TRANSLOCATION OF DUNES SAGEBRUSH LIZARDS (*SCELOPORUS ARENICOLUS*) TO UNOCCUPIED HABITAT IN CRANE COUNTY, TEXAS

FINAL REPORT

Mickey R. Parker [1], Wade A. Ryberg [2], Toby J. Hibbitts [1,2], Lee A. Fitzgerald [1]

[1] Biodiversity Research and Teaching Collections, Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX

[2] Natural Resources Institute, Texas A&M University, College Station, TX

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EXECUTIVE SUMMARY

Research that demonstrates the feasibility of establishing translocated populations of dunes sagebrush lizards is important for conservation and management of the species. This final report includes all results from a four-year research project designed to evaluate the feasibility of establishing translocated populations of dunes sagebrush lizards from relatively large source populations to unoccupied habitat in an area where the species was historically present. This research was the first and only conservation translocation for the dunes sagebrush lizard.

During Project Years 1 and 2, we translocated 76 dunes sagebrush lizards (70 adults and 6 hatchlings; 21 male and 55 female) to an unoccupied site in Crane County, TX. The site consists of suitable habitat with a historical locality where the species no longer occurs. Translocated lizards acclimated to their new surroundings in soft-release enclosures then were released. Intensive post-translocation population monitoring took place over a dense grid of traps that covered 14.7 ha. We also conducted 415 person-hours of visual encounter surveys to increase the chances of finding a dunes sagebrush lizard at the site. Behavioral observations showed the lizards exhibited normal behaviors.

During all project years we conducted 51 trapping sessions amounting to the impressive sum of 112,451 trap-days. This effort resulted in 43 captures of 29 individual dunes sagebrush lizards. Of these, 10 were translocated individuals and 19 were produced at the site. Fifteen, 25, and 3 individuals were captured in in 2016, 2017, and 2018, respectively. Unfortunately, no dunes sagebrush lizards were detected in 2019 despite additional, intensive, monitoring. Therefore, we concluded that no dunes sagebrush lizards persisted at the site in 2019.

We quantified the landscape characteristics at the translocation site and showed that habitat quality at our translocation site was highly suitable for occupancy of dunes sagebrush lizards. The site is within an area known to have been occupied by dunes sagebrush lizards. Habitat at the site has not been disturbed since at least 1996. Our quantitative measures of habitat quality, (area, size, configuration of blowouts) are consistent with these measures at occupied sites throughout the range of the dunes sagebrush lizard.

Major Findings

Despite the translocation effort failing to establish a self-sustaining population of dunes sagebrush lizards, we were able to draw meaningful conclusions that are immediately applicable to dunes sagebrush lizard translocation efforts and conservation of the species:

- We documented survival, nesting, and hatching of dunes sagebrush lizards at the translocation site.
- Translocated dunes sagebrush lizards behaved normally in soft-release enclosures.
- Intensive monitoring is necessary to detect lizards persisting in small populations.
- Reproduction occurred at the site, with 28 total lizards produced.
- A portion of hatchlings produced at the site survived to adulthood.
- Our translocation methodology was appropriate.
- Future translocations could benefit by additional experiments designed to address questions of enclosure size and number, propagule size, and movements and fates of individual dunes sagebrush lizards.

Recommendations

We also formulated recommendations, based on interpretation of results in the report:

- Future translocations should use female-biased propagules.
- Translocations should occur in the breeding season (May-June) to maximize the number of gravid females translocated.
- Large propagule size is recommended. Obtaining large numbers of individuals for propagules is a challenge. A captive breeding program may be necessary to produce propagules for future translocations.
- Monitoring translocated populations needs to be intensive and cover an area of at least 15 ha to maximize detections of lizards in small incipient populations.
- Monitoring should span at least 4 years to accurately assess translocation outcomes.
- Translocations should only occur at sites with contiguous shinnery dune habitat, with large average blowout size and large total area of blowouts. Habitat quality of release sites should be assessed prior to translocations.

- Future translocations may benefit from an experimental approach to enclosure size. For example, we do not know how larger enclosures in place for longer periods may affect translocation outcomes, or the optimal number of small enclosures in an area.

- A recovery plan for the dunes sagebrush lizard, with planned releases at known sites, should be in place before more translocations are undertaken. This is necessary to help ensure meaningful conservation benefits for the species.

- Future translocation sites need permanent legal protection from development and fragmentation. Landowner participation is a necessity and transfer of land ownership should be anticipated and planned for. Without it, translocated populations have uncertain futures.

- Multiple translocations may be necessary to establish self-sustaining populations of dunes sagebrush lizards. This should not be a trial-and-error process. Objectives should be clearly stated at the beginning of the project, and, through adaptive management, adjustments made until objectives are met.

- We recommend against augmenting existing populations. This practice carries many disadvantages and risks, and no known benefits to dunes sagebrush lizard populations. Augmentation of existing populations does not mitigate effects of fragmentation or habitat degradation, which are the known causes of population decline.

INTRODUCTION

A positive next step in conservation and management of the dunes sagebrush lizard (*Sceloporus arenicolus*) is restoring populations of this endemic and sensitive species to areas with suitable habitat where it once occurred but is now extirpated. Dunes sagebrush lizards were known to occur at one locality in Crane County, Texas, but have not been detected there since the original observation on June 19^{th}, 1970. A number of sites in Crane County represent opportunities for re-establishing populations. Herein, we report on results from a four-year research project designed to translocate dunes sagebrush lizards from relatively large populations to historical sites where the species was known to occur and where habitat conditions are still considered highly suitable.

Background and Justification

The dunes sagebrush lizard (*Sceloporus arenicolus*) is restricted to shinnery oak dune blowout formations in the Monahans Sandhills of West Texas and the Mescalero Sands of adjacent New Mexico (Fitzgerald and Painter 2009, Fitzgerald et al. 2011). An ecological specialist, it only occurs in and around sand dune blowouts (Fitzgerald et al. 1997, Hibbitts et al. 2013). Due to its habitat specificity, the dunes sagebrush lizard has very low rates of dispersal to isolated areas of habitat. Many years of mark-recapture and radio-tracking studies have never documented movements of adults more than a few hundred meters (Ryberg et al. 2016 report to Texas State Comptroller, Young et al. 2018, Walkup et al. 2019). Individuals do not traverse any other habitat type as adults or juveniles, and rarely if ever, cross roads (Leavitt and Fitzgerald 2013, Hibbitts et al. 2017). Population genetic studies across the entire range of the species showed negligible rates of migration among populations over evolutionary time scales, meaning that during periods of hundreds of years there was negligible exchange of genes among populations (Chan et al. 2009, Marko and Hart 2011). With fragmentation, which is known to isolate populations (Leavitt and Fitzgerald 2013, Walkup et al. 2017), the potential for migration is presumed to be diminished. These attributes of the species make it clear that research into translocations is needed.

Like most species, the dunes sagebrush lizard does not occur in all areas of suitable habitat. This natural pattern of presence and absence can be due to historical and unpredictable localized extinctions caused by drought, the inability of small populations in isolation to sustain themselves, habitat change, and a number of other causes. It is also possible that over the course of its evolutionary history, the species simply never colonized some areas of shinnery dunes. Without historical records, it is not possible to identify causes of extinction or know with certainty if the species ever occurred at a site.

For translocation, we selected a site in contiguous shinnery oak dunes habitat that is very near the documented historical record for the dunes sagebrush lizard at the intersection of FM 1053 and FM 1233 in Crane County, Texas. The dunes sagebrush lizard was collected there, but has never been found in the area despite many repeated searches (Fitzgerald et al. 2011, Hibbitts and Hibbitts 2015). We do not know the cause of this local extinction. Although the exact translocation site where we had access to perform the research was fragmented by roads and well pads, the habitat condition was good.

This research was the first conservation translocation for the dunes sagebrush lizard.

MATERIALS AND METHODS

TRANSLOCATION APPROACH

We used a soft-release strategy (also referred to as a delayed release), where a series of enclosures in the translocation area were constructed to hold translocated individuals in proximity to each other in their new surroundings during an acclimation period. After an acclimation period, the enclosures were opened and individuals began dispersing throughout the surrounding habitat. The soft-release strategy with enclosures was desirable, as it allowed us to contain translocated individuals while they became accustomed to new surroundings, found refugia, and established home ranges in their new habitat. Enclosures were also important for keeping males and females in close proximity. We used multiple small enclosures for two reasons; 1) to establish lizard home ranges at multiple locations at the translocation site and 2) to avoid putting the entire set of translocated individuals at risk to predators or escape in case the enclosure failed.

Steps in the translocation procedure:

1. We identified candidate sites where the species was known to occur but can no longer be found.
    a. We identified localities in Crane County, Texas near the locality where dunes sagebrush lizards were documented, but have not been detected during multiple recent surveys. By our assessment, habitat condition in the area appears to have changed very little, and we considered these areas suitable habitat for dunes sagebrush lizards.
    b. The translocation site needed to be on land where we had permission to do research, preferably on lands enrolled in the Texas Conservation Plan (TCP), a candidate conservation agreement for the dunes sagebrush lizard.
    c. Other areas with suitable habitat near the historical locality were not enrolled in the TCP and were inaccessible to researchers in this project.
2. We identified source populations where dunes sagebrush lizards could be captured for translocation without compromising the existing population.
    a. We captured lizards using a combination of pitfall trapping, noosing, and hand capture.
    b. We targeted adults for the translocation. Individuals were captured while in breeding condition and translocated during May and June 2016 and 2017. Several females that were translocated had already bred and were gravid with eggs.
    c. In 2017, we also translocated six hatchlings that were captured in late July.
3. We constructed six temporary enclosures for the translocation in 2016 and seven in 2017. Enclosures were built to surround shinnery dune hummocks and portions of dune blowouts that were good sites for dunes sagebrush lizard territories (Figures 1 - 3). A detailed description of enclosure construction is given below.
4. In 2016, we placed 4 adult females and 2 adult males into each enclosure.

5. In 2017, we placed 5 females and 1 male into each enclosure, based on analysis of male-male agonistic interactions in the enclosures in 2016.
    a. More females were placed in each enclosure to reduce male-male competition, and because males can have multiple mates, all females will breed. Based on results from behavior surveys in 2016, we reduced the number of males per enclosure from two to one in 2017. This was done to reduce fighting between the two males and to reduce the level of harassment from males toward females that had already bred and were preparing to lay eggs. One male per enclosure also allowed the males to establish territories.
6. The six hatchlings (three male and three female) were all placed in a separate enclosure in 2017.
7. Translocated lizards were monitored in the enclosures during the post-translocation period until hatchlings began to emerge in late July.
8. Monitoring of the translocated population occurred through 2019.
    a. During the project period, monitoring measured population growth, dispersal throughout the habitat, survivorship, and behavior.
        i. We constructed a large array of 597 pitfall traps to sample lizards in the habitat after the enclosure period.
        ii. We conducted visual encounter surveys at the translocation site to increase chances of detecting dunes sagebrush lizards at the site.
    b. The study was designed for four years. We considered four years the minimum period necessary to ascertain if a new population could be self-sustaining, and to document the extent of dispersal in the habitat.

Temporary Enclosures

We constructed temporary enclosures for translocated dunes sagebrush lizards using Animex® Wildlife Exclusion Fencing that was originally designed for holding desert tortoises. This fencing comes in rolls of 40” tall, heavy duty (0.084” thick), UV-resistant, post-consumer plastic. The dunes sagebrush lizard cannot successfully climb either side of the fencing. One side had a glossy finish, which created a slick surface designed to prevent almost any animal from climbing it. The top of the fencing was scored along the length of the roll, allowing it to be folded down to create a lip to prevent predators from entering the enclosure. The bottom of the fencing was also scored in order to create a lip that is then buried to prevent lizards from digging under the fence. We used 48” metal u-posts as supports for the fence material, and we attached the fencing to the posts using heavy duty, UV-resistant cable ties. We also used these cable ties to join lengths of fencing material together to create an enclosed area. To ensure these joints were not permeable to lizards, we covered them in Gorilla® tape.

We placed enclosures in the best dunes sagebrush lizard habitat in the translocation area. We selected sites containing large dune blowouts with steep slopes, ensuring that the enclosures contained shinnery oak as well as open blowout (Figure 2). We constructed six enclosures in 2016 and seven in 2017 with average areas of 67 m^2 and 85 m^2, respectively.

Figure 1. Construction of temporary enclosures 1 and 2 with Animex® fencing material.

Figure 2. Soft release enclosures at translocation site in 2016. The translocation site includes the entire area covered by the monitoring grid, which also encompassed the enclosure areas.

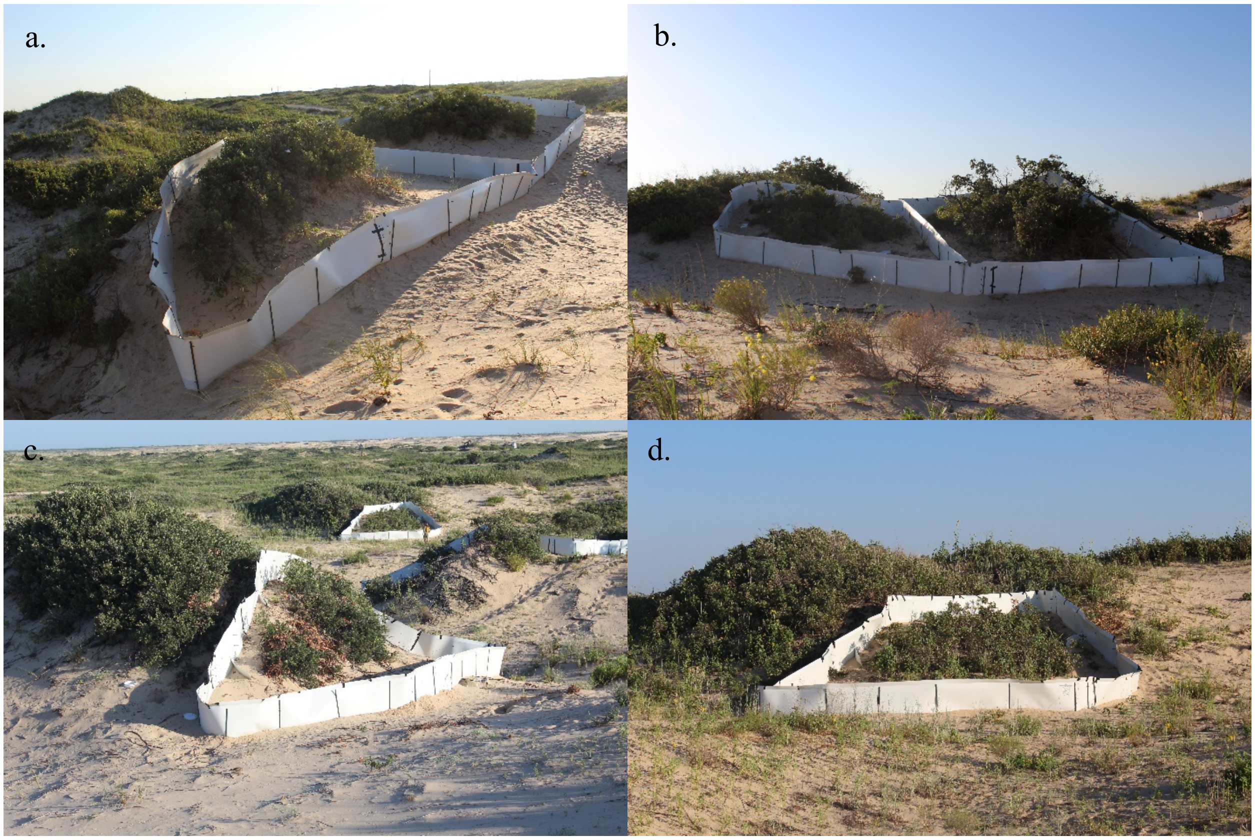

Figure 3. Soft release enclosures used to hold translocated DSL in 2016. (a) Enclosures 1 and 2. (b) Enclosures 3 and 4. (c) Enclosure 5 in foreground. (d) Enclosure 6.

Obtaining Lizards from Donor Sites

Dunes sagebrush lizards were captured at two sites in Andrews County and one site in Winkler County. The lizards for translocation were captured by hand, noosing, and in pitfall traps. We placed traps in dune blowouts at the interface of the open blowout and shinnery oak to maximize capture success. A pitfall trap consisted of a 5-gallon bucket buried flush with the substrate and a cover board propped up over the bucket opening. A few centimeters of sand at the bottom of each bucket allowed lizards to bury themselves and provided a thermal refugium. When a lizard ran under the cover board for shade, it fell into the bucket unharmed.

Once caught, dunes sagebrush lizards were measured and marked, and placed into a holding bucket in the shade. We measured mass, snout-vent length (SVL), and tail length for each lizard captured. We determined the sex of all individuals, and assessed the reproductive condition of all females. Gravid females can be identified by palpating their abdomen to feel developing eggs.

To permanently identify individuals, we toe-clipped all dunes sagebrush lizards captured for translocation. During post-translocation monitoring, described below, we also marked all lizards of other species captured at the translocation site. (The translocation site includes the entire 14.7 ha area covered by the monitoring grid, which also encompassed the enclosure areas.)

We used a marking scheme that allows up to 1,999 individuals to be marked (Figure 4). To allow for identification of individuals from a distance, we used a marker to write an identification number on the dorsum of each dunes sagebrush lizard placed in the enclosures. These numbers last a variable number of days until the lizard sheds its skin or the ink wears off.

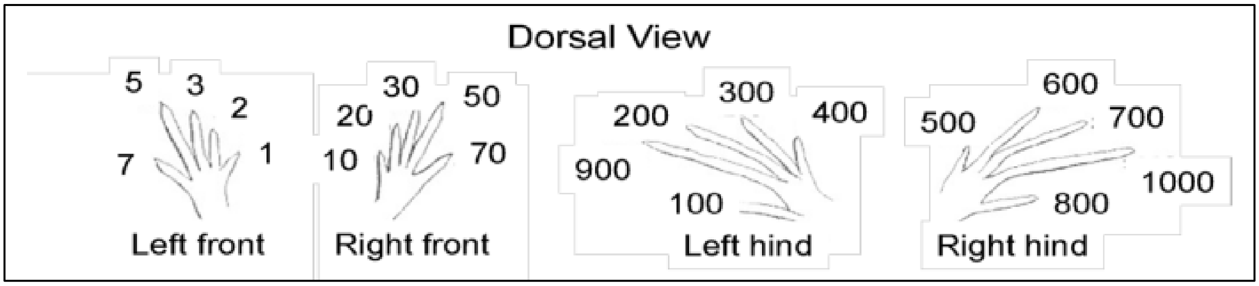

Figure 4. Marking scheme for translocated dunes sagebrush lizards and all lizards captured at the translocation site. Toes can be clipped in combination to provide unique numbered marks for up to 1,999 lizards.

Stocking the Soft Release Enclosures

In both years where we conducted translocations, dunes sagebrush lizards were transported to the translocation site within 24 hours of capture to minimize time in captivity. In Project Year 1, we began adding lizards to the enclosures on 28 May 2016, placing 2 male and 4 female DSL in each enclosure. On 29 July 2016, we removed the enclosures, releasing the lizards remaining in the enclosures. During Project Year 2, we began adding lizards to the enclosures on 23 May 2017, placing 1 male and 5 female dunes sagebrush lizards in each enclosure. We reduced the number of males per enclosure based upon results of behavioral surveys at the enclosures in 2016 (see Behavioral Surveys in Results, below). The last adult lizard was placed into its enclosure on 18 July 2017. We began capturing hatchling dunes sagebrush lizards in pitfall traps at donor sites in mid-July. We constructed an enclosure to hold hatchlings only and placed lizards in it from 16-27 July. We removed five of the adult enclosures on 28 July, one on 1 August, and the hatchling enclosure on 2 August, releasing the lizards into the broader shinnery dune landscape.

POST-TRANSLOCATION MONITORING

Enclosure Monitoring

a. Behavioral Surveys

We monitored the translocated dunes sagebrush lizards during the acclimation period by conducting behavioral surveys at the enclosures. We conducted surveys primarily during the morning and evening activity period, although we also conducted surveys during mid-day to ensure we were not missing any activity. Observers used binoculars to observe the lizards inside the enclosures, and noted their behaviors according to a set of pre-determined behavior categories (see Results, below, for categories).

b. Trapping in Enclosures

Prior to removing the enclosures, we used a combination of funnel and pitfall traps to document hatchling presence and capture individuals that may not have been observed during behavioral surveys.

Population Monitoring

a). Pitfall Trapping

We monitored dunes sagebrush lizard dispersal and population growth at the translocation site using a trapping grid of 597 pitfall traps, which extended 250 m from the enclosures or to the nearest road (Figure 5). Traps were spaced 17.5 m apart. To increase coverage of the study area, rows of traps were offset. The trapping grid covered 147,233 m^2 (14.7 ha, 36.4 acres) and extended to the roads surrounding the translocation area. In May 2018, we added the 78 pitfall traps around the perimeter of the trapping grid on the opposite side of the surrounding roads (Figure 5). Though dunes sagebrush lizards are known to avoid roads (Hibbitts et al. 2017, Young et al. 2018), translocated reptiles have been known to make atypical movements (Nowak et al. 2002, Sullivan et al. 2004). The additional traps increased the likelihood we could document any instances of erratic movements of dunes sagebrush lizards in the translocated population.

A trapping session consisted of 3–5 consecutive days of trapping. Traps were opened on the first day starting at sunrise, kept open and checked daily for the next 2–4 days, then closed starting at sunrise on the final day. Traps were closed with lids that sealed around the opening of the bucket to prevent lizards from entering the trap. Trapping sessions were shortened only due to inclement weather.

All species of lizards encountered were measured, marked, and released using the methods described above.

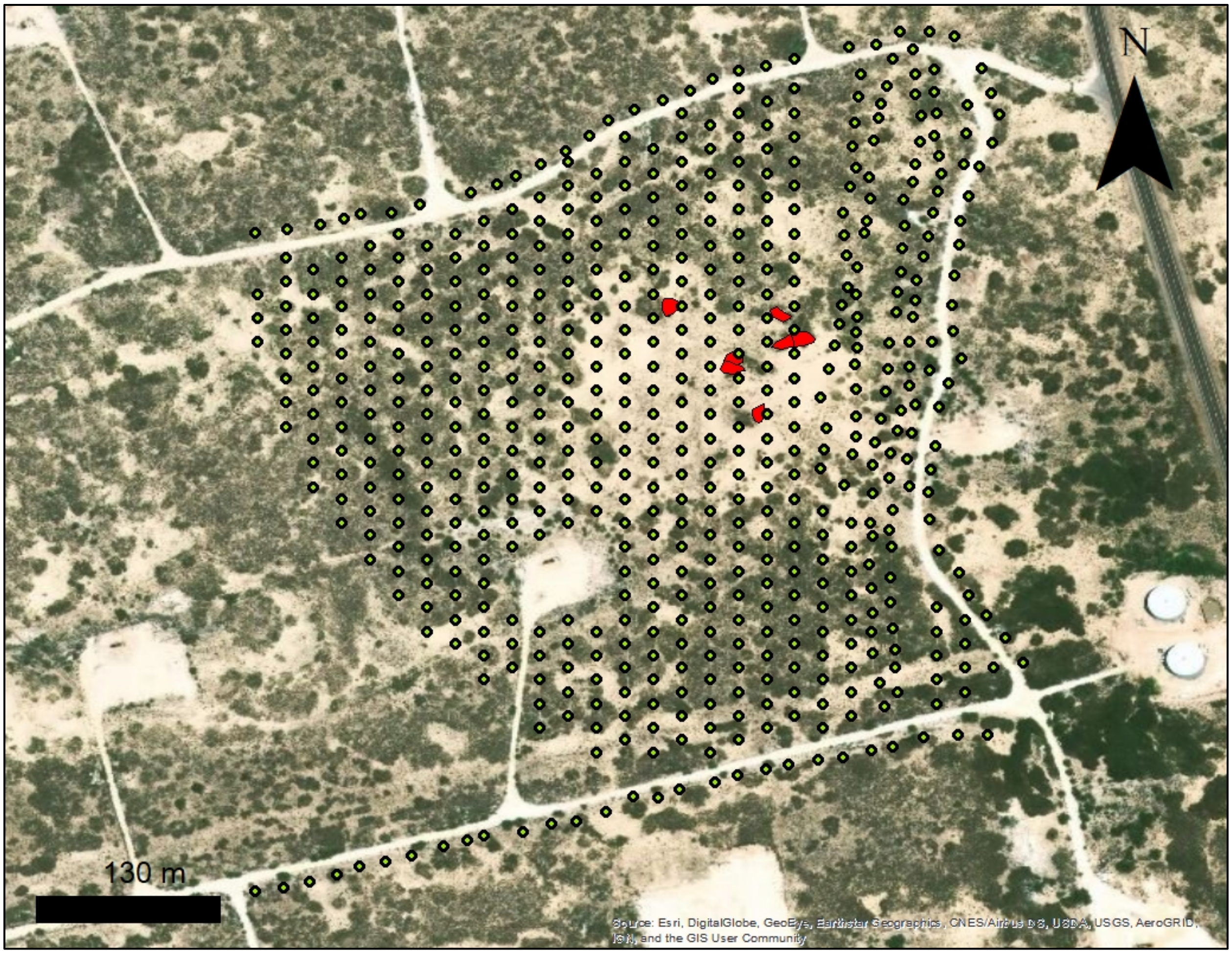

Figure 5. Location of the pitfall grid that was in place from 2016-2019 (green dots). Traps along the roadside were added in 2018. The enclosures used in 2016 and 2017 are shown as red polygons.

b). Visual Encounter Surveys

To increase detections of dunes sagebrush lizards, and gather data to compare visual surveys with trapping surveys in small populations, we began conducting visual encounter surveys at the translocation site in 2018-2019. During the 2019 field season, we also conducted visual encounter surveys in dunes sagebrush lizard habitat at several sites in Monahans Sandhills State Park, where dunes sagebrush lizards are present. These surveys allowed us to compare encounter rates in an area with a known population of dunes sagebrush lizards to encounter rates at the translocation site. During visual surveys, observers walked throughout the habitat using binoculars to scan for lizards. Observers recorded their paths on a handheld GPS unit and focused heavily on habitat with steep slopes, shinnery oak, and open blowouts. When a lizard was seen, the time was noted, the species was positively identified, and UTM coordinates were recorded. Morning surveys began between 0900-1100, and evening surveys began between 1730-1900, depending on weather conditions. Survey start times were based on activity data from behavioral surveys conducted in the temporary enclosures. From these observations we tallied the time to first observation of lizard of each species, total observed, and plotted the locations.

Data Archiving

Data collection on electronic devices carries advantages of data safety, lack of transcription errors, and efficiency. In 2016, we used the Iform Builder mobile data collection platform, which consisted of a smartphone application used in conjunction with an online database. Iform Builder allowed users to create custom data collection forms which could then be accessed in the field using a smartphone application. Because the application did not require cellular service or an internet connection in order to be able to collect data, data could be collected at all times. Once personnel were within range of cellular service or Wi-Fi, these data could be synced to the Iform Builder server. Data could then be accessed by logging in to the Iform website. Data were stored on this server and could be downloaded in Microsoft Excel spreadsheets. In 2017, costs of the Iform Builder platform skyrocketed, so we opted to use the EpiCollect5 mobile data collection platform for subsequent project years. EpiCollect5 had the same features and benefits as Iform Builder, but was completely free to use.

All personnel working on the project had the data collection application downloaded to their smartphones and synced data at least once daily. In case of smartphone failure or battery drainage, we carried notebooks and pens as a backup means for collecting data.

Analysis of Habitat Quality - Blowout Area, Size, and Configuration

Habitat quality at release sites is a crucial consideration for all translocation projects and has been shown to be positively associated with translocation success (Griffith et al. 1989, Wolf et al. 1998). As a habitat specialist, the dunes sagebrush lizard relies on large, contiguous areas of dune blowout habitat. Spatial structure of dunes sagebrush lizard populations, as well as population vital rates, are closely linked to dune blowout configuration (Ryberg et al. 2013, 2015).

We characterized blowout configuration at the translocation site by mapping their locations on a digitized landcover classification of dune blowouts derived directly from 1-m digitally rectified orthoquarterquads taken in 2004 using ArcInfo (Environmental Systems Research Institute, Redlands, CA). We clipped the perimeter of our pitfall trapping grid from this dune blowout landcover layer and calculated landscape metrics within the perimeter using Program FRAGSTATS (McGarigal et al. 2002). We calculated dune blowout area (AREA), radius of gyration (GYRATE), fractal dimension (FRAC), and Euclidean nearest neighbor (ENN), which we used to assess blowout size, extent, complexity, and isolation, respectively.

RESULTS

Translocation

In 2016 and 2017 combined, we conducted pitfall trapping and visual searches at donor sites in Andrews and Winkler counties. Capture effort amounted to 8,383 trap-days and 133 person-hours of visual searching. These efforts resulted in captures of 76 dunes sagebrush lizards (70 adults and 6 hatchlings, 21 male and 55 female) for translocation (Table 1). Of the 55 adult females translocated, 44 were classified as gravid with developing eggs.

Table 1. Origin, sex, and sizes of dunes sagebrush lizards captured for translocation. Lizards were captured for translocation during 2016-17 (project years 1 and 2).

Lizard ID	Capture Date	County of Origin	SVL (mm)	Tail Length (mm)	Mass (g)	Sex	Age Class	Gravid?
1	5/31/2016	Andrews	55	77	5.75	Female	Adult	Yes
2	5/31/2016	Andrews	54	82	4.95	Male	Adult	NA
3	5/28/2016	Andrews	55	82	5.5	Male	Adult	NA
4	6/2/2016	Andrews	52	71.5	4.6	Female	Adult	Yes
5	5/28/2016	Andrews	59	62.5	5.4	Male	Adult	NA
20	5/28/2016	Andrews	58	89	6.3	Male	Adult	NA
101	6/3/2016	Winkler	62	96	7.9	Male	Adult	NA
102	6/3/2016	Winkler	57	84	6.85	Female	Adult	Yes
103	6/4/2016	Andrews	55.5	84.5	7	Female	Adult	Yes
104	6/4/2016	Andrews	54	75	5.7	Female	Adult	Yes
105	6/4/2016	Andrews	51	31.5	5	Female	Adult	Yes
106	6/4/2016	Andrews	52	73	5.1	Female	Adult	Yes
107	6/4/2016	Andrews	52	78	4.6	Male	Adult	NA
108	6/4/2016	Andrews	55	59	5.9	Female	Adult	Yes
109	6/4/2016	Andrews	51	68	5	Male	Adult	NA
110	6/7/2016	Andrews	53	84	5.5	Male	Adult	NA
111	6/8/2016	Andrews	48	68	4.2	Female	Adult	Yes
112	6/8/2016	Andrews	55	78	5.4	Female	Adult	Unknown
113	6/11/2016	Andrews	56	81	5.6	Female	Adult	Yes
114	6/11/2016	Andrews	53	69	5	Female	Adult	Yes
115	6/15/2016	Andrews	54	82	5.55	Female	Adult	Yes
116	6/16/2016	Andrews	51.5	55	5.3	Female	Adult	Yes
117	6/16/2016	Andrews	52.5	79	6.1	Female	Adult	Yes
118	6/16/2016	Andrews	57	52	6.9	Female	Adult	Yes
119	6/18/2016	Winkler	53	84	5	Male	Adult	NA
120	6/20/2016	Andrews	55	81	6.35	Female	Adult	Yes
121	6/20/2016	Winkler	49	82	4.2	Male	Adult	NA
122	6/20/2016	Winkler	51	84	4.9	Male	Adult	NA

123	6/21/2016	Winkler	52	76	4.4	Female	Adult	Yes
124	6/23/2016	Winkler	51.5	80	5.05	Female	Adult	No
125	6/23/2016	Winkler	54	83	5.9	Female	Adult	Yes
126	6/25/2016	Winkler	55	82	6.4	Female	Adult	Yes
127	7/1/2016	Winkler	52.5	74.5	4.9	Female	Adult	Yes
128	7/2/2016	Winkler	50	41	3.7	Female	Adult	No
313	5/31/2016	Andrews	56	60	6.2	Female	Adult	Yes
324	5/28/2016	Andrews	60	88	7.7	Male	Adult	NA
147	5/23/2017	Andrews	45	69	4.5	Female	Adult	No
148	5/23/2017	Andrews	54.5	90	6.9	Male	Adult	NA
149	5/23/2017	Andrews	49	56	6	Female	Adult	Yes
151	5/23/2017	Andrews	57.5	89	6.35	Male	Adult	NA
152	5/27/2017	Andrews	58	75	6.3	Female	Adult	No
153	5/30/2017	Andrews	58	74	6	Female	Adult	Yes
154	5/27/2017	Andrews	57	82	5.1	Male	Adult	NA
155	5/27/2017	Andrews	55	61.5	5	Male	Adult	NA
156	5/27/2017	Winkler	57	75	5.6	Female	Adult	No
157	5/28/2017	Winkler	56.5	82	5.6	Female	Adult	No
158	5/28/2017	Winkler	48	73	3.65	Female	Adult	No
159	5/28/2017	Winkler	48	69	3.7	Female	Adult	No
160	5/28/2017	Winkler	52.5	80	4.55	Female	Adult	No
161	5/29/2017	Winkler	48	70	3.95	Female	Adult	No
162	5/28/2017	Andrews	56	77	6	Female	Adult	Yes
163	5/30/2017	Winkler	52	61	4.45	Female	Adult	No
164	6/2/2017	Winkler	53	73	3.9	Female	Adult	No
165	6/2/2017	Winkler	51	73	3.55	Female	Adult	No
166	6/4/2017	Andrews	55	43	5.75	Female	Adult	Yes
167	6/6/2017	Winkler	49	71	4.5	Female	Adult	No
168	6/12/2017	Andrews	54	67.5	5.8	Female	Adult	Yes
169	6/12/2017	Winkler	51	82	4.75	Female	Adult	Yes
170	6/13/2017	Andrews	52	68	4.45	Female	Adult	Yes
171	6/14/2017	Winkler	50	71	4.2	Female	Adult	Yes
172	6/15/2017	Andrews	59.5	70	6.45	Female	Adult	Yes
173	6/17/2017	Winkler	-	-	-	Female	Adult	Yes
174	6/18/2017	Andrews	55	77	4.75	Female	Adult	Yes
175	6/19/2017	Andrews	58	63	6	Female	Adult	Yes
176	6/21/2017	Winkler	52	79	-	Female	Adult	Unknown
177	6/22/2017	Andrews	55	92	9.4	Male	Adult	NA
178	6/24/2017	Winkler	49.5	38.5	4	Female	Adult	Yes
179	7/10/2017	Andrews	60	50	5	Female	Adult	No
180	7/16/2017	Andrews	28	40	0.65	Female	Hatchling	NA

181	7/18/2017	Andrews	53	69	4.25	Female	Adult	Unknown
184	7/21/2017	Andrews	27	34	0.45	Female	Hatchling	NA
187	7/24/2017	Winkler	26	36	0.45	Male	Hatchling	NA
189	7/27/2017	Andrews	25	34	0.5	Female	Hatchling	NA
190	7/27/2017	Andrews	28	38	0.5	Male	Hatchling	NA
191	7/27/2017	Winkler	26	36	0.45	Male	Hatchling	NA
522	5/27/2017	Andrews	59	91	6.25	Male	Adult	NA

Behavior

During 2016 and 2017, we collected data on dunes sagebrush lizard behavior in the enclosures. The total time spent observing lizard behavior was 498.7 person-hours. Observers recorded 8,864.5 minutes of lizard behaviors. Lizards exhibited a normal suite of behaviors in the enclosures that are compiled in Figure 6. We often observed them foraging, eating, basking, and interacting with conspecifics. Only 1.1% of all observations included lizards attempting to climb the enclosure barrier. Activity in the enclosures was lower in 2017 than in 2016, with 7.8 minutes of lizard behaviors observed per survey-hour in 2017 compared to 23.5 minutes per survey-hour in 2016.

We did not observe any dunes sagebrush lizards in Enclosure 4 after 16 June 2017, and it is possible predation occurred in that enclosure after this date. Therefore, we presume some or all of these individuals died from unknown causes, including predation. It is unlikely all six individuals escaped, as we checked the integrity of every enclosure daily and the enclosure was never breached. We did not observe any predation attempts in the enclosures in either 2016 or 2017. Avian predators, such as loggerhead shrikes (*Lanius ludovicianus*) and roadrunners (*Geococcyx californianus*), were observed at the site though no predation attempts were observed. A dead loggerhead shrike was found in an enclosure; its gut was empty.

We observed a number of interesting interactions between translocated dunes sagebrush lizards in the enclosures. In 2016, we often observed males displaying and chasing one another, and it appeared that one male in each enclosure became the dominant male. By the end of the enclosure period, we only observed one male per enclosure; the second male was either hiding or died (see Table 2). In 2017, we reduced the number of males to eliminate fighting between the two males and to reduce the level of harassment from males toward females that had already bred and were preparing to lay eggs.

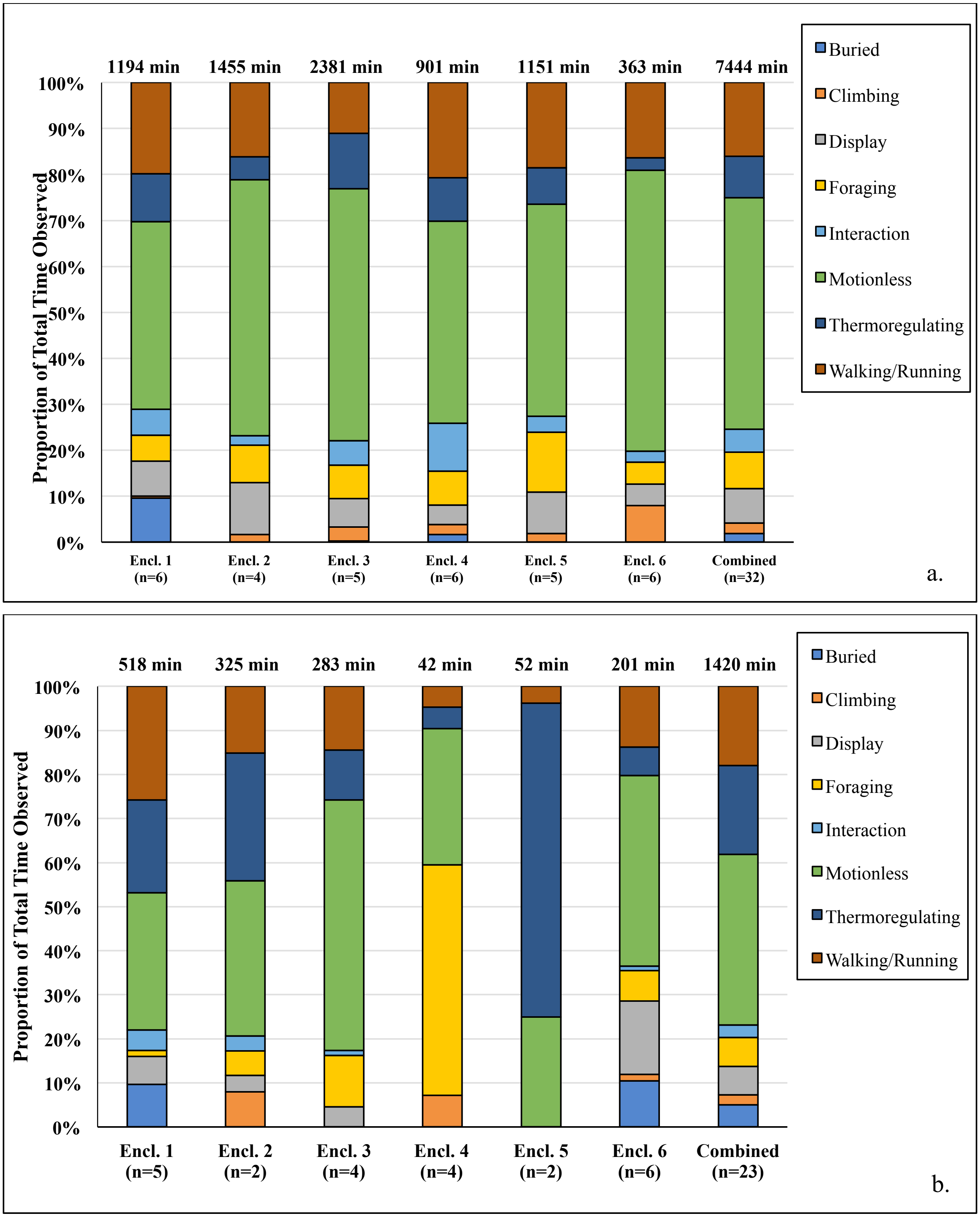

Figure 6. Proportion of dunes sagebrush lizard behaviors observed in soft release enclosures based on total number of minutes lizards were observed in each enclosure in a). 2016 and b). 2017.

Table 2. Observation dates of translocated DSL in the temporary enclosures and whether each was trapped prior to release.

Lizard ID	Date Translocated	Date Last Observed	Trapped in Enclosure?
001	5/31/2016	7/19/2016	No
002	5/31/2016	7/6/2016	No
003	5/28/2016	6/15/2016	No
004	6/2/2016	6/27/2016	No
005	5/28/2016	6/30/2016	No
020	5/28/2016	6/1/2016	No
101	6/4/2016	7/19/2016	Yes
102	6/4/2016	7/8/2016	No
103	6/4/2016	7/20/2016	Yes
104	6/4/2016	7/19/2016	Yes
105	6/4/2016	7/23/2016	Yes
106	6/4/2016	6/15/2016	No
107	6/4/2016	7/23/2016	Yes
108	6/4/2016	6/30/2016	No
109	6/5/2016	6/9/2016	No
110	6/7/2016	6/24/2016	No
111	6/8/2016	6/23/2016	No
112	6/8/2016	6/28/2016	No
113	6/11/2016	7/23/2016	Yes
114	6/11/2016	7/23/2016	Yes
115	6/15/2016	6/28/2016	No
116	6/16/2016	-	No
117	6/16/2016	6/16/2016	No
118	6/16/2016	6/25/2016	No
119	6/18/2016	7/23/2016	Yes
120	6/20/2016	7/13/2016	No
121	6/20/2016	7/3/2016	Yes
122	6/20/2016	6/22/2016	No
123	6/21/2016	-	No
124	6/23/2016	7/17/2016	Yes
125	6/23/2016	7/20/2016	Yes
126	6/25/2016	7/3/2016	No
127	7/2/2016	7/3/2016	No
128	7/3/2016	7/3/2016	No
313	5/31/2016	7/9/2016	Yes
324	5/28/2016	7/23/2016	Yes
147	5/23/2017	6/9/2017	No
148	5/23/2017	7/8/2017	No
149	5/23/2017	-	No

151	5/23/2017	6/10/2017	Yes
152	5/27/2017	7/2/2017	No
154	5/27/2017	5/30/2017	No
155	5/27/2017	7/8/2017	Yes
156	5/27/2017	6/13/2017	No
522	5/27/2017	6/13/2017	No
157	5/28/2017	7/12/2017	Yes
158	5/28/2017	-	No
159	5/28/2017	-	No
160	5/28/2017	-	No
162	5/28/2017	-	No
161	5/29/2017	-	No
153	5/30/2017	6/27/2017	No
163	5/31/2017	7/2/2017	Yes
164	6/2/2017	-	No
165	6/2/2017	6/2/2017	No
166	6/4/2017	6/11/2017	No
167	6/6/2017	-	No
168	6/12/2017	-	No
169	6/13/2017	6/16/2017	No
170	6/13/2017	-	No
171	6/15/2017	-	No
172	6/15/2017	7/4/2017	Yes
173	6/17/2017	7/13/2017	No
174	6/18/2017	6/29/2017	Yes
175	6/19/2017	7/9/2017	Yes
176	6/22/2017	7/5/2017	Yes
177	6/23/2017	6/30/2017	No
178	6/24/2017	-	No
179	7/10/2017	7/31/2017	Yes
181	7/18/2017	-	No

Population Monitoring

Prior to removing the enclosures in 2016 and 2017, we set traps inside them to attempt to capture adults for examination, to detect individuals not observed during behavioral surveys, and to capture neonates that hatched inside enclosures. Even in small enclosures 100% trapping success cannot be achieved (Fitzgerald et al. 2015). In 2016, we recaptured 13 translocated adults (36.1% of total translocated lizards) and captured nine hatchlings that were produced in the enclosures. In 2017, we recaptured nine adults (26.5% of translocated adults) and captured three hatchlings. Not all hatchlings produced by females in the enclosures were captured prior to breaching the enclosures, as evidenced by captures of free-living hatchlings in the trapping grid post-translocation in 2016 and 2017.

During all four years of the project combined, we conducted 51 trapping sessions at the translocation site during March to October (Table 3). Taken together, this effort amounted to the impressive sum of 112,451 trap-days. Over the four-year study, this effort yielded 43 captures of 29 individual dunes sagebrush lizards (10 translocated individuals, 19 individuals produced at the site, Table 4). The location of every dunes sagebrush lizard captured in pitfall traps at the translocation site in all four field seasons is plotted in Figure 7.

Table 3. Dates of all pitfall trapping sessions conducted at the translocation site and number of lizard captures per session in Project Years 1-4.

Trap Session	Year	Start Date	End Date	Lizard Captures-All Species	DSL Captures
1	2016	9-Aug	13-Aug	76	6
2	2016	21-Aug	26-Aug	116	5
3	2016	3-Sep	7-Sep	113	3
4	2016	16-Sep	20-Sep	97	1
5	2016	21-Oct	25-Oct	107	0
6	2017	21-Apr	25-Apr	86	0
7	2017	10-May	14-May	104	0
8	2017	24-May	28-May	47	1
9	2017	8-Jun	12-Jun	31	1
10	2017	22-Jun	26-Jun	48	1
11	2017	6-Jul	10-Jul	41	0
12	2017	20-Jul	24-Jul	55	1
13	2017	3-Aug	8-Aug	79	2
14	2017	13-Aug	18-Aug	63	4
15	2017	22-Aug	26-Aug	61	4
16	2017	31-Aug	5-Sep	55	3
17	2017	11-Sep	16-Sep	54	3
18	2017	23-Sep	24-Sep	7	2
19	2017	14-Oct	18-Oct	61	3
20	2018	23-Mar	26-Mar	51	0
21	2018	27-Apr	30-Apr	38	1
22	2018	12-May	16-May	59	0
23	2018	22-May	26-May	62	1
24	2018	31-May	4-Jun	57	0
25	2018	9-Jun	13-Jun	56	0
26	2018	18-Jun	22-Jun	45	1
27	2018	27-Jun	1-Jul	49	0
28	2018	6-Jul	10-Jul	45	0
29	2018	15-Jul	19-Jul	57	0
30	2018	24-Jul	28-Jul	76	0
31	2018	2-Aug	6-Aug	74	0

32	2018	13-Aug	17-Aug	61	0
33	2018	21-Aug	25-Aug	93	0
34	2018	30-Aug	2-Sep	60	0
35	2018	17-Sep	21-Sep	61	0
36	2019	29-Mar	1-Apr	55	0
37	2019	19-Apr	22-Apr	65	0
38	2019	7-May	11-May	60	0
39	2019	15-May	19-May	58	0
40	2019	24-May	28-May	42	0
41	2019	2-Jun	6-Jun	52	0
42	2019	12-Jun	16-Jun	57	0
43	2019	20-Jun	24-Jun	57	0
44	2019	29-Jun	3-Jul	40	0
45	2019	8-Jul	12-Jul	74	0
46	2019	17-Jul	21-Jul	86	0
47	2019	26-Jul	30-Jul	67	0
48	2019	4-Aug	8-Aug	75	0
49	2019	13-Aug	17-Aug	80	0
50	2019	24-Aug	28-Aug	133	0
51	2019	31-Aug	4-Sep	88	0
Total				**3334**	**43**

Table 4. All dunes sagebrush lizards captured during pitfall trapping sessions at the translocation site in 2016-2018. None were captured in 2019.

Date of First Capture	Lizard ID	Age Class	Sex	Captures	Years Captured	Origin
8/11/2016	103	Adult	Female	1	2016	Translocated in 2016
8/11/2016	124	Adult	Female	2	2016	Translocated in 2016
8/11/2016	138	Hatchling	Female	1	2016	Hatched at site in 2016
8/12/2016	139	Hatchling	Male	1	2016	Hatched at site in 2016
8/12/2016	140	Hatchling	Female	1	2016	Hatched at site in 2016
8/12/2016	141	Hatchling	Male	1	2016	Hatched at site in 2016
8/22/2016	135	Hatchling	Female	1	2016	Hatched at site in 2016
8/22/2016	142	Hatchling	Male	1	2016	Hatched at site in 2016
8/22/2016	143	Hatchling	Female	2	2016/2017	Hatched at site in 2016
8/26/2016	144	Hatchling	Unknown	1	2016	Hatched at site in 2016
9/4/2016	145	Hatchling	Unknown	1	2016	Hatched at site in 2016
9/4/2016	146	Hatchling	Female	2	2016/2017	Hatched at site in 2016
9/6/2016	324	Adult	Male	1	2016	Translocated in 2016
9/16/2016	150	Hatchling	Female	1	2016	Hatched at site in 2016
6/8/2017	106	Adult	Female	1	2017	Translocated in 2016
7/24/2017	185	Hatchling	Male	2	2017	Hatched at site in 2017
8/5/2017	172	Adult	Female	1	2017	Translocated in 2017
8/7/2017	174	Adult	Female	2	2017	Translocated in 2017
8/14/2017	189	Hatchling	Female	2	2017	Translocated in 2017
8/16/2017	182	Hatchling	Female	1	2017	Hatched at site in 2017
8/17/2017	187	Hatchling	Male	5	2017	Translocated in 2017
8/25/2017	192	Hatchling	Female	1	2017	Hatched at site in 2017
9/2/2017	193	Hatchling	Female	4	2017	Hatched at site in 2017
9/4/2017	194	Hatchling	Male	1	2017	Hatched at site in 2017
9/15/2017	183	Hatchling	Male	1	2017	Hatched at site in 2017
9/24/2017	151	Adult	Male	1	2017	Translocated in 2017
10/15/2017	195	Hatchling	Male	2	2017/2018	Hatched at site in 2017
5/28/2018	196	Adult	Male	1	2018	Hatched at site
6/20/2018	191	Hatchling	Male	1	2018	Translocated in 2017

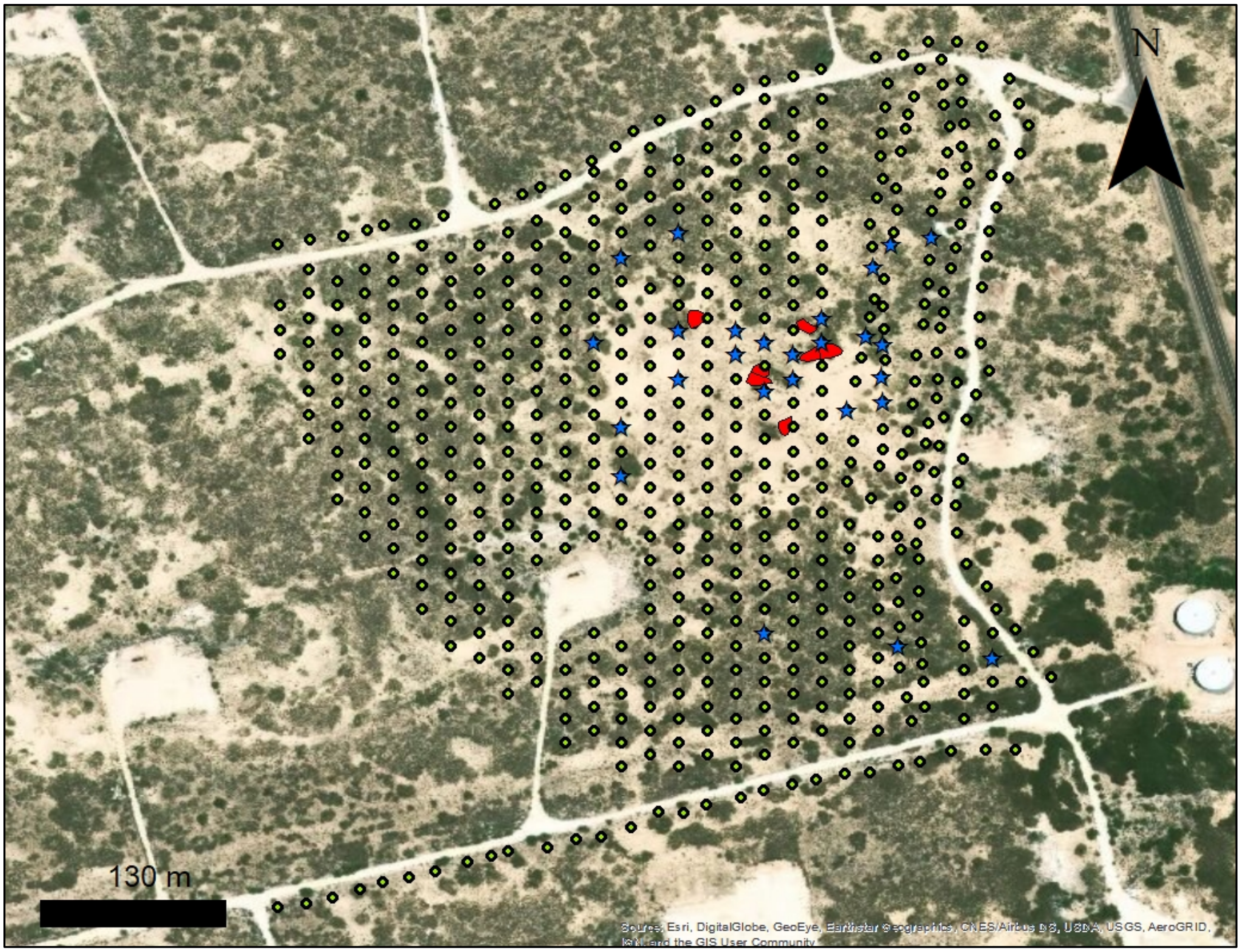

Figure 7. Map of the pitfall array showing all dunes sagebrush lizard captures in all project years (2016-2019). Green dots = pitfall traps, red polygons = temporary enclosures, blue stars = dunes sagebrush lizard capture locations. More than one recapture occurred at a single trap location in most instances, indicating dunes sagebrush lizards were establishing localized home ranges.

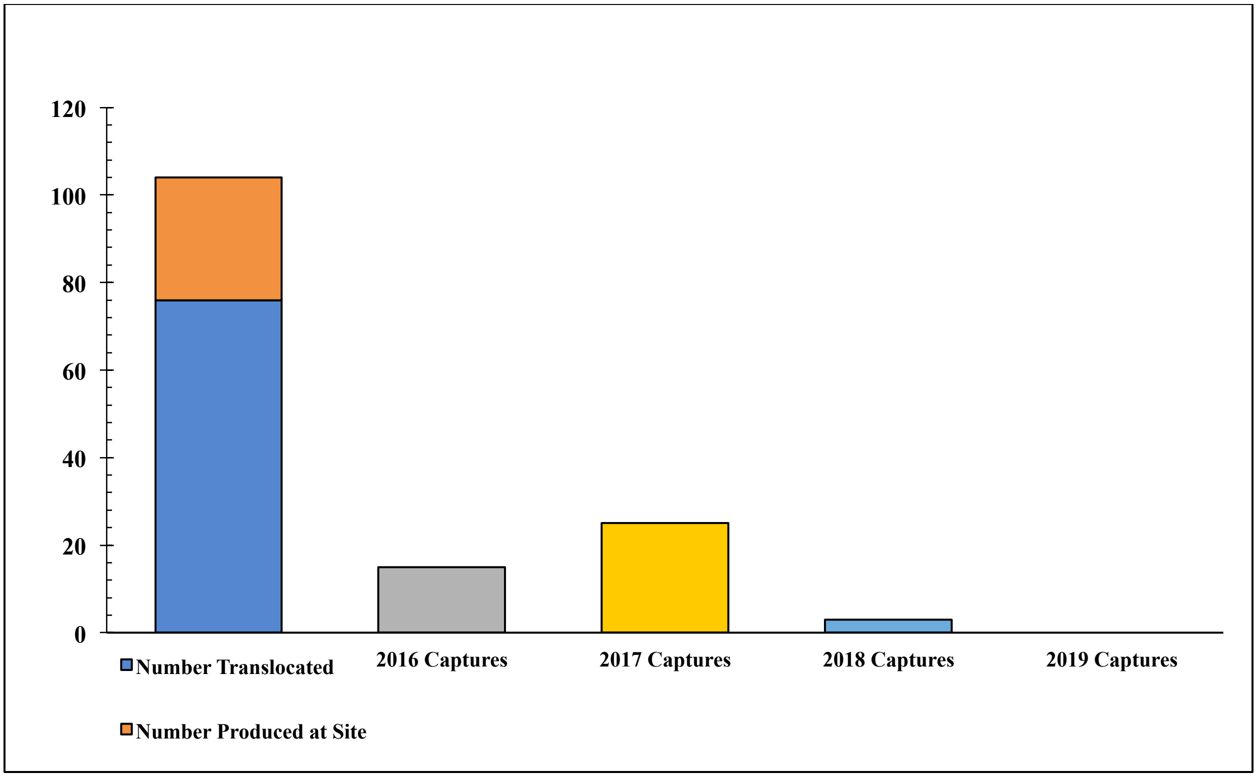

Figure 8. Number of dunes sagebrush lizard captures at the translocation site by year, as well as numbers of lizards translocated to the site and produced at the site.

In addition to dunes sagebrush lizards, a total of 1914 individuals (1377 recaptures) of other lizards comprising three species were captured, measured, marked, and released (Table 5). The only other lizard species present at the translocation site were marbled whiptails (*Aspidoscelis marmoratus*), side-blotched lizards (*Uta stansburiana*), and Texas horned lizards (*Phrynosoma cornutum)*.

Table 5. Other lizard species captured at the translocation site from 2016-2019.

Species	Individuals	Recaptures	Trap-days/Capture
Aspidoscelis marmoratus	376	374	149.9
Phrynosoma cornutum	16	8	4685.5
Uta stansburiana	1522	995	44.7
TOTAL lizards	1914	1377	34.2

To compare visual encounter surveys to our trapping data, we conducted 415 person-hours of visual encounter surveys at the translocation site from 2018-2019. This is a large visual survey effort for one site. For example, most visual surveys for dunes sagebrush lizards at a site are carried out within two to four person-hours (Fitzgerald et al, 1997, Fitzgerald et al. 2011). Analysis of our visual survey data from the translocation site can help inform the science on the efficacy of visual surveys in very small populations.

In 2018, we conducted 271 person-hours of visual encounter surveys at the translocation site and 144 person-hours of visual surveys in 2019. This effort resulted in one observation of one adult female dunes sagebrush lizard in 2018. By comparison, the trapping effort in 2018 resulted in three recaptures. The observed female was located in the same shinnery oak/dune blowout as one of the soft release enclosures. This individual probably was gravid with eggs. She had the yellow and orange coloration typical of females that have mated, and her abdomen was distended. We did observe that her toes had been clipped, indicating that she had been captured previously, but we could not positively confirm her ID number. In 2019, no dunes sagebrush lizards were observed either by trapping or visual surveys.

We also conducted 99.3 person-hours of surveys in 2019 to compare encounter rates between Monahans Sandhills State Park and the translocation site. We found no significant difference in time to first encounter of lizards between these study sites ($t = 1.5$, $df = 116$, $p = 0.1$). However, the number of lizards of all species observed at the park per unit effort of visual surveys was significantly higher than at the translocation site ($t = 7.3$, $df = 125$, $p < 0.01$). Table 6 shows the number of lizards detected at each site in 2018 and 2019.

Table 6. Number of lizard observations and person-hours per observation at the translocation site and Monahans Sandhills State Park during visual encounter surveys in 2018 and 2019. ASMA = *Aspidoscelis marmoratus*, SCAR = *Sceloporus arenicolus*, UTST = *Uta stansburiana*.

	Translocation Site 2018		Translocation Site 2019		Monahans Sandhills SP 2019	
Species	Observations	Hours/Obs.	Observations	Hours/Obs.	Observations	Hours/Obs.
ASMA	8	33.9	6	24.0	55	1.8
SCAR	1	271.1	0	-	4	24.8
UTST	247	1.1	70	2.1	117	0.8
No ID	31	8.7	4	36.0	16	6.2
Total	287	0.9	80	1.8	192	0.5

Reproduction, Growth, and Dispersal

Results from trapping within the soft release enclosures and on the pitfall trapping grid show that 28 individual dunes sagebrush lizards were produced at the site in the first three years of the project. Additionally, we detected one gravid female during visual encounter surveys.

Captures of translocated individuals and hatchlings produced in enclosures provided data on dispersal from enclosures. Considering that recapture locations indicate dispersal, adults dispersed, on average, 23.4 ± 22.8m from enclosures (n = 6, range = 1.2 – 59.4), while hatchlings dispersed 60.7 ± 58.6 m from enclosures (n = 15, range = 1.2 – 200.1)

Multiple recaptures of hatchlings provided data on growth and movements. Hatchlings with multiple recaptures grew 0.15 ± 0.07mm SVL per day (n = 9, range = 0.04–0.24). Hatchlings gained 0.02 ± .01 g per day (n = 9, range = 0.004–0.04), with one individual doubling in mass between first and last captures (40 days). All but one hatchling captured multiple times in 2017 were found in the same trap at every capture, indicating that they probably were establishing stable home ranges. One individual, a male hatchling, was captured four times in the same trap, then was captured in another trap 196m (214 yards) away. Additionally, three individuals were captured in pitfall traps as hatchlings in one year, then captured the next year as adults. One of these individuals moved 71.1 m between recaptures, and another moved 55.5 m. A third individual was captured in the same trap as a hatchling and as an adult.

Habitat

Landscape metrics for blowouts at the translocation site are listed in Table 7. Blowouts comprised 36% (5.3 ha) of the total area of the translocation site. While this is a large percentage of the site, only a few large blowouts contributed to this percentage. Variation in blowout size explained the variation in extent of blowout (radius of gyration, GYRATE), which is to be expected as this metric is dependent on patch size (area). Blowout complexity measured by fractal dimension has been shown to correlate strongly with population dynamics of dunes sagebrush lizards (Ryberg et al. 2015). The fractal dimension (FRAC) of the blowout layer at the translocation site varied as well, with blowouts at the site ranging from simple Euclidean shapes (i.e., FRAC = 1) to highly complex shapes (i.e., FRAC = 2). Blowouts were not isolated at the site, with a mean Euclidean distance between blowouts of 3.4 m ± 1.8.

Taken together, these metrics show that the translocation site was characterized by the presence of a few large blowouts with wide extents interspersed with several smaller, more compact blowouts. Blowouts were mostly regularly-shaped (mean FRAC = 1.2 ± 0.2) and were not isolated from one another.

Table 7. Landscape metrics from FRAGSTATS describing blowout size, shape, extent, complexity, and isolation at the translocation site. AREA = area, GYRATE = radius of gyration, FRAC = fractal dimension, ENN = Euclidean nearest neighbor.

Metric	Range	Median	Mean ± SD
Blowout Size (m^2)	1.0 – 31,260.0	2.0	73.5 ± 1172.9
GYRATE (m)	0.5 – 82.8	0.5	1.6 ± 4.0
FRAC (no units)	1.0 – 2.0	1.2	1.2 ± 0.2
ENN (m)	2.0 – 13.9	2.8	3.4 ± 1.8

DISCUSSION AND CONCLUSIONS

This report describes in detail the first conservation translocation for the dunes sagebrush lizard (*Sceloporus arenicolus*). After four years of fieldwork, our results demonstrated that dunes sagebrush lizards lived and reproduced at the translocation site in small numbers, but by the fourth year the species could no longer be detected at the site. Therefore, we conclude that the translocation site is no longer occupied by dunes sagebrush lizards. Though the translocation was not successful in establishing a new population at the site, the results serve to guide future conservation translocations of dunes sagebrush lizards.

It has long been recognized that the results of unsuccessful translocations are worthy of publication, as they can be used in refining translocation methodology (Dodd and Seigel 1991, Fischer and Lindenmayer 2000). This was demonstrated in a recent paper by Watkins et al. (2018), who reported details of an unsuccessful translocation of Tammar wallabies in Kalbarri National Park, Australia. They identified several factors that likely contributed to this, including timing of release, predation by non-native foxes, and social structure of translocated individuals.

Though their pre-defined success criteria were not met, they gained valuable information that can be used to improve future translocations for the species.

Behavior

Our extensive monitoring of dunes sagebrush lizard behavior showed they behaved normally and nested successfully in temporary enclosures where they acclimated to their new surroundings. A positive outcome of the study was confirmation of successful nesting and hatching of neonates at the translocation site. We identified a total of 28 dunes sagebrush lizards that were produced at the site, both in enclosures and after they were freed from the enclosures. This success is attributed to our strategy of capturing and translocating females that had either already mated or were gravid with eggs. Using gravid females allowed us to quickly prove that habitat at the translocation site was suitable for nesting of dunes sagebrush lizards. Furthermore, the production of hatchlings at the translocation site during the first year of the project served to jump-start growth of the new population. Translocation of juveniles or non-gravid adults would require the propagules to overwinter before females would mate, nest, and produce offspring during their second year at the translocation site. Our approach allowed the population to begin growing during the first translocation season. Translocating more females than males (55 females and 21 males) also set the stage for rapid population growth. Translocation of female-biased sets of propagules was a key factor in the successful translocation of the St. Croix ground lizard (Fitzgerald et al. 2015) and was also suggested for translocations of desert tortoises (Burke 1991).

Monitoring

Calls for intensive, long-term monitoring are standard in reintroduction science (Griffith et al. 1989, Dodd and Seigel 1991, Fischer and Lindenmayer 2000, Germano and Bishop 2009). Compared to any study we are aware of, our level of trapping effort and visual survey efforts was very high and probably exceeded the most intensive monitoring efforts conducted for lizards in the world (McDiarmid et al. 2012). The trapping grid covered an area larger than 100% of the documented movements of dunes sagebrush lizards in previous “super-grid” mark-recapture studies and radio-tracking studies (Ryberg et al. 2016 report to Texas State Comptroller, Young et al. 2018, Walkup et al. 2019). The super-grids sampled 13.69 ha with 324 traps; our monitoring grid covered 14.7 ha with 597 traps. These sampling areas were large enough to contain hundreds of overlapping dunes sagebrush lizard home ranges (Walkup et al. 2019). This intensive level of monitoring was necessary to detect lizards that could be persisting as singletons or in small populations at the translocation site. With such a large pitfall trapping effort, we were able to document overwinter survival of one translocated adult, one adult translocated as a hatchling, and three adults that hatched at the site. These individuals may have been missed without our intensive sampling and high density of traps. Multiple captures of hatchlings in the same traps indicates these individuals were establishing home ranges, with the exception of one individual that dispersed 196 meters. Recaptures of three adult lizards that were first captured as hatchlings indicate that lizards were not regularly dispersing long distances. One of these individuals moved 71.1 meters between recaptures, and another moved 55.5 meters; the third individual was captured in the same trap as hatchling and as an adult. Pitfall trapping and visual survey efforts also allowed us to document reproduction at the site, resulting in observations of gravid females and unmarked individuals in 2017 and 2018.

Our intensive visual encounter surveys spanning many days throughout the season demonstrated that an enormous effort at visual surveys may be required to detect individuals in incipient or critically small populations. However, the visual surveys did yield one observation of one female. This was the only observation of that female; it was never captured in a pitfall trap during that season. Thus, visual encounter surveys work, but much survey effort may be required to have confidence that a population is approaching zero in size, as evidenced by the high number of person-hours to observe one dunes sagebrush lizard at the translocation site in 2018 (see Table 6)

Critical lessons learned from post-translocation monitoring were that very large trapping grids, with high density of traps, are necessary to detect presence and movements of translocated individuals and dispersal of recruits at the translocation site. Though visual encounter surveys are appropriate for range-wide occupancy studies, visual surveys probably would not be sufficient for monitoring incipient populations following translocations.

Habitat Quality

Reviews of translocation case studies indicate that habitat quality at the translocation site is a primary determinant of success (Griffith et al. 1989, Dodd and Seigel 1991, Germano and Bishop 2009). There is every indication that habitat quality at our translocation site was highly suitable for occupancy of dunes sagebrush lizards. First, the site is within a contiguous area of shinnery oak dunes with blowouts that is known to have been occupied by dunes sagebrush lizards. We examined the specimens in the Museum of Southwestern Biology that were collected at or very near the intersection of FM 1053 and FM 1233 in 1970 to verify this important record. Second, the habitat containing the enclosure area and the pitfall trapping grid has not been disturbed during recent decades. Though this entire area of dunes sagebrush lizard habitat is fragmented by roads dating back at least 30 years, examination of aerial views of the site in Google Earth from 1996 to 2018 showed the area has not been further fragmented. The number of well pads in this section did increase from 12 to 25 between 1996 and 2013; however, this activity occurred primarily in the southern and western portions of the section. The translocation site was located in the northeast corner of the section and has been untouched since at least 1996. Finally, our quantitative measures of habitat quality, specifically the total area of blowouts, blowout size, and landscape metrics of blowout configuration are consistent with these measures at occupied sites throughout the range of the dunes sagebrush lizard. Smolensky and Fitzgerald (2011) showed the total area of blowouts and average size of blowouts were positively correlated, and good indicators of habitat quality at sites throughout the range of the dunes sagebrush lizard. Blowouts are the emergent landform in the shinnery oak sand dune landscape that are a critical feature of the habitat for the dunes sagebrush lizard. Dunes sagebrush lizards prefer relatively large blowouts (Fitzgerald et al. 1997), so average size of blowout in an area is a good measure of habitat quality. Landscape metrics at the translocation site indicated the habitat quality was characteristic of good quality dunes sagebrush lizard habitat, consisting of an area of shinnery oak dunes with large average size of blowouts and large total area of blowouts. Total area of blowouts at the translocation site was 36% compared to a range of 8% to 20% at 11 occupied sites studied by Smolensky and Fitzgerald (2011). Average blowout size at those eleven sites ranged from 17 m^2 to 38 m^2, whereas at the translocation site average blowout size was 73.5 m^2.

Future Translocations

Though the incipient population of dunes sagebrush lizards at the site did not persist, one failed attempt should not preclude future translocation attempts. Translocations are inherently complicated, and unsuccessful translocations are commonplace (Armstrong and Seddon 2008, Germano and Bishop 2009, Germano et al. 2014). The *IUCN Guidelines for Reintroductions and Other Conservation Translocations* (IUCN/SSP 2013) describes translocations as "a cyclical process of implementation, monitoring, feedback and adjustment of both biological and non-biological aspects until goals are met or the translocation is deemed unsuccessful." For example, an endangered New Zealand bird, the hihi, became the poster child for reintroduction biology due to its successful translocation to three islands in the country. However, these successful reintroductions only occurred after three failed attempts over a number of years (Armstrong et al. 2007). Perhaps a critical lesson learned from our study is that multiple translocations of dunes sagebrush lizards may be necessary even at places where the species was known to occur and where the habitat is perceived as high in quality.

Though our results are clearly important for addressing some of the uncertainty surrounding dunes sagebrush lizard translocations, we identified several lines of future research that could improve future translocations for this imperiled species.

An important line of research for future translocation efforts of dunes sagebrush lizards could address the effects of soft-release enclosures on the translocation outcome. While it is clear that soft-release enclosures are a necessity, we have no understanding of the effects of enclosure size on the translocation outcome. We used multiple, relatively small, enclosures. The lizards behaved normally, nested, and hatchlings were produced in our small enclosures. Over several years of monitoring, we continued to capture dunes sagebrush lizards in the area where we had constructed the enclosures. These observations tend to support the idea that our enclosures were appropriate for our needs. However, we have no information on the effectiveness of much larger enclosures. We suggest that if future translocations occur, the translocation design include the ability to compare effectiveness of very large enclosures to small ones.

Our intensive monitoring program was focused on the level of populations. It was designed to detect dispersal and measure dynamics of the incipient population. Previous population studies indicated neonates and young-of-year individuals dispersed from their nests to occupy interconnected blowouts. Males are territorial and females maintain stable home ranges (Ryberg et al. 2013, 2015, Walkup et al. 2019). Future translocation research could also include tracking of individual lizards to gain information on the fates of individual lizards once released. This line of research could answer questions about the movements of adults and juveniles that have been translocated to previously unoccupied habitat.

There has been a recent push within the field of reintroduction biology to incorporate principles of adaptive management into translocation designs (Converse and Armstrong 2016).

In the field of conservation translocation research and implementation, adaptive management allows for manipulations in methodology, such as those described above, to provide information for guiding decisions (Converse and Armstrong 2016). Adaptive management for translocations is not a trial-and-error process; rather, manipulations are planned to purposefully reduce uncertainty (Runge et al. 2013). Because the objective of conservation translocations is the establishment and persistence of a self-sustaining population, a translocation program designed in an adaptive management framework may not be effective if too little time is allowed for accomplishing the objectives of the program. Jones and Merton (2012) considered the time frames of most species recovery programs to be unrealistically short, as populations of most species take approximately ten times the age of first breeding to show substantial recovery.

While our project was far too short to be placed into an adaptive management framework, our results, and more importantly, questions raised by the lack of population establishment, are valuable for any future translocation programs. Though we know that lizards successfully reproduced at the site, we do not know what caused the lack of population growth and establishment. Of the 70 adult lizards translocated to the site, we only recaptured ten of those on the pitfall trapping grid. Recaptures within soft release enclosures were also low, especially in 2017. Iterations of our soft-release methodology should aim for increasing survival in the enclosures, possibly through manipulating enclosure size. Though we never observed predation in the soft release enclosures, it is possible that predation occurred. Potential homing behavior or high-post release mortality could be investigated using radiotelemetry, in addition to intensive mark-recapture and visual encounter surveys. Telemetry data could also reveal important information about the porosity of the trapping grid, meaning the extent to which individuals pass through the grid without being trapped.

Past work done by the Fitzgerald lab also presents opportunities to make predictions about the influence of habitat structure on translocated populations. For example, Ryberg et al. (2015) demonstrated the fractal dimension index of blowouts explained more than 70% of the variation in elasticities of population vital rates (i.e., stage-specific survivorship and fecundity), with different demographic stages contributing differently to population growth in areas with irregularly- or regularly-shaped blowouts. They suggested the fractal dimension of blowouts could be used to predict which demographic stages might contribute the most to population growth in a given landscape. These predictions could be tested in translocations for dunes sagebrush lizards where propagules with varying proportions of juveniles and adults were translocated to areas with specific landscape features.

The number of lizards released (i.e., propagule size) probably should be manipulated in future translocations to determine minimum and optimum propagule size for reintroductions. Reintroduced species may face resistance in assuming their previous niche, especially in diverse communities, as other species in the community may exert priority effects, or have undergone niche expansion in the absence of this competitor (Wilson 1961, MacArthur et al. 1972). However, this resistance may be overcome with large propagule size (Von Holle and Simberloff 2005). We note however that in our case overall lizard abundance was relatively low (see Table

6) compared to many sites we are familiar with, and we doubt that resistance caused by the other lizard species had much influence in this translocation.

While large propagule size has been consistently shown to be a predictor of translocation success (Griffith et al. 1989, Wolf et al. 1996, 1998), there are typically limited numbers of individuals available for conservation translocations, whether due to small source populations existing in the wild or stock from captive breeding programs. Research testing the effect of propagule size on community resistance to population establishment could help identify an optimum propagule size that maximizes chances of success and minimizes the number of individuals used. However, all of these experimental approaches described above would require a large supply of propagules that probably would need to be produced in a captive breeding facility. Captive-breeding programs should be coupled with *a priori* plans for translocations at previously identified sites. Otherwise, large investments in a captive breeding program are unlikely to produce desirable conservation outcomes, and may even drive ill-advised translocations of surplus animals into unsuitable habitat or areas where translocations are not needed.

Translocations should occur in suitable habitat that is unoccupied. If suitable habitat is occupied, other conservation measures aimed at habitat protection should be the priority. Augmenting existing populations of dunes sagebrush lizards carries many risks. Augmentation may introduce disease, break down genetic diversity among populations, disrupt established territories and home ranges, and interfere with established neighborhood dynamics that are known to occur in healthy populations. Moreover, augmentation of existing populations does not mitigate effects of fragmentation or habitat degradation, which are the known causes of population decline. Augmentation in itself does not remedy the causes of population decline.

To what extent should translocation research on the dunes sagebrush lizard be pursued at the present time? The answer to this question depends in large part on the availability, size, and permanency of appropriate translocation sites. With no legal protections for the lizard or its habitat in Texas, availability of suitable release sites is limited. Additionally, questions of land tenure come into play that merit very serious consideration for future translocations of dunes sagebrush lizards in Texas. Shifting land tenure can potentially thwart translocation successes if translocation sites and translocated populations do not have permanent legal protection. Specifically, if land ownership changes at a translocation site, any prior voluntary conservation measures may be discontinued.

Issues of land ownership and participation in the Texas Conservation Plan (TCP) carried a strong influence on this translocation effort. The history of this translocation experience provides concrete lessons in identifying translocation sites in Texas for future translocation efforts. In 2015 during project planning, one participant in the TCP provided access to the suitable habitat in Crane County that was desirable for the translocation. This limited our choice of release sites to a 5.5 km^2 area, much of which did not contain suitable habitat. Ultimately, the translocation site chosen for this project in Crane County, Texas was close to ideal in terms of habitat quality, because it was in suitable habitat contiguous with the location of an historical record, but unoccupied. The project was initiated with full support of the landowners, who were participants in the TCP. During 2018, the TCP became inoperative. Then, in March 2019, we learned by surprise that the land where the translocation took place had been sold. There were no planned communications—we proceeded normally in project year four and were approached by new landowners in the field to ask what we were doing there! The new landowners were completely unaware of the project. Fortunately, they granted permission to continue our work for the rest of the season. Subsequent conversations indicated continued permissions past 2019 were unlikely. Because the TCP was inoperative, it was somewhat moot whether or not new landowners would enroll in the TCP. An upshot of this situation is that it is unclear whether we could have continued monitoring the population in the future, even if it had become established. We feel this experience demonstrates a clear need for long-term, preferably permanent, legal protections that transfer with land ownership for translocation sites. These arrangements should be made well in advance of translocation activities.

A captive breeding program may be desirable as a source of individuals for future translocations. However, a captive breeding program should have clearly defined conservation goals and objectives (IUCN/SSC 2014). If a captive breeding program produces individuals without clearly defined end goals for properly designed translocations, there may be misguided releases of individuals. Translocations undertaken simply to release excess captive stock are frowned upon and not considered to be conservation translocations (IUCN/SSC 2013).

This project has also produced numerous broader impacts beyond the results of the translocation. This translocation has inspired other research aimed at improving outcomes of future translocations for dunes sagebrush lizards and other taxa worldwide. As part of his doctoral dissertation research, Mickey Parker, the graduate student supported on this project, is leading research to examine effects of interspecific competition and habitat fragmentation on population establishment of translocated dunes sagebrush lizards. Specifically, he is interested in the extent to which competition between the generalist common side-blotched lizard and the dunes sagebrush lizard may affect establishment of the dunes sagebrush lizard. Habitat fragmentation may exacerbate these effects. In November 2018, Mickey attended the 2nd International Wildlife Reintroduction Conference in Chicago, IL and presented results from this project. He has also presented results from the study at Biology of Lizards Symposium, Texas Herpetological Society, and Southwest Partners for Amphibian and Reptile Conservation. The presentations and project were very well received by the international community of scientists specializing in translocations. Mickey also attended a four-day workshop on planning effective conservation translocations, taught by leading experts in the field of reintroduction biology.

The project outcomes and measures discussed above have great potential for influencing future translocations for the species in Texas, when they are deemed necessary. When appropriate protections for the species and its habitat are in place, conservation translocations can potentially play an important role in the recovery and conservation of the dunes sagebrush lizard.

RECOMMENDATIONS

- Future translocations should use female-biased propagules.

- Translocations should occur in the breeding season (May-June) to maximize the number of gravid females translocated.

- Large propagule size is recommended. Obtaining large numbers of individuals for propagules is a challenge. A captive breeding program may be necessary to produce propagules for future translocations.

- Monitoring translocated populations needs to be intensive and cover an area of at least 15 ha to maximize detections of lizards in small incipient populations.

- Monitoring should span at least 4 years to accurately assess translocation outcomes.

- Translocations should only occur at sites with contiguous shinnery dune habitat, with large average blowout size and large total area of blowouts. Habitat quality of release sites should be assessed prior to translocations.

- Future translocations may benefit from an experimental approach to enclosure size. For example, we do not know how larger enclosures in place for longer periods may affect translocation outcomes, or the optimal number of small enclosures in an area.

- A recovery plan for the dunes sagebrush lizard, with planned releases at known sites, should be in place before more translocations are undertaken. This is necessary to help ensure meaningful conservation benefits for the species.

- Future translocation sites need permanent legal protection from development and fragmentation. Landowner participation is a necessity and transfer of land ownership should be anticipated and planned for. Without it, translocated populations have uncertain futures.

- Multiple translocations may be necessary to establish self-sustaining populations of dunes sagebrush lizards. This should not be a trial-and-error process. Objectives should be clearly stated at the beginning of the project, and, through adaptive management, adjustments made until objectives are met.

- We recommend against augmenting existing populations. This practice carries many disadvantages and risks, and no known benefits to dunes sagebrush lizard populations. Augmentation of existing populations does not mitigate effects of fragmentation or habitat degradation, which are the known causes of population decline.

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