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Is mitigation translocation an effective strategy for conserving common chuckwallas?

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Abstract: Mitigation translocation remains a popular conservation tool despite ongoing debate regarding its utility for population conservation. To add to the understanding of the effectiveness of mitigation translocation, in 2017 and 2018 we monitored a population of protected common chuckwallas (*Sauromalus ater*) following translocation away from the area of construction of a new highway near the South Mountains, Phoenix, Arizona, USA. We removed chuckwallas from the construction right-of-way, paint-marked and pit-tagged them, and then released them in a nearby municipal preserve. We deployed very high frequency radio-telemetry transmitters on a sub-sample of 15 translocated adult chuckwallas. We monitored the radio-marked chuckwallas once a day at 1- to 3-day intervals for up to 46 days to document survival, body mass, and post-release movements. The average distance moved following translocation was 359 ± 53 m. Using minimum convex polygons, the average home range size of translocated lizards was 0.9 ± 0.3 ha, which was 18–45 times larger than expected for the species. Following translocations, we surveyed the translocation sites 1 month later and again 1 year later to determine the presence of translocated chuckwallas. Translocated individuals were rarely observed a second time: in 2017, only 11 of 160 translocated chuckwallas were seen again, and in 2018, only 11 of 192 translocated chuckwallas were detected. In the light of low recapture rate, consistent loss of body mass, and large movements of marked lizards, we conclude that survival of translocated chuckwallas was low over a single year. In the future, efficacy of mitigation translocation could be better evaluated by assessing the spatial ecology of both resident and translocated individuals simultaneously using radio-telemetry.

Key words: abundance, Arizona, body mass, common chuckwalla, lizards, mark-recapture, mitigation translocation, *Sauromalus ater*, survival, telemetry

Human–wildlife interactions are increasing as the wildland–urban interface expands in proportion to the sprawl of metropolitan areas. Increased interactions with wildlife may negatively affect societies' perceptions of wildlife if they result in real or perceived conflicts with hu-

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Figure 1. An adult male common chuckwalla (*Sauromalus ater*; left) and study area habitat (right) located within the South Mountain Park and Preserve, Maricopa County, Arizona, USA (*photos courtesy of D. Leavitt [left] and C. Rubke [right]*).

man livelihoods, health and welfare, or economic opportunity (Messmer 2000). One strategy to resolve such conflicts is a form of translocation, the movement of wild individuals from a part of their range to another to avoid human–animal conflict, termed "mitigation translocation" (International Union for Conservation of Nature [IUCN] 2013). This practice is increasingly used to remedy conflicts arising between endangered species and anthropogenic actions (e.g., Armstrong 2008, Riedl et al. 2008, Gardner and Howarth 2009, Miller et al. 2014). One unifying theme of mitigation translocations is that they are often conducted in the absence of relevant information about the source or target sites (Germano et al. 2015, Sullivan et al. 2015). Further, because many mitigation translocations occur on a short timeline, they do not allow for intensive study or development of plans that align with conservation needs or values.

Concomitantly, the practice of translocating animals to mitigate human–wildlife conflicts should be considered separately from the translocation of large numbers of individuals to conserve threatened or endangered species because the former concerns the welfare of individual organisms rather than a population (IUCN 1987, 1998, 2013). The IUCN differentiates mitigation translocation from conservation translocation, due in part to the high failure rate of mitigation translocation. Because the public and some resource professionals are optimistic about the utility of mitigation translocation (Brand et al. 2016, Box et al. 2019, Dickson et al. 2019), and because public investment in mitigation translocations often exceeds investment in alternative conservation actions for the same species (Germano et al. 2015), this practice warrants further scrutiny. This is especially true for nongame animals such as herpetofauna that often receive scant attention from applied conservation biologists (Sullivan et al. 2015).

Mitigation translocation is frequently used to rescue individual organisms from conflict with humans, but the effects on translocated individuals vary and may often be negative. Homing behavior, wandering movements, and decreased survival have been documented in translocated carnivores (Fontúrbel and Simonetti 2011, Boast et al. 2016), mesopredators (Mosillo et al. 1999, Robinson et al. 2020), small mammals (Lehrer et al. 2016), large mammals (Alldredge et al. 2015), and aquatic reptiles (Krochmal et al. 2018). Mitigation translocation has increasingly been used to protect individual reptiles and amphibians from human conflict,

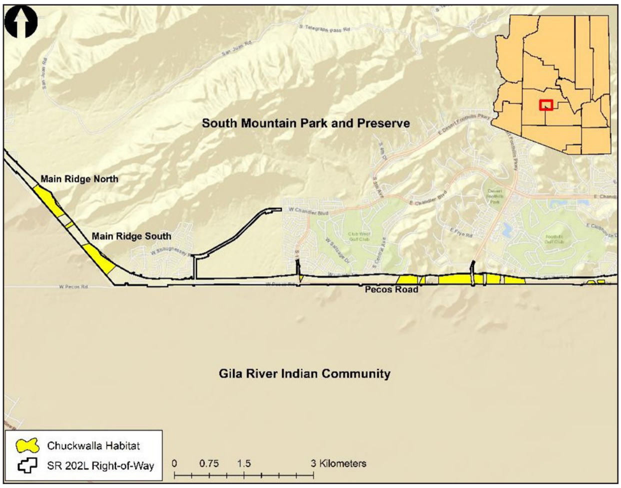

Figure 2. Planned route of the State Route 202 Loop (SR 202L) and intersecting common chuckwalla (*Sauromalus ater*) habitat in Maricopa County, Arizona, USA.

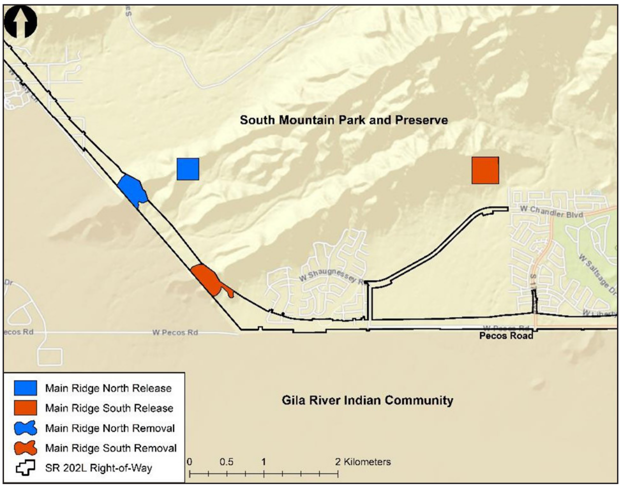

Figure 3. Common chuckwalla (*Sauromalus ater*) habitat surveyed on Main Ridge North and Main Ridge South, Maricopa County, Arizona, USA, 2017–2018.

but with a few notable exceptions, outcomes are poorly studied (Germano and Bishop 2009, Miller et al. 2014, Sullivan et al. 2015, Romijn and Hartley 2016). When outcomes are known, translocated individuals often exhibit increased movements and decreased survival (Dodd and Seigel 1991, Nowak et al. 2002, Devan-Song et al. 2016, Kraus et al. 2017). Translocations are inherently risky, and success varies among taxa; therefore, some species may be more suitable for translocations than others (Griffiths et al. 1989, Burke 1991, Rout et al. 2013, Ebrahimi et al. 2015). Accordingly, we sought to evaluate the success of a mitigation translocation project for a large, protected lizard and to contribute to the limited data on the success of mitigation translocations of herpetofauna.

The common chuckwalla (*Sauromalus ater*; Figure 1) is a large, herbivorous lizard of the Sonoran Desert in Arizona and California, USA, and Mexico, as well as the Mojave Desert in California, Nevada, and Utah, USA (Kwiatkowski et al. 2009). Adult chuckwallas live at least 16 years in the wild; some may reach 30 years of age (Abts 1987, Sullivan and Sullivan 2012). Chuckwalla home range estimates vary considerably across their distribution but are typically 0.02–1.90 ha (Kwiatkowski and Sullivan 2002*b*). Home range estimates are influenced by a number of habitat-related factors, including surface geology, availability of critically important refugia used to escape predators (i.e., rock crevices), food resources, and population density (Kwiatkowski et al. 2009). Where they occur, chuckwalla population densities range from 2–65 per ha (Kwiatkowski and Sullivan 2002*a*, *b*). They are also relatively tolerant of some anthropogenic impacts as long as their rocky microhabitats remain intact. They are present in all the parks and preserves of the Phoenix Mountains (Arizona) with rock outcrops even though other large squamates (e.g., desert iguanas [*Dipsosaurus dorsalis*] and leopard lizards [*Gambelia wislizenii*]) are absent or declining (Sullivan and Flowers 1998, Sullivan and Sullivan 2008) in these areas. Chuckwallas in the South Mountain Park and Preserve (SMPP) are protected by the state of Arizona (Arizona Revised Statue Title 17-303, Commission Order 43) because they are an endemic color morph (Hollingsworth 1998) that is subject to destructive collection practices common in the commercial trade of herpetofauna (Goode et al. 2005).

In 2016, the Arizona Department of Transportation (ADOT) initiated the reconstruction of Arizona State Route 202L (SR 202L) South Mountain Freeway in Maricopa County, Arizona, (Figure 2). The right-of-way for SR 202L intersected chuckwalla habitat on the southwestern edge of SMPP (Leavitt 2016*a*). As part of the highway construction mitigation plan, the ADOT, in coordination with Arizona Game and Fish Department and the Gila River Indian Community, agreed that chuckwallas found within the right-of-way for SR 202L construction would be relocated into adjacent areas, including SMPP (Leavitt 2016*b*).

Our goal was to determine whether mitigation translocation of chuckwallas was an effective conservation mitigation strategy. To accomplish this goal, we: (1) removed all chuckwallas in the right-of-way using destructive habitat sampling, (2) translocated them to translocation sites within high quality habitat in the adjacent SMPP, (3) radio-marked a sub-sample of translocated individuals, and (4) conducted follow-up surveys on the translocation sites to assess the efficacy of translocation for this species. Specifically, we sought to determine movement patterns, condition, and ultimate survivorship of translocated chuckwallas over a 12-month period.

Study area

Our study area was located within the southwestern region of SMPP, a 6,400-ha municipal park administered by the City of Phoenix Parks, Recreation, and Library Department. It encompasses 3 minor mountain ranges that are collectively known as the South Mountains. These mountains are a small desert range located on the southern periphery of the city of Phoenix in southcentral Arizona (Figure 2). The South Mountains extend approximately 18.5 km in length and range in elevation from 360–820 m above sea level. Yearlong recreation (e.g., hiking, biking) is common in SMPP but occurs infrequently within the remote regions of the park where our work occurred. Within the SMPP, we designated 2 sites for translocation (Figure 3). The Main Ridge North and Main Ridge South translocations plots consisted of 6 and 9 ha, respectively. Translocation plots were 1.4–2.5 km from capture locations.

The climate of our study area was typical of regions in the Arizona Upland and Lower Colorado River Valley subdivisions of the Sonoran Desert (Turner and Brown 1982). These subdivisions are characterized by high summer temperatures and low levels of annual precipitation. Mean annual precipitation for SMPP from 1983 to 2018 was 181 mm (range = 55–337 mm). Rainfall typically occurred in 2 seasons, winter and mid-to-late-summer (monsoon season). Winter rains tended to be calm and prolonged and usually occurred over broad regions. Summer rainfall events were intense, brief, and localized. Typical summer high temperatures routinely exceeded 43°C, while winter low temperatures occasionally approached 0°C.

The topography at SMPP is complex. Geologically, it is comprised of 2 main rock types, each forming approximately half of the range. The western half is primarily metamorphic rock, while the eastern half is predominantly granodiorite igneous. A major portion of the range consists of mountainous slopes of exposed bedrock. Gently sloping bajadas and valley bottoms are boulder-strewn and bisected by steep-sided dry washes. Plant growth is generally open, with most trees confined to arroyos. The most extensive plant community is the paloverde-cacti-mixed scrub series characteristic of the Arizona Upland. Commonly encountered plant species include saguaro (*Carnegiea gigantea*), brittlebush (*Encelia farinosa*), ocotillo (*Fouquieria splendens*), creosote (*Larrea tridentata*), and foothills paloverde (*Parkinsonia microphylla*).

Methods

Removal surveys

During spring (April to May) and summer months (June to September) of 2016 to 2018, we completed ground surveys for chuckwallas in potential habitat within the proposed SR 202L right-of-way. To complete the surveys, up to 10 surveyors searched under rocks, in cracks and fissures in rocks, and in boulder piles within chuckwalla habitat. In September 2016 (7 days), we completed removal surveys along the Pecos Road section of the right-of-way (Figure 2). In June 2017 (8 days) and September 2017 (9 days), and in April 2018 (8 days), we completed removal surveys along the Main Ridge North and Main Ridge South section of the right-of-way (Figure 3).

Destructive habitat sampling included surveyors using metal pipes and crowbars to open up rock fissures and to remove all chuckwallas encountered. We captured each chuckwalla by hand, recorded the capture time and location, and placed the chuckwalla in a collection bag in a cooler maintained at 28°C ± 2°C to prevent overheating until it was processed and then translocated to a translocation plot. The hold time did not exceed 8 hours. Each day after removal surveys were completed, the captured chuckwallas were processed (approximately 15

Figure 4. Male common chuckwalla (*Sauromalus ater*) with radio-telemetry set-up on pelvis, Maricopa County, Arizona, USA (*photos courtesy of W. Crumbo*).

minutes per individual) on-site at a centrally located workstation. We marked captured individuals with a subdermal BioMark passive integrated transponder (PIT) tag inserted into the lower left side of the animal's abdomen. The site of injection was disinfected prior to injection, and sterile conditions were maintained. Disinfectant was used post-injection, and the insertion site was sealed with surgical glue. Each lizard was then given an external paint mark for visual re-sight (i.e., lizard forelegs were painted white with a non-toxic paint). We visually assessed health, noting signs of lethargy, ectoparasites, and injury. We also measured snout-vent length (SVL; mm) using a 200-mm ruler placed along the ventral midline of the outstretched lizard and determined their mass (g) using a 300-g Pesola spring scale.

After processing, we translocated the chuckwallas in designated sites on lands south of Pecos Road (in September 2016; a site that was not used in follow-up studies) or SMPP (in June and September 2017 and April 2018). All individuals were released within 8 hours of capture into potential habitat (rocky outcrops or boulder piles) that had been visually ascertained to represent the nearest appropriate (rocky) habitat to their respective capture sites. When lizards were captured as a group, they were released together to maintain any existing social familiarity. We did not complete surveys of existing chuckwalla populations at the translocation sites prior to the releases due to limited site access and project funding. We followed best practices and guidelines for use of live amphibians and reptiles in field and laboratory research as outlined by Beaupre et al. (2004) as well as our own staff experts.

Radio-telemetry

We radio-marked 15 translocated chuckwallas on the Main Ridge South plot with detachable radio-telemetry transmitters in September

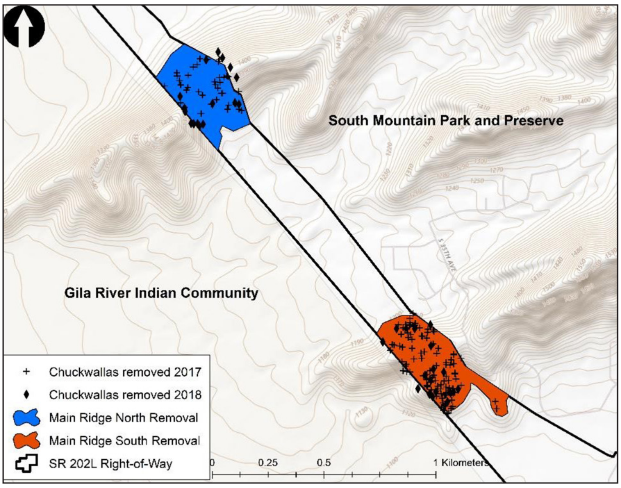

Figure 5. Location of all common chuckwalla (*Sauromalus ater*) captures and common chuckwalla removal areas along the right-of-way for State Route 202 Loop (SR 202L) on Main Ridge South and Main Ridge North, Maricopa County, Arizona, USA, 2017–2018.

2017 so that we could document space use and behavior. We affixed Holohil PD-2 transmitters (Holohil Systems, Ltd., Ontario, Canada) with super glue (Cyanoacrylate acid) to a small harness constructed of braided nylon line that was fitted on the chuckwalla (Kwiatkowski and Sullivan 2002*b*; Figure 4). We monitored the 15 chuckwallas between September 6 and October 22, 2017. We collected location data once a day at 1- to 3-day intervals for up to 46 days. During this time, each chuckwalla was located on 5–9 (mean 7) times. We conducted additional follow-up surveys in May 2018. Surveys totaled 11 person-days of effort.

Follow-up surveys

Following translocations in 2017 and 2018, we surveyed the sites 1 month later (June: 4 days), then again 1 year later (May: 6 days). During the surveys, we recorded number of chuckwallas observed that were translocated (marked) and resident (unmarked). Follow-up surveys were conducted on the translocation plots between sunrise and 1400 hours. Surveyors walked parallel, straight-line transects at 5-m intervals to ensure complete coverage of each plot.

We recorded location data in Universal Transverse Mercator units (datum: NAD 83) for all chuckwallas detected. When individuals could be extracted from shelters without injury to the lizards or damage to the habitat, they were remeasured, reweighed, and scanned for PIT tags. Comparing initial mass and SVL (when removed from right-of-way habitat) with mass and SVL recorded during follow-up surveys allowed us to calculate growth rate and weight change in each recaptured individual.

Data analysis

To visualize and interpret the translocated chuckwalla movements, we plotted each individual's path in ArcGIS 10.6.1 (ESRI, Redlands, California). We calculated step lengths (average distance moved per day) and minimum convex polygon (MCP) area using ArcGIS. To estimate home range size, we used each animal's location to generate an MCP using the minimum bounding geometry tool in ArcToolbox. We did not include the release point in home range estimates to allow for and exclude from calculations an initial dispersal event. To determine the minimum total distance moved by an individual, we used the points to line tool in ArcToolbox to generate a single line for each common chuckwalla. We then used the split line by vertices tool in ArcToolbox to calculate the length of each line segment. To determine the average daily distance moved, we divided the total distance moved by the number of days the individual was tracked. This allowed us to compare daily movements of individuals with varying tracking durations. Because these methods incorporate straight-line distances, our MCP values and estimates of daily movements are likely to be underestimates.

Results

Removal surveys

In 2016, we detected 50 chuckwallas during the walking surveys of 22.9 ha of habitat in the Pecos Road section of the right-of-way. The population density of animals detected in this section was estimated as 2.2 common chuckwallas per ha. Of these, we translocated 47 chuckwallas to land south of Pecos Road (3 immature lizards died during the removal process). Of the 47 individuals moved, 23 were adults (11 male, 12 female) and 24 were immature. On average, males (mean +/- SD; SVL: 152.1 ± 4.9 mm; mass: 140.7 ± 10.5 g) were larger than females (SVL: 135.4 ± 7.2 mm; mass: 92.7

Table 1. Body condition of recaptured common chuckwallas (*Sauromalus ater*) at the South Mountain release sites, Maricopa County, Arizona, USA, 2017–2018. Time between initial capture and most recent capture was 1–11 months. SVL = snout-to-vent length. Unk = unknown.

Chuckwalla ID	Sex	Initial capture year	Initial capture SVL (mm)	Most recent SVL (mm)	Mean relative growth (%)	Initial capture mass (g)	Most recent mass (g)	Total weight change (g)	Weight change (%)
DCT01	F	2017	160	163	1.9	137	133	-4	-3
RLH3	Unk	2017	113	118	4.4	54	41	-13	-24
JM3	M	2017	165	164	-0.6	185	108	-77	-42
CR1	F	2018	124	124	0	85	70	-15	-18
NM1	Unk	2017	104	107	2.9	39	33	-6	-15
CAR4	M	2017	141	141	0	81	75	-6	-7
CAR1	M	2017	143	146	2.1	95	86	-9	-9
SAR2	M	2017	159	154	-3.1	145	128	-17	-12
AJO9	M	2017	152	159	4.6	116	102	-14	-12

± 10.0 g), and the immatures were all similar in size (SVL: 54.3 ± 0.6 mm; mass: 6.0 ± 0.2 g). No obviously gravid females were encountered during this time, and no chuckwallas shed their tails through this removal effort.

In 2017, we detected 160 chuckwallas during surveys of 14.7 ha of habitat in the Main Ridge North and Main Ridge South sections of the right-of-way. The population density of animals detected in this section was 10.9 chuckwallas per ha. All 160 individuals were translocated within SMPP. Chuckwallas captured on the Main Ridge North and Main Ridge South removal areas were translocated to the Main Ridge North and Main Ridge South translocation plots, respectively. Of the individuals moved, 124 were adults (67 male, 57 female), and 36 were immature. More chuckwallas were captured on the south side of Main Ridge South (Figure 5). On average, males (SVL: 152.6 ± 15.7 mm; mass: 133.9 ± 43.3 g) were larger than females (SVL: 127.9 ± 21.2 mm; mass: 85.7 ± 40.4 g) and immatures (SVL: 74.3 ± 25.9 mm; mass: 23.5 ± 19.7 g).

In 2018, we detected 32 chuckwallas in walking surveys of the same 14.7 ha of habitat along the right-of-way that was surveyed in 2017. The population density of animals detected in this section was 2.2 per ha. Combining individuals captured in the same areas over 2 years (2017 and 2018) yielded an average density of 13.1 per ha. Of the 32 individuals translocated to SMPP, 23 were adults (8 male, 15 female), and 9 were immature. Nearly equal numbers of individuals were detected on Main Ridge North (n = 17) and Main Ridge South (n = 16). On average, males (SVL: 145.2 ± 5.0 mm; mass: 111.7 ± 11.4 g) were larger than females (SVL: 134.7 ± 3.3 mm; mass: 85.7 ± 5.3 g) and immatures (SVL: 101.4 ± 2.1 mm; mass: 31.9 ± 1.7 g).

In 2017, removal-based population densities from Main Ridge (North and South) were 10.9 per ha. When this same area was resurveyed in 2018, we captured 2.2 lizards per ha. Most of these lizards are likely to have been individuals missed in 2017. Thus, the total population density was estimated to be at least 13.1 lizards per ha. From this, we estimate our detection probability in 2017 to be roughly 83%.

Follow-up surveys

In 2017, we detected 69 chuckwallas on the translocation plots (n = 39 at Main Ridge North plot; n = 30 at Main Ridge South plot). Of these 69 detections, 11 were translocated individuals as identified by paint markings. Of the 11 marked lizards, 5 were safely extracted from habitat and individually identified by their PIT tags (Table 1). These individuals had a mean change in weight of -11% (range: -7% to -15%; Figure 6) in the <1 month since their translocation.

In 2018, we detected 77 chuckwallas on the 2 translocation plots (n = 40 at the Main Ridge North plot; n = 37 at the Main Ridge South plot). Of these 77 detections, 11 were translocated individuals (confirmed by batch marks). Of these,

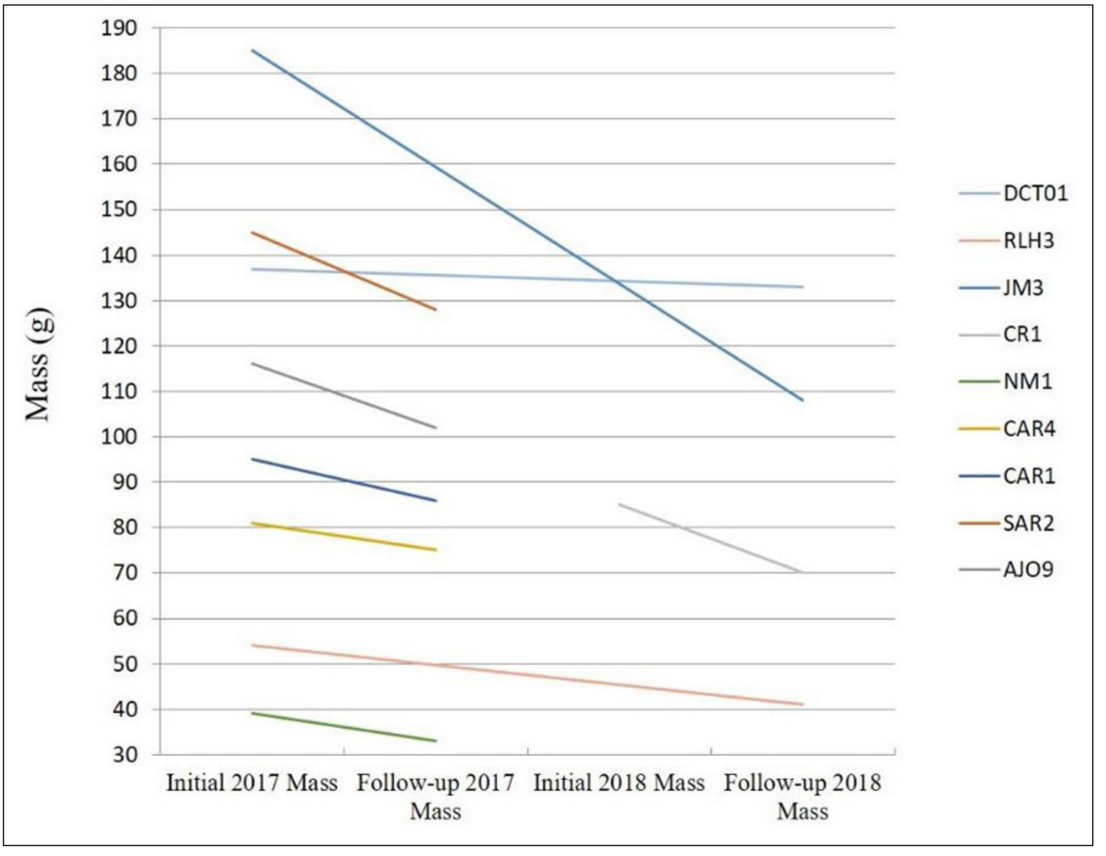

Figure 6. Changes in mass of recaptured translocated common chuckwallas (*Sauromalus ater*) at the South Mountain Park and Preserve release sites, Maricopa County, Arizona, USA, 2017–2018.

4 could be individually identified (Table 1) by their PIT tags. The remaining 7 were too deep to be safely extracted from shelters, but surveyors noted the presence of batch markings. The 4 individuals had a mean change in weight of -22% (range: -3% to -42%: Figure 6) in the ≤11 months since their translocation.

Radio-telemetry

The 15 radio-marked chuckwallas were monitored between September 6 and October 22, 2017 (Table 2; Figure 7). Some transmitters detached earlier than anticipated. This led to a substantial variation in the number of days an individual lizard was tracked and the number of locations that were recorded.

The average MCP size was 0.9 ± 0.3 ha (0.0–3.4), average total distance moved was 359 ± 53 m (24–676), and average daily distance moved was 13.5 ± 3.2 m (0.6–52). There were no differences between male and female MCP ($t = 0.54$; $P = 0.59$), total distance moved (Student's t-test, $t = 0.05$; $P = 0.96$), or daily distance moved ($t = 0.05$; $P = 0.96$), but these comparisons are limited by small sample sizes. Radio-tracked individuals varied in their initial response to translocation. Six individuals stayed within the boundary of the translocation plot, 3 moved ≤100 m outside the plot boundary, and 6 moved >100 m beyond the plot boundary.

Movements tended to be upslope and in a northwest orientation toward contiguous habitat. Radio-tracked common chuckwallas were last seen alive up to 46 days after translocation, and there were no signs of attempted predation. Our tracking effort occurred after the peak active season for common chuckwallas and spanned a very short time relative to the animal's life expectancy (at least 10–20 years). Although the tracking duration was short, we did not observe attempts of relocated lizards to return toward their original habit within the right-of-way (i.e., no "homing behavior").

Table 2. Common chuckwallas (*Sauromalus ater*) radio-tracked in 2017, their movements, and minimum convex polygons, Maricopa County, Arizona, USA. Observations = number of times a lizard was tracked to a location. MCP = minimum convex polygon.

Chuckwalla ID	Sex	Date released	Date last seen	Days	Observations	MCP (ha)	Total distance (m)	Daily distance (m)
CC1	F	6-Sep-17	17-Oct-17	41	8	0.02	24	0.59
WLC3	F	6-Sep-17	22-Oct-17	46	7	1.36	430	9.35
SAR5	F	6-Sep-17	10-Oct-17	34	8	0.50	341	10.03
SAR3	F	6-Sep-17	17-Oct-17	41	9	0.99	445	10.85
AJO1	F	6-Sep-17	21-Oct-17	45	8	3.44	676	15.02
WLC2	F	6-Sep-17	19-Sep-17	13	5	2.02	673	51.77
LW2	F	7-Sep-17	19-Sep-17	12	5	0.03	47	3.92
LW1	F	7-Sep-17	5-Oct-17	28	6	0.20	192	6.86
SAR2	M	6-Sep-17	28-Sep-17	22	7	0.79	235	10.68
BW2	M	6-Sep-17	22-Oct-17	46	9	2.74	576	12.52
WLC1	M	6-Sep-17	26-Sep-17	20	5	0.53	354	17.70
AEG1	M	6-Sep-17	17-Sep-17	11	6	0.42	292	26.55
SAR6	M	7-Sep-17	19-Oct-17	42	7	0.10	166	3.95
AJO9	M	7-Sep-17	17-Oct-17	40	7	0.14	409	10.23
TR1	M	8-Sep-17	22-Oct-17	44	6	0.73	527	11.98

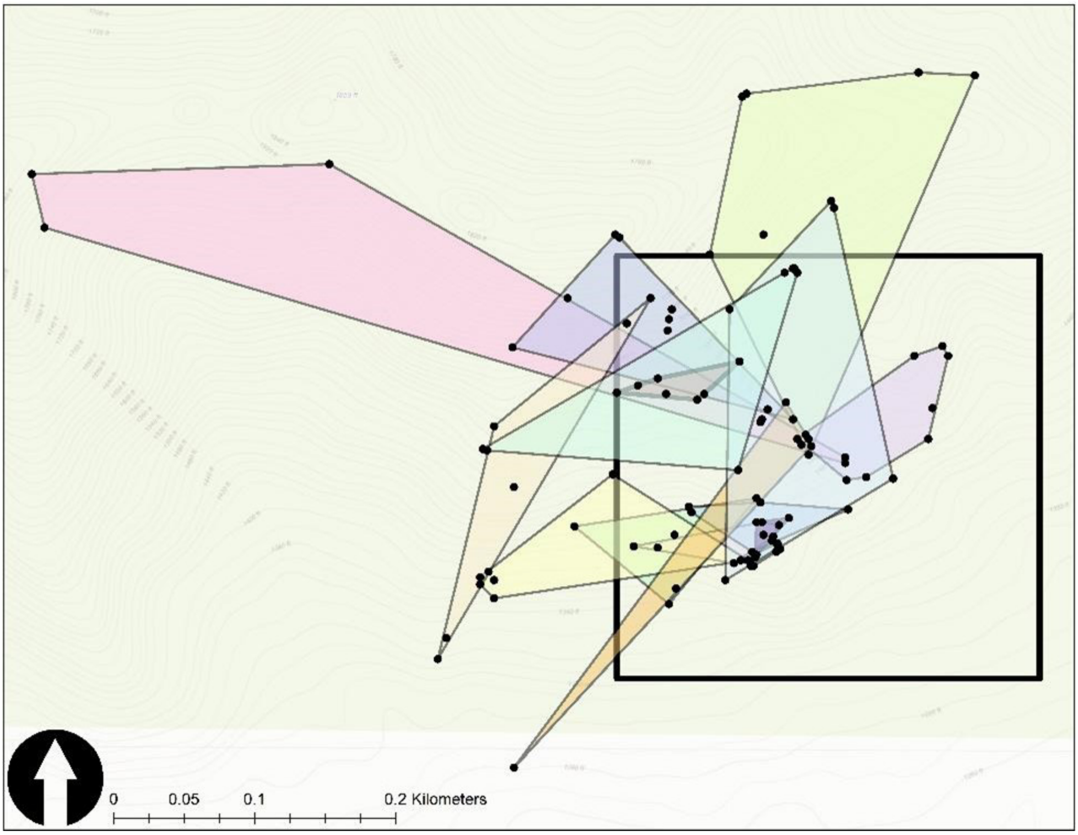

Figure 7. Locations and minimum convex polygons of telemetered common chuckwallas (*Sauromalus ater*) on the Main Ridge South relocation plot at South Mountain Park and Preserve, Maricopa County, Arizona, USA, 2017.

Discussion

The majority of chuckwallas that we translocated were not resighted either 1 month or 1 year after translocation. Similarly, those that were translocated and then radio-tracked exhibited large home ranges and high movement rates. Although only a small number of individuals could be recaptured after translocation, they all exhibited a reduction in mass. Taken together, these results are consistent with the view that as territorial, long-lived animals that make use of consistent refuges for their unique anti-predator behavior (Sullivan and Sullivan 2012), chuckwallas represent poor candidates for mitigation translocation. Nonetheless, the inferences drawn from our observations must be qualified given limitations associated with temporal and fiscal constraints in the execution of our study—limitations common to many mitigation translocation efforts (Sullivan et al. 2015). In the absence of any alternative conservation action in the anticipation of pending habitat loss, we suggest that future studies include detailed observations on the resident population of chuckwallas at translocation sites. These data will provide a more complete picture of the relative impacts of translocation on males, females, and juveniles and may allow identification of individuals better suited to translocation. Additionally, given that at least a small number of chuckwallas survived 1 year, perhaps future mitigation translocations with this species should include islands of habitat that have recently lost their resident population as a destination for translocated individuals.

The timing and duration of our surveys in early spring 2018 were dictated by the imminent start of freeway construction. Mitigation translocation is often critiqued because developer schedules, rather than ecological assessments and biological windows, dictate the timing of required actions (Germano et al. 2015). Ideally, removal efforts for common chuckwallas would take place from May through June to maximize detection probabilities and to allow additional time to complete the removal process. Some locations could only be surveyed by destructive habitat sampling. Even so, there were locations where common chuckwallas might have taken refuge deep below the surface, therefore making them inaccessible to surveyors. A significant amount of time and effort is needed to depopulate a site completely of resident animals. While our objective to remove as many resident animals as possible from right-of-way habitat had positive motivations, more often the attempt to remove an entire population from a specific area is associated with invasive or nonnative wildlife control (Rosen and Schwalbe 1995, Freeman et al. 2010, Diller et al. 2013, Love et al. 2018). Often times, these eradication efforts are extensive and resource intensive. And while the motivations are contradictory to ours (eradicate vs. rescue), they clearly illustrate removing a species from an area is expensive, difficult, and unlikely to be complete.

Without a marked population of resident chuckwallas in the plots that received translocated lizards, it is difficult to interpret these resighting data. The low ratio of translocated lizards to resident lizards (11:69 in 2017 and 11:77 in 2018) could reflect emigration of translocated lizards, poor survival of translocated lizards, an exceptionally large resident population, or reduced detection probability of translocated lizards compared to resident lizards. Although densities of resident lizards on our translocation plots were unknown, population densities of chuckwallas have been well studied elsewhere. Given the total size of the translocation plots (6 ha for the north plot and 9 ha for the south plot), the resulting density of 67–90 lizards per ha would have to be higher than any previously reported for the species to account for the low frequency of translocated lizards without differential mortality or emigration. Published estimates of common chuckwalla population density range from 2 lizards per ha (Sullivan and Sullivan 2012) to 65 lizards per ha but are most frequently in the range of 7–14 lizards per ha (Kwiatkowski and Sullivan 2002*b*, and herein). Given that few translocated lizards were resighted and that unreasonably high estimates of population density would have to be assumed to account for the low ratio of marked to unmarked lizards without emigration or mortality, the likely explanation is that most of the translocated lizards either died or emigrated from the plot. If we assume a moderately high total density of 14 resident lizards per ha, then our proportion of marked lizards would indicate 33 remained alive on our plot in 2017 (21%) and 30 in 2018 (17%).

Population-level conclusions such as these are tenuous without a marked resident population. Better evidence for direct negative effects of translocation on common chuckwallas comes from individual-level data. The 9 translocated individuals that were identified during the follow-up surveys of 2017 and 2018 all exhibited a decline in body condition in the 1–11 months between captures (Table 1; Figure 6). While some individuals continued to grow in length (SVL), each lost weight. Weight loss has been documented in other translocations of herpetofauna (Platenberg and Griffiths 1999, Matthews 2003, DeGregorio et al. 2017). Since we did not compare changes in weight in residents during the same tracking period, we cannot state definitively whether this was due to effects of translocation or poorer habitat conditions. Chuckwallas do typically lose weight through dry periods (Nagy 1973), but our animals continued to lose weight even in wet periods. And while weights vary based on when the individual last fed, drank, or defecated, the universal reduction in mass suggests translocated lizards failed to thrive. Relocated adult animals, especially if long-lived, may have strong behavioral and physiological ties to their natal habitat (Sullivan et al. 2015). Because of this presumed long-term dependence on sites within home ranges, relocation could have negative consequences depending on the degree to which individuals rely on particular refuges and their ability to identify and learn new refuges (Greenburg 2002, Brown et al. 2011).

Our individual-level telemetry data allows us to directly address the possibility that translocated chuckwallas survived but moved out of our survey area. Of the 15 telemetered individuals in 2017, 6 moved considerable distances from their release location (>100 m beyond the relocation plot boundary), another 6 moved <100 m beyond the relocation plot boundary, and 3 individuals did not leave the relocation plot in the 46 days we monitored them (Figure 7).

Translocation and release of common chuckwallas on sites already containing common chuckwallas may induce competition with resident lizards for mates, food, refugia, or other resources. Though our data are limited, they demonstrate atypically large home ranges and long movements of translocated individuals. At South Mountain, male territories and female home range sizes were reported to be 0.05 ha ± 0.01 for males and 0.02 ha ± 0.01 for females (Kwiatkowski and Sullivan 2002*b*). Our mean home range sizes were 18–45 times larger. Our largest home range (3.4 ha) was recorded for an adult female and is 170 times greater than the average for females reported by Kwiatkowski and Sullivan (2002*b*). Likewise, our largest home range for a male common chuckwalla was recorded at 2.74 ha, nearly 55 times greater than the average reported for males at this site (Kwiatkowski and Sullivan 2002*b*).

Given an expectation of male territoriality among residents at the relocation site, it is unsurprising that translocated males ranged widely after release. The large home ranges for adult females, however, are in dramatic contrast to the observations of Sullivan and Sullivan (2012): they recaptured female common chuckwallas within 25 m of their original capture sites 16 years between detections in the Phoenix Mountains approximately 40 km to the north of South Mountain. Crevices used as retreats during the 1990s were still in use during their surveys in 2011. While a majority of our telemetered lizards quickly dispersed from their release locations, it is possible they established a home range off the primary site. Our home range estimates may be influenced by dispersal movements prior to establishing a home range, but by excluding initial movements we minimized this effect. Unfortunately, limiting factors such as transmitter battery life and advancing freeway construction dictated the extent to which we were able to follow the telemetered lizards. The relatively small number of locations used to calculate home range size indicates that if anything, our data underestimate the home range sizes and that the negative effects of translocation on individuals are likely even larger than our data indicate.

In other species, a period of increased movement shortly after translocation, followed by a return to more typical movement behavior in the subsequent years, has been observed (Sealy 1997, Mosillo et al. 1999, Reinert and Rupert 1999, Nussear et al. 2012). Increased activity has been documented in the mitigation translocation of other herpetofauna, including another large-bodied desert lizard of the American Southwest. Translocated Gila monsters (*Heloderma suspectum*) exhibited mean daily movements almost 5 times greater than nontranslocated individuals (Sullivan et al. 2004). For typically sedentary lizards such as common chuckwallas and Gila monsters, this increased movement incurs significant energetic and thermoregulatory costs as well as predation risks. In eastern hognose snakes (*Heterodon platirhinos*), translocated individuals survived, on average, about a third of the time of resident individuals. This was likely due to increased predation exposure, though other factors almost certainly contributed (Plummer and Mills 2000). Nevertheless, all our 15 telemetered individuals in this study were last seen alive, and there were no signs of attempted predation by the end of the study (Table 2). The high short-term survival rate of the telemetered common chuckwallas was encouraging, but low resighting rates, universal weight loss, atypically large home ranges, and atypically long movements of individuals indicate that long-term persistence of these individuals might be unlikely.

The relative success of scientific conservation-driven translocations is being used to justify the increased use of mitigation-driven translocations (Germano et al. 2015). Although a common management practice for other vertebrates, relocation is rarely attempted with reptiles, especially large lizards. Even more rarely has the success of lizard relocations been monitored. To potentially improve mitigation translocation efforts for reptiles, an onus should be placed on finding unoccupied habitat, or habitat with low occupancy, at release sites. Although it might be argued that mitigation translocation is making the best of a bad situation, the lack of knowledge about the fate of translocated individuals contributes to an ongoing perception of mitigation translocation as a preferred alternative action (Sullivan et al. 2015). Despite its intent as a positive solution to human–wildlife conflict, mitigation translocation of long-lived species with restrictive life-history characteristics can have very low success and may result in prolonged harm to translocated individuals.

Management implications

Our study showed that translocated chuckwallas move more often, farther, and have larger home ranges than is typical for the species. Our low recapture rate of translocated chuckwallas suggested that relocated animals likely did not survive long-term. Our results provided an example of follow-up on a mitigation translocation of a reptile, and they offer baseline data for other similar translocations. We conclude that mitigation translocation is a less-than-ideal conservation tool for chuckwallas.

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