002; Sun et al. 2011). Our diurnal transects for lizards were even slower than those recommended in inventory and methods handbooks because lizards: (1) may be very small; (2) are more cryptic on an unpaved than a paved backdrop; (3) may be cryptic in dappled sunlight under shrubs; and (4) are primarily detected adjacent to the road, rather than on it. Our LSRT approach to RC was designed to overcome these speed-associated obstacles to detect a wider array of diurnally surface-active lizards of all sizes than would be encountered at higher speeds. We know of no other diurnal RC inventories where very low speeds were employed. We traveled on average from 2.26 to 3.29 kph (including stopping time to record and photograph vouchers) when conducting RC surveys. We consistently recorded large numbers of small individuals by driving very slowly, including hatchling *U. stansburiana* that only measure 18–23 mm snout-vent length (Tinkle 1967).

Similar to both surveys, virtually all detected species were primarily heliothermic (Brattstrom 1965; Pianka and Vitt 2003). Detectable taxa included those that Pianka (1966) regarded as diurnal sit-and-wait species (phrynosomatids and crotaphytids), herbivorous species (*D. dorsalis*), and widely foraging species (teiids). *Heloderma suspectum* is rarely detected by any method because it may spend up to 95% of its life underground, and it is diurnal in the spring but primarily nocturnal during the summer in southern Arizona (Beck 2005). Nevertheless, RC is often regarded as a valuable method to locate *H. suspectum*. For example, Farrar et al. (2017) found most of their 100 individuals from roads rather than on foot.

Roads and roadsides all represent disturbed environments to varying degrees (Andrews et al. 2008) but may also provide complex artificial habitats, especially along unpaved backroads (Jones 2020). Some of the associated habitat features include berms,

Table 3. Comparison of lizard detections during road cruising (RC) and walking surveys (WS), Bajada study site, Arizona, USA, April-September 2020. Abbreviations are n = total number of individuals by species by method, ER = encounter rate (n /km), P Vis = proportion of visits in which the species was detected, ND = not detected, and N/A = not applicable. Significant differences of ER in bold from adjusted Mann Whitney U test by species (*P*-values for unidentifiable and total are not adjusted).

	RC (39 surveys)			WS (20 surveys)			
Species	n	ER	P Vis	n	ER	P Vis	*P*
Aspidoscelis tigris (Tiger Whiptail)	32	0.15	0.49	125	1.43	0.95	**0.007**
Callisaurus draconoides (Zebra-tailed Lizard)	978	4.72	1.00	386	4.42	1.00	0.905
Dipsosaurus dorsalis (Desert Iguana)	244	1.18	1.00	27	0.31	0.40	**0.007**
Gambelia wislizenii (Long-nosed Leopard Lizard)	11	0.05	0.21	6	0.07	0.15	1.290
Phrynosoma solare (Regal Horned Lizard)	ND	ND	ND	1	0.01	0.05	1.881
Sceloporus magister (Desert Spiny Lizard)	60	0.29	0.82	13	0.01	0.40	**0.054**
Urosaurus ornatus (Ornate Tree Lizard)	1	0.01	0.03	ND	ND	ND	1.896
Uta stansburiana (Common Side-blotched Lizard)	49	0.24	0.54	46	0.53	0.40	0.944
Unidentifiable	13	0.06	0.90	84	0.96	0.80	**<0.001**
Total	1,388	6.07	N/A	680	7.78	N/A	0.309

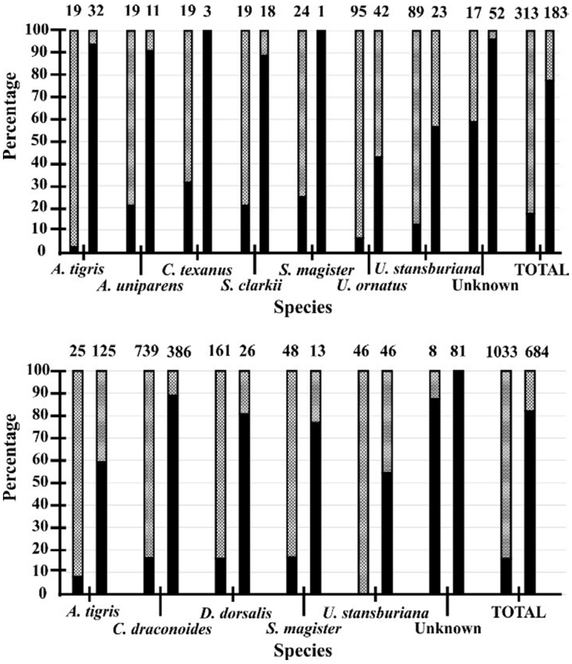

Figure 3. Flight response behavior of commonly detected lizards during road crusing (RC; left bar of pairs) and walking census (WS; right bar of pairs) at Marijilda (top) and Bajada (bottom) study sites, Arizona, USA. Stippled area represents percentage of individuals that did not flee upon approach, while black bars represent the percentage that did flee. Sample sizes are given above the bars. Total = total of identified species that does not include unknowns but does include species not shown. Standard English names, left to right and top to bottom, at first use: Tiger Whiptail (*Aspidoscelis tigris*), Desert Grassland Whiptail (*A. uniparens*), Greater Earless Lizard (*Cophosaurus texanus*), Clark's Spiny Lizard (*Sceloporus clarkii*), Desert Spiny Lizard (*S. magister*), Ornate Tree Lizard (*Urosaurus ornatus*), Common Side-blotched Lizard (*Uta stansburiana*), Zebra-tailed Lizard (*Callisaurus draconoides*), and Desert Iguana (*Dipsosaurus dorsalis*).

water diversions, roadcuts, shoulders, debris piles, edge vegetation, anthropogenic structures, disturbed areas, adjacent upland habitat, and sometimes the road surface itself. The roadway and adjacent habitats represent an environment that many lizards may find attractive for a variety of life-history needs (Fig. 4). These include basking, burrowing, hibernating, feeding, territorial advertisement and defense, seeking mates, and ovipositing (Parker and Pianka 1976; Sherbrooke 2002, 2003; Aresco 2005; Kaunert and McBrayer 2015; Jones 2020). Some species seem to generally favor disturbed environments, such as parthenogenetic *Aspidoscelis* (Wright and Lowe 1968), as supported by Walker (1987) for Laredo Spotted Whiptail (*A. laredoensis*) and Jennings (2009) for New Mexico Whiptail (*A. neomexicanus*).

The impacts of roads on amphibians and reptiles can be profound and include roadkill, landscape fragmentation, changes in predator populations and behavior, altered fire frequency, and alteration of various physical conditions in the vicinity of roads (Dodd et al. 1989; Rosen and Lowe 1994; Andrews et al. 2008). Only a few studies, however, have analyzed the effects of roads on lizards (e.g., Brehme 2003; García et al. 2007; Brehme et al. 2013, 2018). Nonetheless, there is some indication that most lizard species may be less susceptible to road mortality than other herpetofauna. Andrews (2008) suggested lizards are less susceptible to road mortality because they move quickly, have small home ranges, and exhibit site fidelity. Brehme et al. (2018) reported that lizards (and plethodontid salamanders) are the least susceptible herpetofaunal groups to road mortality and fragmentation in California, USA, except for a few species. The exceptions include *H. suspectum* and horned lizards (*Phrynosoma* spp.),

Figure 4. Desert Iguana (*Dipsosaurus dorsalis*) from the Bajada study site, Arizona, USA, basking on a berm. (Photographed by Lawrence L.C. Jones).

which are prone to road mortality, presumably because they move slowly or linger motionless in the road. Most species, however, are primarily encountered when adjacent to the road surface; when encountered on the roadway, they are usually alert and quick to flee from vehicles, at least on low-speed backroads. Also, animals on low-speed unpaved roads are less likely to be killed by vehicles than on higher-speed paved roads, as evidenced by studies at the Saguaro National Park, where road mortality of vertebrates was nearly 13 times higher on paved than unpaved roads (Kline and Swann 1998).

At our study sites, we observed advantages and disadvantages of both RC and WS. Available transect routes depend on the availability of roads, and if using them, trails. At Marijilda, there were no trails, while Bajada had many trails and only two roads. In these rough, arid environments, safety and physical fitness of field crews may be of concern. Road cruising seems advantageous because surveyors do not physically exert themselves and can carry everything they need in an air-conditioned vehicle. Occupants of a vehicle can seek safety or medical facilities more rapidly than if walking. Even with the slow pace of our RC, drivers covered more distance in a shorter span than with WS, suggesting there should be more encounters from greater area covered per unit time when lizards are active than with WS. Perhaps the most compelling reason to use RC is for positive identification (i.e., fewer unknowns), a critically important aspect of inventory and target-taxa detection (Guyer and Donnelly 2012). Because most animals did not flee from cars, there was a good opportunity for voucher photographs.

Figure 5. A Common Side-blotched Lizard (*Uta stansburiana*), left, and an Ornate Tree Lizard (*Urosaurus ornatus*), right, on a boulder along the edge of Marijilda Road, Arizona, USA. (Photographed by Lawrence L.C. Jones).

Sullivan (2012) provided anecdotal information on RC as a potential technique for detecting certain lizard taxa in arid environments, and Andrews (2013) surmised that RC for lizards is only likely to be useful in the Western USA and possibly Florida (for exotic species). Neither of these papers provided many citations to substantiate the notion that the geographic scope of RC utility is so limited. For us to determine if the method might have wider applicability across the USA, we compiled unpublished data from our own observations (Supplemental Information Table S1) and those of colleagues (Supplemental Information Table S2), and we conducted a limited literature search of published anecdotal accounts (Supplental Information Table S3). These sources suggests that RC has potential as a valuable tool for detecting heliothermic and nocturnal lizards in most areas of the USA, and perhaps other areas in the world, but detailed studies are largely lacking. We encourage researchers to include RC (including, but not limited to, LSRT) as a lizard-sampling regimen, if only to document applicability to other areas, including beyond the USA. We do not suggest that RC alone will suffice to document lizard communities of any particular area, but it could be a helpful tool to add to other techniques.

Acknowledgments.—Anne Casey helped extensively with field work and contributed to discussions of this study. Shayna Brent, Lindsay Helleksen, Luke Hetherington, Karina Hilliard, and Roger Joos also assisted in the field. Jason Jones, Erika Nowak, Trevor Persons, and Roger Repp generously allowed us to use unpublished data from their RC studies (see Supplemental Information). Dylan Kelsch, Bryce Street, Jim Vanas, and George Ward provided personal communications about road cruising for lizards in other parts of the country. Richard Hill, Tom Jones, Lance

Koch, Chrissy Kondrat, Adam Springer, and Don Swann assisted with permitting and logistics. Janet Jones, Danny Martin, and Brian Sullivan critically reviewed earlier drafts of the manuscript. Cameron Barrows, Heather Bateman, Brian Blais, Margarethe Brummermann, William Cooper, Jim Dixon, Eric Dugan, Matt Goode, Terry Hibbitts, Toby Hibbitts, Troy Hibbitts, Dan Leavitt, Jeff Lemm, Rob Lovich, Dave Prival, Phil Rosen, Sherburn Sanborn, Cecil Schwalbe, Wade Sherbrooke, Barry Sinervo, Tom Skinner, and Laurie Vitt all provided helpful dialogue on lizard biology and methods during the course of this study.

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Supplemental Information: http://www.herpconbio.org/Volume_17/Issue_2/Jones_etal_2022_Suppl

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