RESULTS FROM THE SECOND YEAR OF RESEARCH: EFFECTS OF MANAGEMENT PRACTICES FOR OIL AND GAS DEVELOPMENT ON POPULATIONS OF THE DUNES SAGEBRUSH LIZARD, *SCELOPORUS ARENICOLUS*

A REPORT SUBMITTED TO THE BUREAU OF LAND MANAGEMENT, CARLSBAD OFFICE

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PROJECT GOAL

The aim of this project is to gain insight into the effects of management practices on patterns of landscape fragmentation and populations of the endemic lizard, *Sceloporus arenicolus*. Management practices currently used by the Bureau of Land Management and other agencies rely on controlling or minimizing the placement of caliche well pads and roads within shinnery oak sand dune complexes that are presumed to be occupied by *S. arenicolus*. The effectiveness of this strategy and the specific stipulations placed on oil and gas development have not been evaluated with an experimental ecology approach. It is critical to understand at what spatial scale the management practices may be most effective, and at which scale they may be ineffective. Our research is assessing this issue with both mensurative and manipulative experimental approaches. Initially, we will draw comparisons of landscape characteristics and population size of *S. arenicolus* between areas that have already been developed by oil and gas to those that have not. In the future, we will use a before-after-control-intervention (BACI) design to quantify landscape change as a result of oil and gas development and to document changes in population size of *S. arenicolus*. We created nine study areas with three trapping grids within each. This design will allow us to analyze for effects at small scales, < 5 hectares, which corresponds to single well pad sites, and at larger landscape scales, 100 hectares.

INTRODUCTION

Sceloporus arenicolus (Dunes Sagebrush Lizard) occurs within shinnery-oak dune landscapes of west Texas and southeastern New Mexico (Degenhardt and Jones 1972, Degenhardt et al. 1996, Fitzgerald and Painter 2009). *Seloporus arenicolus* is a habitat specialist, occurring only in dune blowouts (Sena 1985, Fitzgerald et al. 1997). As a consequence of a small geographic distribution, habitat specialization and concern regarding human impacts in this region, *S. arenicolus* is listed as Endangered by the New Mexico Department of Game and Fish (2006) and is a candidate for federal listing by the US Fish and Wildlife Service (Federal Register September 12 2006). State and federal agencies charged with natural resource conservation in southeastern New Mexico and west Texas need basic ecological information on *S. arenicolus* in order to formulate scientifically defensible conservation plans.

Landscape management practices will likely decide the fate of *S. arenicolus*. Researchers have explored the effects of some land-use practices in this region on *S. arenicolus*. Snell et al. (1997), in a comparative study, demonstrated the negative effect of shinnery oak (*Quercus havardii*) removal by the herbicide tebuthiron on lizard captures, and specifically on *S. arenicolus*. Significantly fewer lizards were found on treated sites than on untreated sites resulting in the management suggestion to cease use of such herbicides within a 500 m buffer surrounding occupied habitat (Painter et al. 1999). Research conducted by Sias and Snell (1996, 1998) demonstrated the potential for effects of oil and gas development on *S. arenicolus*. They found a significant negative correlation between proximity to oil well pads and presence of *S. arenicolus*. This research initiated current management practices to locate caliche oil well pads and roads outside of occupied habitats in the shinnery-oak flats (Painter et al. 1999) and the suggestion to restrict surface occupancy 200 m away from occupied sites (U. S. Fish and Wildlife Service et al. 2008).

Because previous research has identified this pattern of fewer observations of *S. arenicolus* near well pads, we intend to see if these patterns exist across larger scales. Additionally, the development associated with oil and gas development fragments the landscape. Thus, it is unknown what may occur to *S. arenicolus* populations once the surrounding landscape becomes fragmented. This project aims to assess the current land management practices utilized in the Mescalero Sands ecosystem in southeastern New Mexico through manipulative and mensurative studies on landscape fragmentation and population monitoring of *S. arenicolus*. With the before-after design, we are intending to tease apart the effects of land management practices through manipulation and avoid some of the potential effects associated with observed differences. We intend to analyze these effects alongside other relevant ecological patterns and processes at multiple scales. Patterns such as resource availability and landscape structure, and processes such as interaction rates and community turn-over are of interest to this study. The following report is written following the conclusion of the second field season of research.

METHODS

Study area site selection: Our study areas are 100 hectare regions, each containing 3 trapping grids, of which each is 1.2 ha. Nine study areas were selected to accommodate three treatment groups. These groups are: fragmented, non-fragmented, and experimental (non-fragmented areas that will become fragmented following year two). The criteria used to select treatments were as follows: study areas 1) must lie in shinnery-oak dune landscape and 2) be less than 0.5 kilometer distant from a known *S. arenicolus* specimen locality 3) and if density of well pads exceeded 12 active wells per 100 hectares treatments were considered fragmented if not they were selected to be either non-fragmented or experimental. All study areas are located in Eddy and Lea counties, NM (Fig. 1) in the vicinity of the villages of Loco Hills and Maljamar. Within each study area we randomly chose three areas large enough to place a pitfall trapping grid (1.2 ha.). Grids were randomly positioned by using a random number generator and an x/y grid in Microsoft Excel. Grid size was determined based upon the known home range size variability for *S. arenicolus*. (Hill and Fitzgerald 2007). Additionally, all trapping grids are

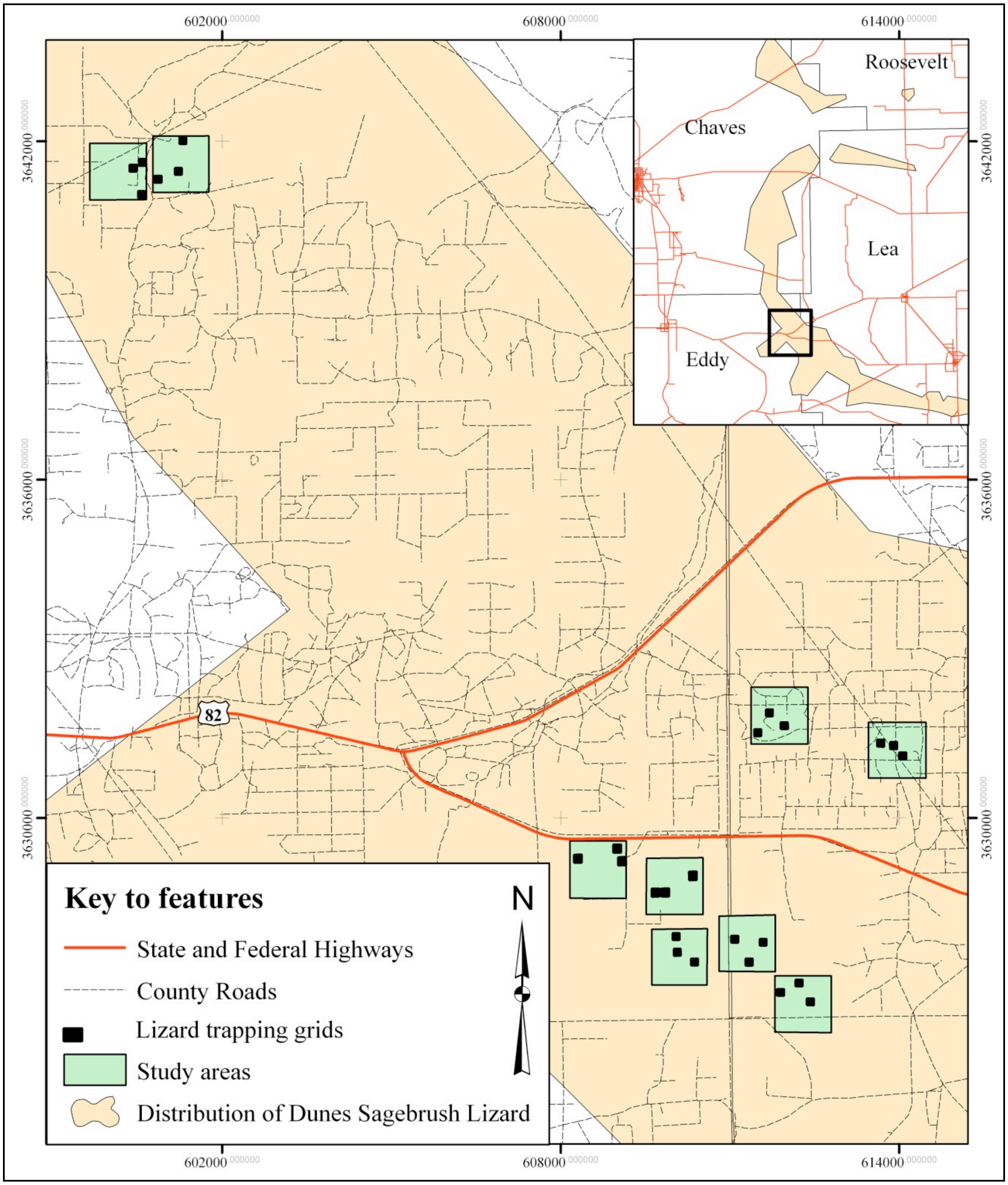

Figure 1. Locality of Study areas (100 ha.) with inset map of Dunes Sagebrush Lizard distribution in southeastern New Mexico (datum: NAD 83, zone 13).

approximately 100 m distant from each other, to minimize the potential of *S. arenicolus* dispersal between grids (Fitzgerald et al. 2005).

Pitfall trapping: To capture lizards for population and community analysis we used pitfall trapping grids. Trapping grids consist of 30 pitfall buckets spaced 20 meters apart in a 6 x 5 (rows to columns) format. Following installation, each trapping grid was operated for six five-day operation cycles in 2010 (equaling 30 days per grid). The operation cycles were staggered between 26 April and 20 August to account for any seasonal or climatic related lizard activity issues. Daily operation of a trapping grid consisted of visiting each trap, processing each lizard captured, and removing all living organisms from the trap. Processing lizards included identifying individuals to species, determining sex, measuring the snout-to-vent length (SVL: a straight line distance from rostrum to cloaca), measuring tail, any regenerated tail, recording mass (g) of each individual with a pesola spring scale, individually marking by toe-clip (Waichman 1992), and releasing them back to the study grid near the area of capture. Additionally, all other vertebrates captured during trapping were individually marked, measured and weighed. The nomenclature used for reptiles and amphibians and mammals follow recent trends by Crother et al. (2008) and Schmidly (2004), respectively.

Small mammal trapping: To compare lizard communities with like sized terrestrial communities we trapped small mammals on each grid in 2010. Beginning on July 25 and ending on 13 August we trapped the middle 4 rows of each trapping grid using Sherman live traps (H. B. Sherman Traps, Tallahassee, Florida; 23 x 9 x 7.5 cm). Two hours before sunset, we baited traps with rolled oats and all traps were checked at sunrise the following morning. We recorded common morphological measurements (total length, tail length, hind foot length, ear length, and mass) before they were released. All animals were marked with individually marked small animal ear tags (National Band & Tag Company, Newport, Kentucky; styles 1005-1 & 1005-3) for recognition between trapping sessions.

Arthropod collection: To assess resource availability and trophic structure on these trapping grids, we collected arthropods. On each individual grid, three randomly assigned bug trapping areas were dedicated as sampling sites. At each of these sites a termite trap (Haverty 2001) was installed nearby to account for subterranean arthropods. On the fourth day of each trapping period all arthropods were collected out of the pitfall bucket to account for surface active arthropods. Over the summer months of 2010, the collections made in 2009 were analyzed by an undergraduate student helper in the laboratory at Texas A&M University the identification efforts are on-going.

On site habitat comparison: To account for structural and environmental variability, both coarse and fine scale measures of habitat structure were measured on each grid. In 2009, we measured leaf litter and relative cover. At each trap in 2010, we calculated 16 more microhabitat variables. Woody debris was measured with a 1 m^2 Daubenmire frame on the ground 2 m away from each pitfall bucket measured at a random angle similar to the centered-point quarter method (Cottam et al. 1953). The dominant slope of the 1 m^2 was measured with a magnetic angle locator (Johnson Level & Tool Mfg. Co., Mequon, Wisconsin) placed on a flat piece of metal strap. Aspect was determined with a folding military lensatic compass (Brunton, Riverton, Wyoming) facing the direction of the dominant slope. Soil compaction was measured with a penetrometer (Lang Penetrometer, Inc., Gulf Shores, Alabama). Soil temperature and moisture were calculated at two depths (40 cm and 80 cm) with a digital meter (Aquaterr Instruments & Automation, Costa Mesa, California). The presence of metal, pipelines, overhead power-lines, and oil spills within 20 meters of a trap was identified. Also, the dominant plant cover was recorded. Another variable determined whether a bucket was in blowout or shin-oak matrix. Measurements on height and length dimensions of blowouts were calculated following the recommendations of Fitzgerald et al. (1997).

Statistical analysis: Because landscape manipulation has not yet occurred, non-fragmented and experimental treatments were grouped for statistical comparison with fragmented treatments. All means are reported ± SD, and we determined a relationship to be significant if two –tailed *P*-values were < 0.05. Total lizard captures, total lizard recaptures, unique lizard captures, lizard diversity, small mammal captures, small mammal diversity, arthropod captures, and arthropod diversity were analyzed separately with an *t*-Tests (Zar, 1999). Using this same test we individually analyzed each common species' total captures, recaptures, and unique captures per treatment. We calculated a species diversity index (Δ1; Hurlbert, 1971) from the species compositions at each site per year where,

$$\Delta_1 = \left(\frac{N}{N-1}\right)\left(1 - \Sigma\left(\frac{N_i}{N}\right)^2\right)$$

where N is the total number of individuals, N_i is the total number of individuals of species i (this calculates a value between 0 and 1 with 1 being even across all species and 0 being uneven). Hurlbert's diversity measure was chosen due it robustness at low sample sizes (Olszewski, 2004).

RESULTS

The following species of vertebrates (including 8 species of lizard, 4 species of small mammal, 9 species of snake, 5 species of amphibians and 1 turtle species) account for the 4394 total captures in the pitfall traps in 2010 (of this 4216 were lizards): Common Lesser Earless Lizard (*Holbrookia maculata*), Common Side-blotched Lizard (*Uta stansburiana*), Dunes Sagebrush Lizard (*Sceloporus arenicolus*), Great Plains Skink (*Plestiodon obsoleta*), Marbled Whiptail (*Aspidoscelis marmorata*), Prairie Lizard (*Sceloporus consobrinus*), Six-lined Racerunner (*Aspidoscelis sexlineata*), Texas Horned Lizard (*Phrynosoma cornutum*), Northern Grasshopper Mouse (*Onychomys leucogaster*), Plains Harvest Mouse (*Reithrodontomys montanus*), Silky Pocket Mouse (*Perognathus flavus*), Spotted Ground-squirrel (*Spermophilus spilosoma*), Coachwhip (*Coluber flagellum*), Glossy Snake (*Arizona elegans*), Gophersnake (*Pituophis catenifer*), Long-nosed Snake (*Rhinocheilus lecontei*), Massasauga (*Sistrurus catenatus*), Milksnake (*Lampropeltis triangulum*), Plains Black-headed Snake (*Tantilla nigriceps*), Prairie Rattlesnake (*Crotalus viridus*),Texas Threadsnake (*Leptotyphlops dulcis*), Western Diamond-backed Rattlesnake (*Crotalus atrox*), Couch's Spadefooted Toad (*Scaphiopus couchii*), Great Plains Toad (*Anaxyrus cognatus*), Green Toad (*Anaxyrus debilis*), Plains Spadefoot (*Spea bombifrons*), Texas Toad (*Anaxyrus speciosus*), and Desert Box Turtle (*Terrapene ornata*). There were a total of 24,300 trap days in 2010, and the lizard capture rate was 17.4 % (higher than in 2009; 12.3%). Additionally the following mammals were among the 178 animals captured in Sherman traps: Ord's Kangaroo Rat (*Dipodomys ordii*), (*Perognathus flavescens*), Southern Plains Woodrat (*Neotoma micropus*), White-footed Mouse (*Peromyscus leucopus*), Deer Mouse (*P. maniculatus*) and the capture rate was 8.2 %. Finally, 66 species of arthropods representing 13 taxonomic orders were captured in 2009.

The total number of lizards captured per grid between treatments was significantly different (t = 2.22, P = 0.03), with the non-fragmented grids averaging more captures (234.5 ± 69.4) than the fragmented (188.6 ± 37.8). Total recaptures were also significantly different with more recaptured individuals trapped on the non-fragmented grids (t = 2.16, P = 0.04; non-fragmented: 40.9 ± 16.2, fragmented: 30.8 ± 8.3). When corrected for recaptures (total – recaptured), the total number of unique individuals captured was significantly different (t = 2.18, P = 0.04) with fragmented grids having lower unique lizard captures than the non-fragmented grids (157.8 ± 30.4 and 193.6 ± 55.0, respectively).

Diversity was significantly different between treatments as well with a non-fragmented grids being more diverse than fragmented grids ($t = 6.12$, $P < 0.01$; non-fragmented: 0.40 ± 0.10, fragmented: 0.20 ± 0.06). Small mammal captures per grid between treatments were not significantly different ($t = 0.39$, $P = 0.66$; non-fragmented: 6.39 ± 4.95, fragmented: 7.00 ± 3.12). Likewise, there was no difference detected in small mammal diversity between treatments ($t = 0.34$, $P = 0.74$; non-fragmented: 0.50 ± 0.34, fragmented: 0.46 ± 0.26). There was no detectable signature of fragmentation with either arthropod capture rate or arthropod diversity ($t = 1.24$, $P = 0.23$; non-fragmented: 41.8 ± 22.7, fragmented: 33.7 ± 11.4; $t = 0.19$, $P = 0.85$; non-fragmented: 0.88 ± 0.09, fragmented: 0.89 ± 0.07, respectively).

Capture rates per lizard species were compared by treatment (Fig. 2). The species having significantly different capture rates between treatments were *S. arenicolus*, *S. consobrinus*, *H. maculata*, and *P. cornutum* (Fig. 3). Each of these species were in significantly higher abundances on the non-fragmented trapping grids with the exception of *P. cornutum* (*S. arenicolus*: $t = 4.62$, $P < 0.01$, *S. consobrinus*: $t = 2.28$, $P = 0.03$, *H. maculata*: $t = 2.54$, $P = 0.02$, *P. cornutum*: $t = 3.03$, $P = 0.01$). Conversely, no differences were detected between treatments for *U. stansburiana*, *A. marmorata*, *A. sexlineata* or *P. obsoleta*.

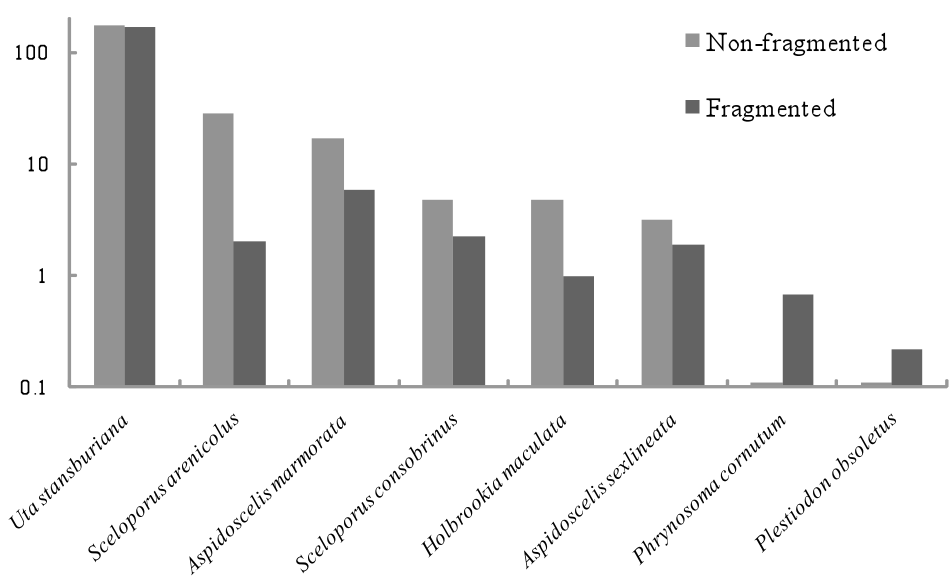

Figure 2. Rank abundance of lizard captures between two treatment types, lizard abundance axis on log scale.

The Dunes Sagebrush Lizard (*S. arenicolus*) still occurs in much lower frequency on fragmented grids versus non-fragmented grids (Table 1). The populations existing on fragmented grids are so low that we have not had any recaptures yet which will influence our ability to reasonably estimate population sizes.

Table 1. Presence, total captures, average capture rate per grid, maximum captures, minimum captures, and recaptures for *Sceloporus arenicolus* on trapping grids in 2009 and 2010.

	Presence	Total	Average	Max	Min	Recaptures
Non-fragmented (*N* = 18)	17	512	28.4	96	7	104
Fragmented (*N* = 9)	5	28	3.1	9	1	0

DISCUSSION/ WORK IN PROGRESS

These data demonstrate significant differences in lizard communities among the treatment types. Non-fragmented sites (experimental and non-fragmented) had significantly more lizard captures, more unique captures, greater lizard diversity and a higher average number of species. Interestingly, there is no apparent difference in arthropod communities between treatments; however, we recognize that this may be a result of taxonomic resolution. In the future a full identification of these organisms to sub-familial categories is preferred. Similarly, no sign of an effect of landscape fragmentation is apparent within the small mammal communities.

Our data suggest differences exist in lizard diversity and density where land management practices differ. Study areas in fragmented treatments demonstrated fewer species, including fewer *S. arenicolus*, *S. consobrinus*, and *H. maculata*. As a result of this, fragmented study areas demonstrate lower lizard diversity than those that are non-fragmented. The goal of our research is to relate the effects of management practices on patterns of landscape fragmentation and populations of the endemic lizard, *S. arenicolus.* At this stage, it is too early to confidently estimate population sizes of *S. arenicolus* in all of our study areas (Table 1). In time, these estimates will provide an important addition to the relationships we have already reported on. Currently, we are drawing comparisons between fragmented areas and areas that have not yet been fragmented. Until the proposed experimental treatments become fragmented we cannot identify the proximate mechanism that is responsible for the differences observed between fragmented and non-fragmented habitats.

Our ongoing research is focused on both landscape patterns and resource availability. Between now and the next field season we will accomplish a variety of tasks. A more thorough analysis of landscape characteristics and community compositions will be conducted. Additionally, methods to capture more information regarding the functional differences between species will be devised for implementation during the following field season. Using information from these sources we hope to better understand how our data will be useful in promoting conservation strategies and rule in or out resource availability in our analysis.

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LITERATURE CITED

COTTAM, G., J. T. CURTIS, AND B. W. HALE. 1953. Some sampling characteristics of a population of randomly dispersed individuals, Ecology 34:741-757.

CROTHER, B. I., ET AL. 2008. Scientific and standard English names of amphibians and reptiles of North America, north of Mexico, with comments regarding confidence in our understanding. Society for the Study of Amphibians and Reptiles, Shoreview, MN.

DEGENHARDT, W. G., AND K. L. JONES. 1972. A new sagebrush lizard, *Sceloporus graciosus*, from New Mexico and Texas, Herpetologica 28:212-217.

DEGENHARDT, W. G., C. W. PAINTER, AND A. H. PRICE. 1996. Amphibians and reptiles of New Mexico. University of New Mexico Press, Albuquerque, New Mexico.

FEDERAL REGISTER SEPTEMBER 12. 2006. Review of native species that are candidates or proposed for listing as endangered or threatened; annual notice of findings on resubmitted petitions; annual description of progress on listing actions, Pp. 53755–53835.

FITZGERALD, L. A., AND C. W. PAINTER. 2009. Dunes Sagebrush Lizard. *Sceloporus arenicolus*, Pp. 198-201 in: Lizards of the American Southwest (L. L. C. Jones and R. E. Lovich, eds.). Rio Nuevo, Tucson, AZ.

FITZGERALD, L. A., C. W. PAINTER, D. S. SIAS, AND H. L. SNELL. 1997. The range, distribution and habitat of *Sceloporus arenicolus* in New Mexico, P. 31.

FITZGERALD, L. A., M. W. SEARS, AND C. W. PAINTER. 2005. Interdune dispersal of sand dune lizards (*Sceloporus arenicolus*) in the mescalero sands ecosystem. P. 13.

HAVERTY, M. I. 2001. The role of toilet paper in studies of desert subterranean termites (Isoptera) in Arizona, USA: a substrate for nondestructive observations of foraging activity, Sociobiology 37:245-252.

HILL, M. T. AND L. A. FITZGERALD. 2007. Radiotelemetry and population monitoring of the sand dune lizards (*Sceloporus arenicolus*) during the nesting season. P. 7.

HURLBERT, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology. 52:577-586.

NEW MEXICO GAME AND FISH DEPARTMENT. 2006. Threatened and endangered species of New Mexico: draft biennial review and recommendations. Authority: Wildlife Conservation Act (NMSA 17-2-37+B1 through 17-2-46, 1978).

OLSZEWSKI, T. D. 2004. A unified mathematical framework for the measurement of richness and evenness within and among multiple communities. Oikos. 104:377-387.

PAINTER, C. W., L. A. FITZGERALD, D. S. SIAS, L. J. S. PIERCE, AND H. L. SNELL. 1999. Management plan for *Sceloporus arenicolus* in New Mexico, P. 45.

SCHMIDLY, D. J. 2004. The mammals of Texas, Rev. ed. University of Texas Press, Austin.

SENA, A. P. 1985. The distribution and reproductive ecology of *Sceloporus graciosus arenicolus* in southeastern New Mexico, P. 81. unpublished manuscript, University of New Mexico, Albuquerque, NM.

SIAS, D. S., AND H. L. SNELL. 1996. The dunes sagebrush lizard *Sceloporus arenicolus* and sympatric reptile species in the vicinity of oil and gas wells in southeastern New Mexico. Final report for 1995 field studies, P. 32.

SIAS, D. S., AND H. L. SNELL. 1998. The sand dune lizard *Sceloporus arenicolus* and oil and gas development in southeastern New Mexico, P. 27.

SIMPSON, E. H. 1949. Measurement of diversity, Nature 163:688.

SNELL, H. L., L. W. GORUM, L. J. S. PIERCE, AND K. W. WARD. 1997. Results from the fifth year research on the effect of shinnery oak removal on populations of sand dune lizards, *Sceloporus arenicolus*, in New Mexico P. 13.

U.S. FISH AND WILDLIFE SERVICE (DOI), U.S. BUREAU OF LAND MANAGEMENT (DOI), AND THE CENTER FOR EXCELELLENCE IN HAZARDOUS MATERIALS MANAGEMENT. 2008. Candidate conservation agreement for the lesser prairie-chicken (*Tympanuchus pallidicinctus*) and sand dune lizard (*Sceloporus arenicolus*) in New Mexico, P. 81.

WAICHMAN, A. V. 1992. An alphanumeric code for toe clipping amphibians and reptiles, Herpetological Review 23:19-21.

ZAR, J. H. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River, NJ.

ABSTRACT AND PRELIMINARY RESULTS: SPATIAL VARIATION IN VITAL RATES AND MOVEMENT RATES ACROSS SIX POPULATIONS OF THE DUNES SAGEBRUSH LIZARD, *SCELOPORUS ARENICOLUS*, AT CAPROCK WILDLIFE AREA

A REPORT SUBMITTED TO THE BUREAU OF LAND MANAGEMENT, CARLSBAD OFFICE

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ABSTRACT

Understanding and predicting the dynamics of harvested, invasive, disease-causing, or endangered species' populations is a central goal of ecology and conservation biology. Put simply, species' population dynamics are driven by changes in birth, death, immigration, and emigration rates. These vital and movement rates are often determined by extrinsic factors (abiotic: weather, fire; biotic: predation, resource availability) that vary in space and time causing spatiotemporal variation in the dynamics of populations with consequences for species' conservation and management. Here we used 5 years of mark-recapture data from 6 sites at Caprock Wildlife Area (NM; Hill and Fitzgerald 2007) to estimate spatial variation in vital rates and diffusion rates of populations of the lizard *Sceloporus arenicolus*, an endemic sand-dune blowout habitat specialist in an ecosystem of conservation concern, the Mescalero Sands (Fitzgerald et al. 1997).

Cormack–Jolly–Seber (CJS) mark–recapture models were used to estimate vital rates rather than robust design mark–recapture models, because no immigration among sites was detected. Model-averaged estimates for apparent survival rates (ϕ, 0.88-0.95) were high across all six sites with no differences among them (Tables 1 and 2). There also was no difference between female and male survival within and among all six sites (Tables 1 and 2). Model-averaged estimates of recapture probability (*p*) varied through time for sites 2 and 4 (Table 3), but were consistent through time and between sexes for sites 1, 3, 5, and 6 (*p*, 0.21-0.31; Table 3). Site specific estimates of lambda (population growth rate) calculated from model-derived vital rates hovered near 1 for all sites (i.e., lizards were numerically replacing themselves; Table 4). Model-derived estimates of recruitment rates were also similar across all sites (0.13-0.16; Table 4). Lizard abundance or density, however, was highly variable among sites (abundance range 23-

125; density range 0.4-2.2 lizards/100m^2; Table 4) and showed a positive relationship with distance between sand-dune blowout habitats at the site scale (i.e., approximately 0.5 hectares; Figure 1).

Population diffusion models were parameterized with data on individual lizard movements calculated from the 5 years of mark-recapture data across sites. These models were used to estimate the redistribution of *S. arenicolus* populations at each site (Turchin 1998). Mean distance per move, total distance moved, and number of moves were similar across sites, but overall, juveniles made larger individual moves on average than adults (no difference between sexes) and males made more moves and thus moved longer total distances (i.e., greater total displacement; Table 6). Turning angles were typically reversals, with some variation among sites (Table 6). Diffusion rates estimated from movement data indicate that *S. arenicolus* populations redistribute themselves at different rates across sites (Table 6). Increasing diffusion rates appear to be a positive function of lizard density (Figure 2).

These and other results are currently being compiled for a manuscript describing spatial variation in vital rates and movement rates of *Sceloporus arenicolus* populations. This manuscript will discuss the implications of these results for the conservation and management of *S. arenicolus* populations. Charles Painter and Michael Hill of the New Mexico Department of Game and Fish are collaborators on this research and co-authors on this manuscript.

LITERATURE CITED

FITZGERALD, L. A., C. W. PAINTER, D. S. SIAS, AND H. L. SNELL. 1997. The range, distribution and habitat of *Sceloporus arenicolus* in New Mexico.

HILL, M. T. AND L. A. FITZGERALD. 2007. Radiotelemetry and population monitoring of the sand dune lizard (*Sceloporus arenicolus*) during the nesting season.

TURCHIN, P. 1998. Quantitative analysis of movement. Sinauer Associates, Inc., Sunderland, Massachusetts.

Table 1. Model ranking of Cormack–Jolly–Seber (CJS) mark–recapture models estimating apparent survival (φ) and recapture probability (*p*) for *Sceloporus arenicolus* across six sites in the Mescalero Sands from 2005-09. Shown are delta Akaike's information criteria corrected for small sample size (ΔAICc), the AICc weight (AICc wt), the number of parameters and the deviance for each model. A '(·)' denotes time-invariant parameters, '(*t*)' denotes time-variant parameters, and '(*g*)' denotes sex-dependent parameters.

Site	Model	ΔAICc	AICc wt	Parameters	Deviance
1	φ(.) *p*(.)	0.00	0.49	2	229.7
	φ(.) *p*(*g*)	1.73	0.20	3	229.3
	φ(*g*) *p*(.)	1.74	0.20	3	229.3
	φ(*g*) *p*(*g*)	3.08	0.10	4	228.5
	φ(.) *p*(*t*)	16.28	<0.01	19	202.5
2	φ(.) *p*(*t*)	0.00	0.78	19	255.2
	φ(*g*) *p*(*t*)	2.78	0.19	20	255.2
	φ(.) *p*(.)	8.49	0.01	2	304.4
	φ(.) *p*(*g*)	9.38	0.01	3	303.2
	φ(*g*) *p*(.)	10.58	<0.01	3	304.4
3	φ(.) *p*(.)	0.00	0.31	2	100.2
	φ(*g*) *p*(.)	0.03	0.31	3	97.8
	φ(*g*) *p*(*g*)	0.39	0.25	4	95.7
	φ(.) *p*(*g*)	1.94	0.12	3	99.7
	φ(*t*) *p*(.)	39.83	<0.01	18	74.1
4	φ(.) *p*(*t*)	0.00	0.75	18	428.1
	φ(*g*) *p*(*t*)	2.23	0.25	19	428.0
	φ(.) *p*(*g***t*)	12.31	<0.01	35	397.4
	φ(*g*) *p*(*g***t*)	14.30	<0.01	36	396.7
	φ(.) *p*(.)	21.13	<0.01	2	484.2
5	φ(.) *p*(.)	0.00	0.55	2	147.6
	φ(*g*) *p*(.)	2.08	0.19	3	147.5
	φ(.) *p*(*g*)	2.16	0.19	3	147.6
	φ(*g*) *p*(*g*)	4.24	0.07	4	147.4
	φ(*t*) *p*(.)	18.87	<0.01	15	131.8
6	φ(*g*) *p*(.)	0.00	0.31	3	145.7
	φ(.) *p*(.)	0.25	0.27	2	148.1
	φ(.) *p*(*g*)	0.26	0.27	3	145.9
	φ(*g*) *p*(*g*)	1.54	0.14	4	144.9
	φ(*t*) *p*(.)	13.87	<0.01	16	121.9

Table 2. Model-averaged estimates of apparent survival for female and male *Sceloporus arenicolus* across six sites in the Mescalero Sands from 2005-09 derived using Cormack-Jolly-Seber (CJS) mark-recapture models. Also shown are the standard error (SE), unconditional SE and 95% confidence intervals for each model-averaged estimate.

Site	Sex	□	SE	Uncon SE	95% CI
1	Female	0.93	0.016	0.016	0.89-0.96
	Male	0.93	0.018	0.019	0.88-0.96
2	Female	0.95	0.010	0.010	0.93-0.97
	Male	0.95	0.010	0.010	0.93-0.97
3	Female	0.94	0.025	0.029	0.85-0.98
	Male	0.88	0.044	0.060	0.71-0.96
4	Female	0.94	0.010	0.010	0.92-0.96
	Male	0.94	0.010	0.010	0.92-0.96
5	Female	0.93	0.023	0.023	0.87-0.96
	Male	0.93	0.024	0.025	0.86-0.96
6	Female	0.93	0.027	0.032	0.83-0.97
	Male	0.95	0.020	0.023	0.88-0.98

Table 3. Sex-specific or time-variant (depending on model ranking; Table 1) model-averaged estimates of recapture probability for *Sceloporus arenicolus* across six sites in the Mescalero Sands from 2005-09 derived using Cormack-Jolly-Seber (CJS) mark-recapture models. Also shown are the standard error (SE), unconditional SE and 95% confidence intervals for each model-averaged estimate.

Site	Sex/Interval	*p*	SE	Uncon SE	95% CI
1	Female	0.27	0.042	0.043	0.19-0.36
	Male	0.29	0.049	0.054	0.19-0.40
2	June 2005-06	0.66	0.18	0.20	0.26-0.91
	June-July (2006)	0.20	0.08	0.08	0.09-0.41
	July-May (2007)	0.59	0.12	0.14	0.31-0.81
	May-June (2007)	0.13	0.07	0.07	0.04-0.33
	June-July (2007)	0.09	0.06	0.06	0.02-0.30
	July-Aug (2007)	0.05	0.05	0.05	0.01-0.30
	Aug-Sept (2007)	0.005	0.001	0.03	0.001-0.06
	Sept-May (2008)	0.37	0.13	0.13	0.16-0.64
	May-June (2008)	0.13	0.07	0.07	0.04-0.34
	June-July (2008)	0.18	0.08	0.08	0.07-0.40
	July-Aug (2008)	0.05	0.04	0.05	0.006-0.29
	Aug-Sept (2008)	0.13	0.07	0.07	0.04-0.35
	Sept-April (2009)	0.19	0.10	0.10	0.06-0.47
	April-May (2009)	0.27	0.10	0.10	0.12-0.51
	May-June (2009)	0.19	0.09	0.09	0.07-0.43
	June-July (2009)	0.24	0.10	0.10	0.10-0.49
	July-Aug (2009)	0.05	0.05	0.05	0.006-0.31
	Aug-Sept (2009)	0.25	0.09	0.10	0.11-0.47
3	Female	0.21	0.06	0.07	0.10-0.38
	Male	0.27	0.08	0.10	0.12-0.50
4	June-July (2006)	0.60	0.14	0.14	0.33-0.83
	July-May (2007)	0.69	0.23	0.23	0.21-0.95
	May-June (2007)	0.25	0.13	0.13	0.08-0.56
	June-July (2007)	0.38	0.11	0.11	0.19-0.60
	July-Aug (2007)	0.0002	0.00002	0.00003	0.00002-0.005
	Aug-Sept (2007)	0.32	0.10	0.10	0.15-0.54
	Sept-May (2008)	0.61	0.12	0.12	0.37-0.80
	May-June (2008)	0.46	0.08	0.08	0.31-0.62
	June-July (2008)	0.17	0.06	0.06	0.08-0.32
	July-Aug (2008)	0.18	0.06	0.06	0.09-0.33
	Aug-Sept (2008)	0.17	0.06	0.06	0.08-0.33
	Sept-April (2009)	0.23	0.07	0.07	0.12-0.41
	April-May (2009)	0.40	0.08	0.09	0.25-0.57
	May-June (2009)	0.38	0.08	0.08	0.24-0.54
	June-July (2009)	0.35	0.08	0.08	0.21-0.51

	July-Aug (2009)	0.15	0.06	0.06	0.07-0.30
	Aug-Sept (2009)	0.17	0.06	0.12	0.04-0.53
5	Female	0.30	0.05	0.05	0.21-0.42
	Male	0.31	0.06	0.06	0.21-0.43
6	Female	0.23	0.05	0.06	0.13-0.37
	Male	0.28	0.06	0.07	0.17-0.42

Table 4. Site specific model estimates of lambda (population growth rate), recruitment, and abundance followed by estimated density (per 100 m^2) for *Sceloporus arenicolus* across six sites in the Mescalero Sands from 2005-09. Also shown are the standard error (SE) and confidence interval [95% CI].

Site	Lambda	Recruitment	Abundance	Density
1	1.00 (0.01) [0.98-1.02]	0.13 (0.04) [0.08-0.22]	57 (6) [50-80]	1.0
2	1.00 (0.01) [0.99-1.02]	0.14 (0.03) [0.09-0.21]	83 (6) [75-100]	1.5
3	0.98 (0.01) [0.96-1.01]	0.13 (0.07) [0.04-0.32]	23 (3) [20-36]	0.4
4	1.02 (0.01) [1.00-1.04]	0.16 (0.03) [0.11-0.22]	125 (7) [114-144]	2.2
5	1.02 (0.02) [0.99-1.05]	0.15 (0.05) [0.07-0.28]	40 (3) [36-51]	0.7
6	0.99 (0.01) [0.97-1.02]	0.09 (0.05) [0.03-0.27]	32 (3) [28-45]	0.6

Table 5. Mean individual growth rates and fertility estimates for *Sceloporus arenicolus* across six sites in the Mescalero Sands from 2005-09. Standard errors (SE) are also shown.

Site	Growth Rate in mm/day			Fertility
	Juvenile	Female	Male	
1	0.27 (0.03)	0.05 (0.02)	0.04 (0.02)	2.5 (0.3)
2	0.21 (0.02)	0.06 (0.02)	0.05 (0.01)	2.4 (0.2)
3	0.32 (0.07)	0.04 (0.03)	0.03 (0.03)	3.0 (0.4)
4	0.27 (0.02)	0.05 (0.02)	0.06 (0.01)	2.4 (0.2)
5	0.30 (0.03)	0.09 (0.03)	0.05 (0.03)	2.2 (0.3)
6	0.30 (0.02)	0.04 (0.02)	0.05 (0.02)	2.3 (0.3)
Overall	**0.28 (0.02)**	0.06 (0.01)	0.05 (0.01)	2.4 (0.1)

Table 6. Mean distance per move, total distance moved, and number of moves for juvenile (distance per move only), female, and male *Sceloporus arenicolus* across six sites in the Mescalero Sands from 2005-09. Standard errors (SE) are also shown. Turning angles for *S. arenicolus* movements at each site are given. Population-level diffusion rates (m^2 per generation) at each site were estimated from movement data following Turchin 1998.

Site	Distance per Move (m)			Total Distance Moved (m)		Number of Moves		Turn Angle									Diffusion Rate
	J	F	M	F	M	F	M	0	45	90	135	180	225	270	315	Sum	m^2/gen
1	15.3 (6.0)	14.1 (4.4)	18.6 (3.5)	15.4 (5.5)	13.1 (4.5)	0.6 (0.2)	1.4 (0.1)	0	1	2	1	7	2	2	0	15	9,553
2	13.1 (4.4)	11.0 (3.9)	16.6 (2.9)	13.8 (4.6)	19.4 (3.7)	0.6 (0.2)	0.9 (0.1)	1	0	3	0	3	1	0	1	9	7,034
3	63.0 (12.0)	18.5 (5.1)	20.6 (6.0)	19.9 (7.2)	30.6 (7.6)	0.7 (0.2)	1.1 (0.3)	0	0	1	0	0	0	1	0	2	5,508
4	16.5 (3.5)	13.5 (3.2)	15.1 (2.4)	15.6 (3.8)	26.8 (3.0)	0.8 (0.1)	1.3 (0.1)	1	2	6	5	18	3	3	2	40	18,371
5	16.4 (6.0)	21.7 (4.7)	15.5 (4.6)	19.6 (5.8)	30.1 (5.6)	0.6 (0.2)	1.1 (0.2)	1	1	0	3	3	0	0	0	8	9,134
6	21.0 (5.7)	6.0 (0.6)	10.8 (4.7)	19.8 (6.9)	16.0 (6.2)	1.0 (0.2)	0.7 (0.2)	0	0	1	1	2	1	2	0	7	2,786
Overall	**24.2 (2.8)**	14.1 (2.1)	16.2 (1.7)	17.4 (2.4)	**25.5 (2.2)**	0.7 (0.1)	**1.1 (0.1)**	3	4	13	10	33	7	8	3	81	

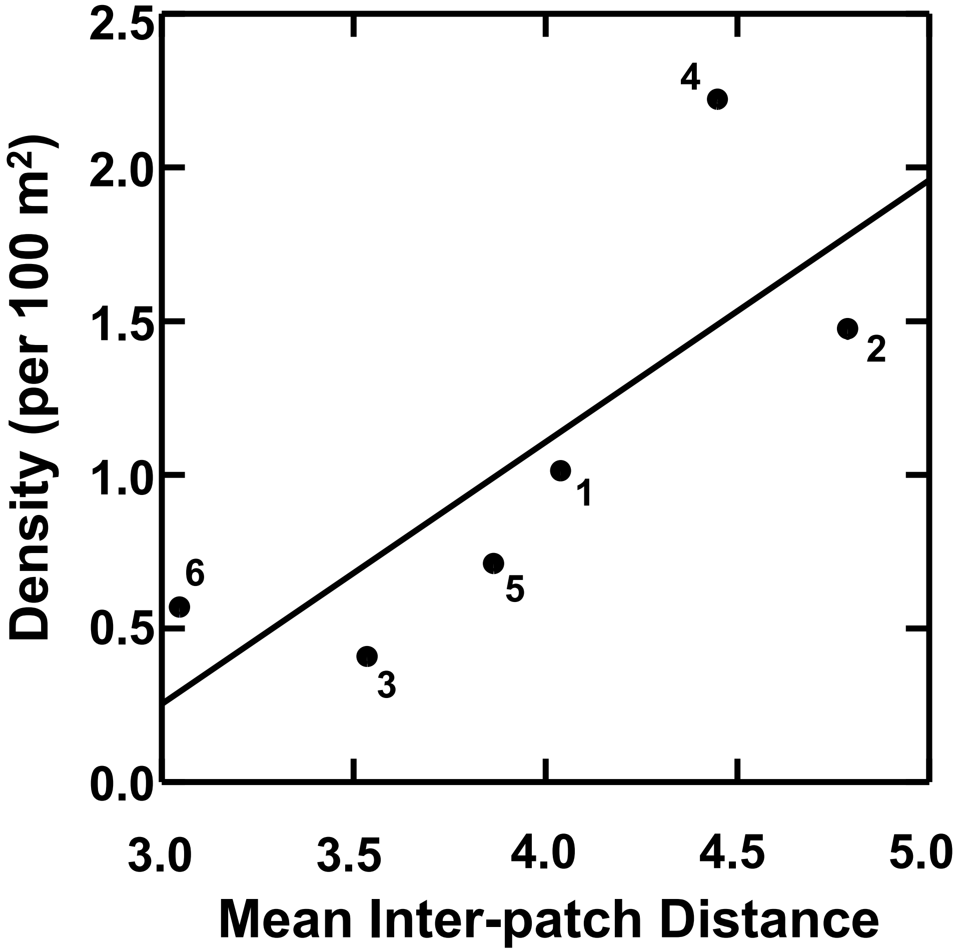


Figure 1. Density of lizards (per $100m^2$) plotted as a function of mean inter-patch distance ($y = 0.85x - 2.3$, $r^2 = 0.52$, $P = 0.065$). Data points are labeled by site.

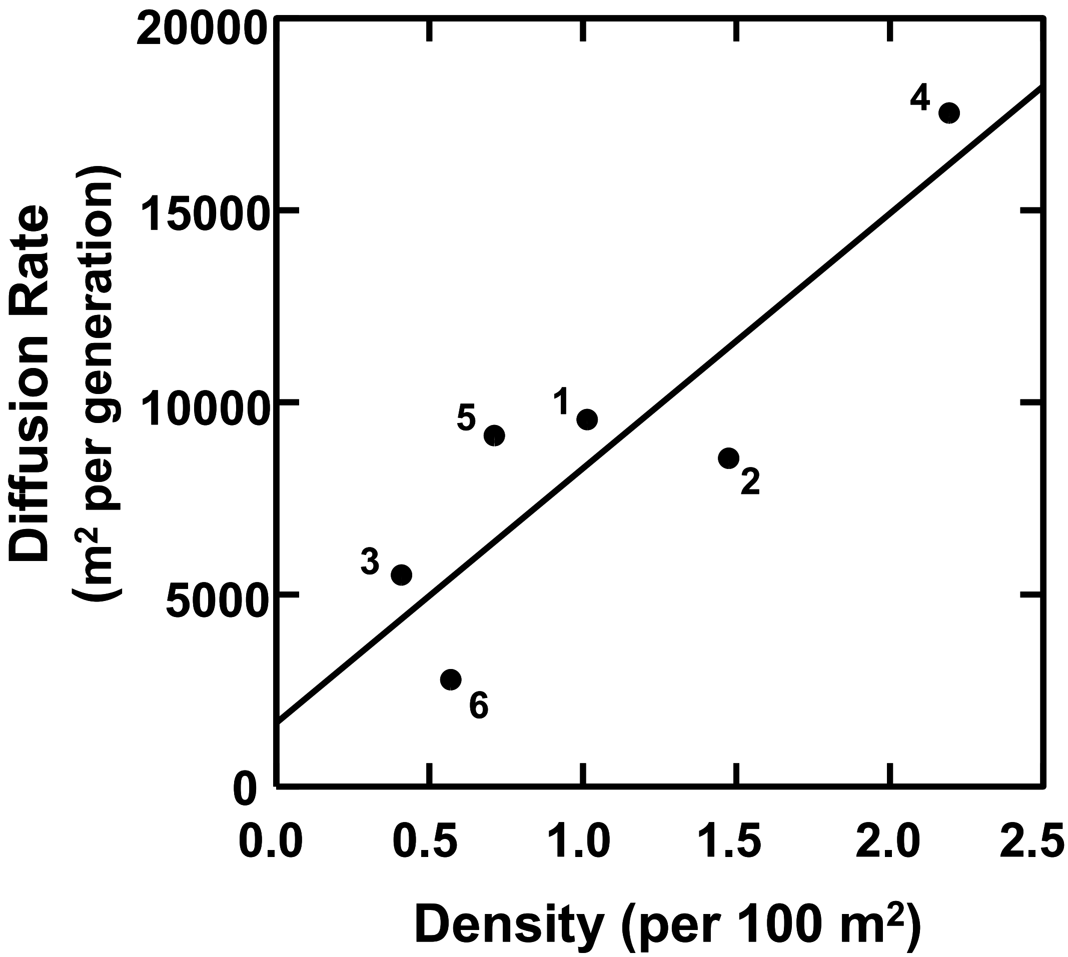


Figure 2. Diffusion rate (m^2 per generation) plotted as a function of lizard density (per $100m^2$) ($y = 6633x + 1655$, $r^2 = 0.64$, $P = 0.03$). Data points are labeled by site.

UPDATE ON THE ATLAS OF DISTRIBUTION AND HABITAT OF *SCELOPORUS ARENICOLUS* IN NEW MEXICO

Submitted by Laura Laurencio and Lee A. Fitzgerald

21 October 2010

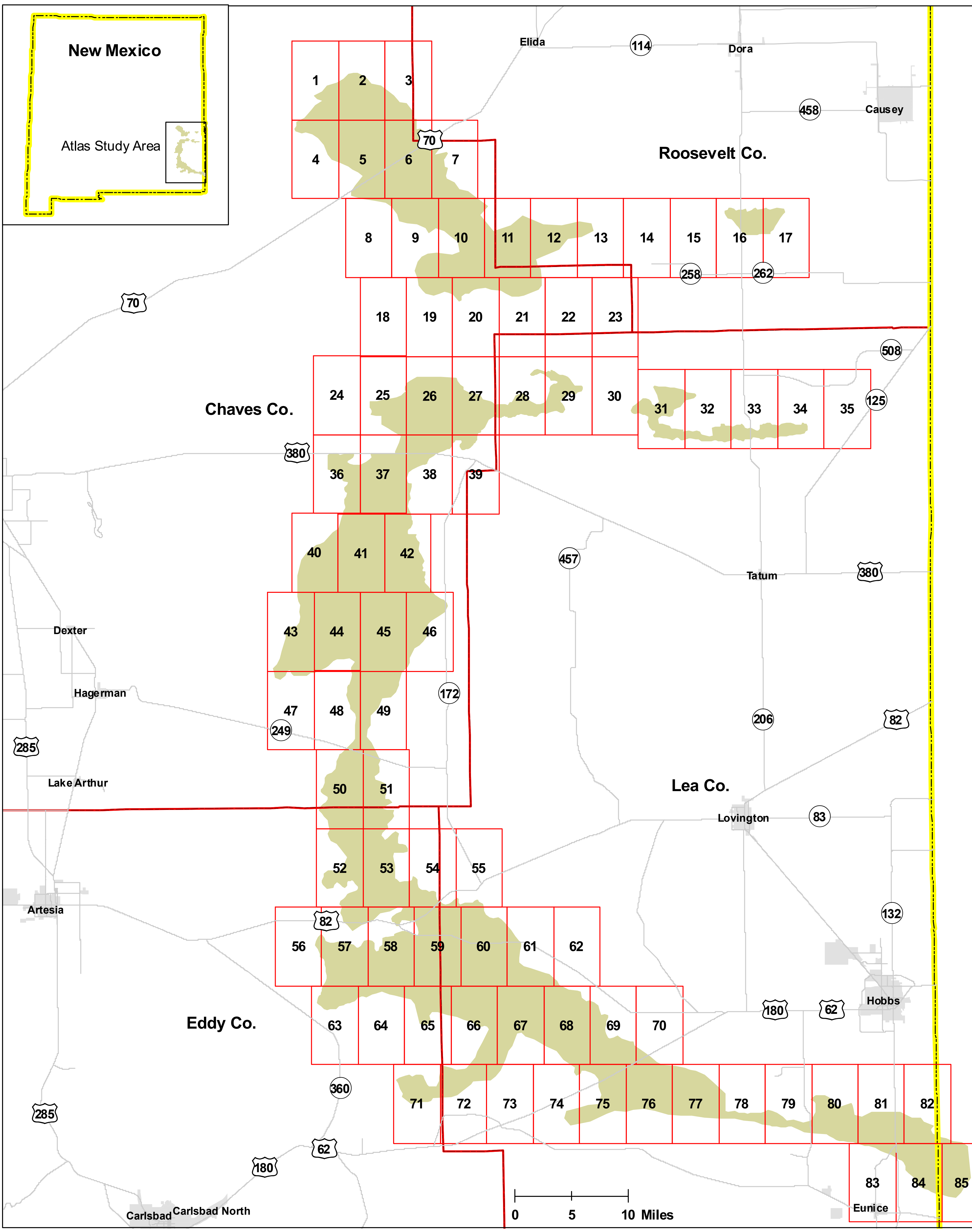
We created an atlas of maps that show the presence of S. arenicolus on DOQQs that clearly show the extent of shinnery oak dune habitat. This document includes the cover page, which shows an updated polygon of the outline of the species' range, the legend, map and sample appendix page.

This atlas is a visual tool for understanding the geographic distribution of the dunes sagebrush lizard (*Sceloporus arenicolus*) in the context of its unique and easily identifiable habitat, shinnery oak dune complexes. *Sceloporus arenicolus* is endemic to the Mescalero Sands and Monahans Sandhills ecosystem and occurs exclusively in shinnery oak dune complexes characterized by open sand dune blowouts. Because these features can be accurately perceived with remotely sensed imagery, the atlas serves to identify potential and suitable habitat of *Sceloporus arenicolus*. The atlas illustrates the extent, connectivity, and fragmentation of the species' habitat in New Mexico.

The Atlas is currently under peer review. Once reviewer comments are addressed the atlas will be published with an ISBN number. It can be cited and will be housed in several university libraries. We will disseminate it to BLM and other groups and individuals interested in *Sceloporus arenicolus*. We intend to print a limited number of copies, and post the entire pdf on the Texas A&M University Herpetology Lab website. The atlas will also be available electronically as a publication in the Texas A&M University Digital Repository of the Evans Library.

Atlas of distribution and habitat of the dunes sagebrush lizard *(Sceloporus arenicolus)* in New Mexico

Grid numbers refer to detailed map pages



Key to Features

- ★ ***Sceloporus arenicolus*** **historical species occurrences**
- ☆ ***Sceloporus arenicolus*** **presence verified since 2005**
- 55 **U.S. route**
- 55 **State route**
- 55 **County road**
- Road **Road**
- City **Populated area**
- **Township boundary**
- **Distribution boundary**
- **Shinnery Oak dominated shrubland and duneland, classified by Natural Heritage New Mexico**

Atlas of distribution and habitat of the dunes sagebrush lizard (*Sceloporus arenicolus*) in New Mexico

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Lee A. Fitzgerald

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Texas A&M University, College Station, TX 77843-2258

CITATION

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PRINTING INSTRUCTIONS

The electronic (pdf) file of this atlas is designed to be printed on 11x17 pages. At this size, the map scale is 1:30,000, and 1.0 inch corresponds to 0.47 mile. If printed at a different size the graphic scale on each page allows accurate determination of distance.

ISBN 978-0-615-40937-5

Purpose

This atlas is a visual tool for understanding the geographic distribution of the dunes sagebrush lizard (*Sceloporus arenicolus*) in the context of its unique and easily identifiable habitat, shinnery oak dune complexes. *Sceloporus arenicolus* is endemic to the Mescalero Sands and Monahans Sandhills ecosystem and occurs exclusively in shinnery oak dune complexes characterized by open sand dune blowouts. Because these features can be accurately perceived with remotely sensed imagery, the atlas serves to identify potential and suitable habitat of *Sceloporus arenicolus*. The atlas illustrates the extent, connectivity, and fragmentation of the species' habitat.

Scale

The atlas is designed to be printed on 11"x17" pages. When printed at this size, the scale of the map is 1:30,000. Therefore, 1" (2.54 cm) on the map is equivalent to 0.47 mi or 0.76 km. The graphic scale on each page allows accurate determination of distance if the atlas is printed at a different size.

Atlas Data Layers and Details

The atlas was created in ArcInfo 9.3 by overlaying the following layers:

- One-meter resolution Digital Orthophoto Quarter Quads (DOQQs) from 2004 serve as the basemap of the atlas;
- *Sceloporus arenicolus* locality data, derived from specimen voucher data obtained from natural history collections and surveys conducted in 2008 – 2010;
- Vegetation classification from Natural Heritage New Mexico[1,2] illustrating shinnery oak (*Quercus havardii)* dominated shrubland and duneland;
- *Sceloporus arenicolus* geographic range polygon, described below;
- Township-and-Range based on the Public Land Survey System available from the Bureau of Land Management, New Mexico State Office.

A total of 85 detailed maps covering the range of *Sceloporus arenicolus* in New Mexico are provided in this atlas. A separate atlas covers the species' range in Texas[3] These maps cover the known geographic distribution of the lizard, and also potential habitat that that has not been surveyed but appears suitable based on DOQQs and vegetation classification (e.g., maps 18 and 24). In addition to the map layers described above, UTM coordinates on the corners of each page assist the user in finding localities and potential sites. Road names are included for many of the roads that are visible on the maps. GIS road layers, Google map, and Yahoo map were used to determine and provide as many road names as possible.

Sceloporus arenicolus presence is depicted using different colors for historical localities and for localities where *Sceloporus arenicolus* has been found since 2005. This distinction is only provided to allow the user with more information; the atlas is not intended to analyze patterns of colonization or extirpation. An appendix gives coordinates for the *Sceloporus arenicolus* localities. It is important to note that the locality numbers in the atlas were generated for the purposes of this publication, and do not correspond to site numbers associated with any projects or research on *Sceloporus arenicolus*.

Geographic Range Polygon

The range of *Sceloporus arenicolus* was determined by visual assessment of the following data layers in ArcInfo 9.3:

- *Sceloporus arenicolus* presence and absence localities, derived from surveys conducted in 1994 – 1996[4], and 2008 – 2010, and from specimen voucher data.
- A series of 1-meter resolution Digital Orthophoto Quarter Quads (DOQQs) from 2004. These ortho-rectified aerial photos allow visual assessment of the shinnery oak sand dune blowout landforms throughout the range of *S. arenicolus* as of 2004.
- Vegetation classification from Natural Heritage New Mexico[1,2,] illustrating shinnery oak (*Quercus havardii*) vegetation.
- A soil model provided by BLM, Carlsbad Office, produced by Ty Allen that illustrates areas that have sandy soils with sand sub-surface, which is correlated to *Sceloporus arenicolus* localities.

Using the above information, the known geographic range of *Sceloporus arenicolus* was delineated to include continuous blowout landforms and shinnery oak vegetation where soils were categorized as suitable and where *Sceloporus arenicolus* presence has been verified. Where vegetation or soils were unavailable (due to extent of the GIS layer), delineation relied on DOQQs and survey data.

References:

[1]Neville, P., T. Neville, and K. Johnson. 2005. Lesser prairie-chicken habitat map for portions of Eastern New Mexico, Natural Heritage New Mexico Publication No. 05-GTR-285, University of New Mexico, Albuquerque. 77 pp.

[2]Neville, P., T. Neville, and K. Johnson. 2007. Map of a portion of potential sand dune lizard habitat in Southeastern New Mexico. Natural Heritage New Mexico Publ. No. 07-GTR-318. Natural Heritage New Mexico, University of New Mexico, Albuquerque, NM. 71 p.

[3]Laurencio, D., L.R. Laurencio, and L.A. Fitzgerald. 2007. Geographic Distribution and Habitat Suitability of the Sand Dune Lizard (*Sceloporus arenicolus*) in Texas. Final report to Texas Parks and Wildlife Department, Austin, TX. 17 pp + appendix.

[4]Fitzgerald, L.A., C.W. Painter, D.A. Sias, H.L. Snell. 1997. The range, distribution and habitat of Sceloporus arenicolus in New Mexico. Final report to New Mexico Department of Game and Fish, Santa Fe, NM. 30 pp + appendices.