



*VIA EMAIL AND E-PLANNING Website*

September 7, 2021

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**Re: Comments on the Proposed Draft Environmental Assessment for the Arica and Victory Pass Solar Projects DOI-BLM-CA-D060-2020-0009-EA (Arica Solar), DOI-BLM-CA-D060-2020-0010-EA (Victory Pass Solar)**

Dear Mr. Anderson:

These comments are submitted on behalf of the Center for Biological Diversity and the Mojave Desert Land Trust regarding the Draft Environmental Assessment for the Arica and Victory Pass Solar Projects dated August 2021 and issued by the Bureau of Land Management (“BLM”).

The development of renewable energy is a critical component of efforts to reduce greenhouse gas emissions, avoid the worst consequences of global warming, and to assist California in meeting its ambitious emission reductions goals. The Center for Biological Diversity (the “Center”) strongly support the development of renewable energy production, and the generation of electricity from solar power, in particular. However, like any project, proposed solar power projects should be thoughtfully planned to minimize impacts to the environment. In particular, renewable energy projects should avoid impacts to sensitive species and habitats and should be sited in proximity to the areas of electricity end-use in order to reduce the need for extensive new transmission corridors and the efficiency loss associated with extended energy transmission. Only by maintaining the highest environmental standards with regard to local impacts, and effects on species and habitat, can renewable energy production be truly sustainable.

The Center participated regularly in the processes that resulted in the BLM’s adoption of the Desert Renewable Energy Conservation Plan (DRECP). We support adherence to the Conservation Management Actions (CMAs) in the DRECP and are concerned about the implementation of the requirements within the Riverside-East Development Focus area where the two projects are located. Our concerns are detailed below.

The proposed action alternative - Alternative B - includes the disturbance on 2,665 acres of habitat for a variety of desert plants and animals in the Colorado Desert. The projects are located on BLM-managed public lands within the Riverside East Development Focus Area (DFA) designated by the Desert Renewable Energy Conservation Plan (DRECP). The Arica solar project is a proposed 265 MW solar project with 200 MW of battery storage. It is proposed to cover 1,355 acres. The Victory Pass is a proposed 200 MW solar project with 200MW of battery storage. It is proposed to cover 1,310 acres. Because of the reduction in the proposed project areas, increased density of the panels will require complete removal of all on-site vegetation in the solar project areas. The projects will share a 3.2-mile overhead gen-tie line that will include an additional 50 acres for the gen-tie ROW corridor and is anticipated to develop 10-15 acres within that ROW corridor.

Almost half of the Arica project lies within the DRECP's modeled habitat for Mojave fringe-toed lizard and the DEA confirms occupancy (at pg. 80). The southwest corner of the Victory Pass project is proposed to have panels placed in the BLM-identified Wildlife Connectivity Corridor, one of only two wildlife connectivity corridors within the DFA, significantly compromising the functionality of this requisite corridor. The gen-tie and part of the Victory Pass solar project will impact federally designated critical habitat for the threatened desert tortoise.

### **Failure to Adequately Analyze and Mitigate Impacts to Mojave Fringe-toed Lizard**

The DEA states that 794 acres of modeled Mojave fringe-toed lizard habitat will be directly "impacted by construction of the solar fields" (at pg. 85) of the proposed Arica solar project. Figure 2 of Appendix F-1 of the DEA shows the overlap of the proposed Arica project with the sand transport corridor which creates habitat for the lizard. Figure 5 of Appendix F-1 shows that a majority of the proposed Arica project site is "Active Eolian Sources Qyf". The DEA relies on the determination that "This is consistent with the DRECP EIS Table IV.7-20 (page IV.7-130) which estimated 6,000 acres of impacts to MFTL habitat" (at pg. 85). However, the DEA fails to identify the number of acres of the sand transport corridor that have already been affected by existing and permitted projects in the DFA. It fails to analyze the development of the proposed Arica project on the "Active Eolian Sources Qyf" which appears to be greater than the 794 acres identified in the DEA. Figure 6 of Appendix F-1 shows that a majority of the proposed Victory Pass project site is "Active Eolian Sources Qyf". No quantification of the actual acreage of impact to "Active Eolian Sources Qyf" is provided for either project. The DEA fails to provide a cumulative impact analysis to the sand transport corridor functionality when coupled with all the existing and permitted projects' direct impacts. The DEA conjectures that the design of the solar fields will not impede saltation or fluvial sand transport yet provides no documentation of the success of such designs. It also fails to evaluate the impacts from the perimeter site fencing of the proposed projects which is known to reduce sand migration particularly if wind-blown detritus builds up along the upwind fencing.

The DEA fails to provide an analysis of the down-wind impacts of the projects on the sand transport corridor that create and maintain dune habitat. Appendix F-1 (at pg.8) states

"The primary off-site impact could be the disruption of sand being transported to the sand transport corridor. Potential indirect impacts of a solar facility could be sand shadows that extend beyond a project boundary. Sand shadows are defined as areas where the upwind supply of sand is cut off by fences and other infrastructure, and therefore, existing sand can be eroded downwind without replacement from upwind sources, resulting in the loss of the fine sand upon which dune habitats are dependent."

The DEA needs to fully analyze the off-site impacts including cumulative off-site impacts from existing and permitted projects.

The DEA proposes to mitigate the direct impacts to Mojave fringe-toed lizard habitat as follows:

“...direct impacts to habitat would be compensated for at a ratio of 1:1 as required in MM BIO-6 (Compensation for Special-Status Species Habitat Impacts). MM BIO-6 further requires that compensation lands provide habitat value that is comparable to the habitat impacted.”

DEA at pg. 86

Other solar energy projects proposed to impact Mojave fringe-toed lizard habitat have identified mitigation ratios of 5:1 and 3:1 for direct impacts to all occupied Mojave fringe-toed lizard habitat and lesser ratios for indirect impacts. For example, Desert Sunlight project was required to mitigate any unavoidable impacts to the Mojave fringe-toed lizard habitat up to 5:1 for direct impacts to all occupied Mojave fringe-toed lizard habitat and lesser ratios for indirect impacts (Desert Sunlight FEIS at 4.4-40). The Desert Harvest project (Desert Harvest FEIS at Wil-4) was also required to produce a Mojave Fringe-toed Lizard Protection Plan. The DEA provides no explanation for failing to require a Mojave Fringe-toed Lizard Protection Plan for this proposed project which clearly is sited in Mojave fringe-toed lizard habitat. The DEA fails to identify why only a 1:1 mitigation ratio is being required for direct impacts. The DEA fails to evaluate or propose mitigation for indirect impacts which is wholly inadequate because indirect impacts will impact Mojave fringe-toed lizard habitat. As Barrows et al. (2006)<sup>1</sup> found, edge effects are significant for fringe-toed lizards and, in addition, the increase in predators associated with developed edges may also have a significant adverse effect on fringe-toed lizards and other species, therefore additional mitigation is warranted.

Due to the DEA’s failure to analyze off-site impacts, the proposed mitigation is inadequate. The DEA also fails to identify if adequate “comparable” habitat is even available for permanent conservation due to the existing and permitted projects’ need for mitigation for their direct and indirect impacts to the sand transport corridor and Mojave fringe-toed lizard habitat. Is the proposed mitigation even feasible?

### **Failure to Adequately Analyze and Mitigate Impacts to Wildlife Connectivity/Corridor**

Wildlife connectivity corridors are place-based areas that are often unmitigable if impacts occur. The DRECP identified and established three wildlife connectivity corridors in the Riverside-East DFA (DRECP at Figure H-1). The attached Figure (Attachment 1) shows the overlap of Victory Pass’ solar field into the BLM’s Wildlife Connectivity Corridor designated as required by the DRECP. Figure 3.12-5 appears to be a much larger connectivity corridor than BLM’s GIS-layer that is publicly available and that was part of the DRECP in the Proposed LUPA and Final EIS at Figure H-1.

The DEA states:

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<sup>1</sup> Barrows et al. 2006

“Within the Cadiz Valley and Chocolate Mountains ecoregion subarea, where the Project areas are located, landscape-level habitat linkages cover approximately 905,000 acres as noted in the DRECP EIS Section III.7.8 (page III.7-231). These linkage areas are primarily located along the desert valleys, providing connectivity between isolated mountain ranges within the ecoregion sub-area. The Projects are located within the Palen McCoy Mountains–Chocolate Mountains linkage (see DRECP EIS Figure III.7-26). Approximately 59 acres of the western portion of the Victory Pass Project overlaps with the easternmost edge of the multiple-species linkage area identified in the DRECP (BLM, 2016)”.

DEA at pg. 81.

The above paragraph suggests that there is plenty of room for wildlife to connect in the area (905,000 acres). The DEA fails to identify that *within* the Riverside East DFA, this corridor is narrowly constrained and only one of two wildlife connectivity corridors that have been designated within the DFA. The DEA fails to identify the acres of BLM’s Wildlife Connectivity Corridor that is within the two project areas. A revised draft need to adequately identify the number of acres of the BLM-designated wildlife corridor within the project boundary and the impact from fencing off 59 acres.

Regarding mitigation to offset impacts to BLM’s Wildlife Connectivity Corridor the DEA states:

“The direct and indirect effects would be avoided, minimized, or offset through habitat compensation and a series of APMs and CMAs provided in full in Appendix E. This section of the EA identifies MMs to ensure effective mitigation of each potential impact. The full text of the mitigation measures (MM) appears in Appendix E.”

DEA at pg. 81

The proposed AMPs, MMs and CMAs in Appendix E (both E-1 and E-2) do not mention wildlife connectivity or propose avoidance, minimization or any mitigation. Because wildlife connectivity is hyper-focused on local landscape parameters and that local wildlife rely on, impacts are difficult to avoid, minimize and mitigate. The reason BLM identified the connectivity was to safeguard existing wildlife corridors through the DFA. Encroaching on the BLM-designated Wildlife Connectivity Corridor, particularly the cumulative impacts (i.e. Oberon project directly west of Victory Pass) which were not addressed in the EA will likely render the corridor useless to wildlife and defeat the purpose of the BLM’s designation.

### **Failure to Adequately Analyze and Mitigate Impacts to Wildlife Habitat Management Areas**

Even after the DRECP was adopted some aspects of the CDCA/NECO plan remain in effect overall. Under the NECO plan, Wildlife Habitat Management Areas (WHMAs) “address other special status species and habitat management” (NECO at 2-2). NECO also states that “The existing restricted areas, DWMAs, and WHMAs form the Multi-species Conservation Zone” (NECO at 2-2) which is the conservation basis of the NECO plan. The proposed project area overlaps one of the multi-species WHMA that includes the Mule Mountains. Management emphasis for the Mule Mountain WHMA is on active management of specific species and habitats mitigation, and restoration from authorized allowable uses. The overlap of the proposed project is not addressed in the DEA/DEIR. The NECO Plan goals and objectives for “Other Special Status Animal and Plant Species, Natural Communities, and Ecological Processes” are very specific and focus on conservation:

Goals for special status animal and plant species, natural communities, and ecological processes are as follows:

- Plants and Animals. Maintain the naturally occurring distribution of 28 special status animal species and 30 special status plant species in the planning area. For bats, the term "naturally occurring" includes those populations that might occupy man-made mine shafts and adits.
- Natural Communities. Maintain proper functioning condition in all natural communities with special emphasis on communities that a) are present in small quantity, b) have a high species richness, and c) support many special status species.
- Ecological Processes. Maintain naturally occurring interrelationships among various biotic and abiotic elements of the environment.

The objectives are to

- a. protect and enhance habitat
- b. protect connectivity between protected communities

(NECO Plan at 2-52.) Further, the NECO Plan adopted action items to promote the objectives to “Protect and enhance habitat” (NECO Plan at 2-55), and “Protect connectivity between protected communities” (NECO Plan at 2-58). *See also* NECO Plan ROD at D-1, D-3.

For the first objective, to protect and enhance habitat, the first “action” is to:

Designate seventeen multi-species WHMAs (totaling 555,523 acres) such that approximately 80 percent of the distribution of all special status species and all natural community types would be included in the Multi-species Conservation Zone (Map 2-21 Appendix A). See Appendix H for a description of the process used to define the WHMA and the concept of conservation zones.

(NECO Plan at 2-55.) For the second objective, to protect connectivity, one of the actions states that: “The fragmenting affects of projects should be considered in the placement, design, and permitting of new projects.” (NECO Plan at 2-58.) Other relevant “actions” include:

Require mitigation of impacts of proposed projects in suitable habitat within the range of a special status species and within natural community types using commonly applied mitigation measures and conduct surveys in the proposed project area for special status species as follows (also see range maps 3-6a-f and 3-7a-f Appendix A):

(NECO Plan at 2-55.)

Thus under the NECO plan, the impacts to multiple species WHMA and to sand and playa areas and Mojave fringe-toed lizard should be avoided. The DEA does not mention, much less analyze impacts to the WHMA as required by the NECO plan (as well as NEPA). Attachment 2 shows that most of the Arica project lies within a WHMA. A revised EA must identify this WHMA and analyze impacts from the proposed project on it.

## The Analysis of Cumulative Impacts in the DEA/DEIR Is Inadequate

A cumulative impact is “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.” 40 C.F.R. § 1508.7. The Ninth Circuit requires federal agencies to “catalogue” and provide useful analysis of past, present, and future projects. *City of Carmel-By-The-Sea v. U.S. Dept. of Transp.*, 123 F.3d 1142, 1160 (9<sup>th</sup> Cir. 1997); *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 809-810 (9<sup>th</sup> Cir. 1999).

“In determining whether a proposed action will significantly impact the human environment, the agency must consider ‘[w]hether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment.’ 40 C.F.R. § 1508.27(b)(7).” *Oregon Natural Resources Council v. BLM*, 470 F.3d 818, 822-823 (9<sup>th</sup> Cir. 2006). NEPA requires that cumulative impacts analysis provide “some quantified or detailed information,” because “[w]ithout such information, neither courts nor the public . . . can be assured that the Forest Service provided the hard look that it is required to provide.” *Neighbors of Cuddy Mountain v. United States Forest Service*, 137 F.3d 1372, 1379 (9<sup>th</sup> Cir. 1998); *see also id.* (“very general” cumulative impacts information was not hard look required by NEPA). The discussion of future foreseeable actions requires more than a list of the number of acres affected, which is a necessary but not sufficient component of a NEPA analysis; the agency must also consider the actual environmental effects that can be expected from the projects on those acres. *See Klamath-Siskiyou Wildlands Ctr. v. BLM*, 387 F.3d 989, 995-96 (9<sup>th</sup> Cir. 2004) (finding that the environmental review documents “do not sufficiently identify or discuss the incremental impact that can be expected from each [project], or how those individual impacts might combine or synergistically interact with each other to affect the [] environment. As a result, they do not satisfy the requirements of the NEPA.”) Finally, cumulative analysis must be done as early in the environmental review process as possible, it is not appropriate to “defer consideration of cumulative impacts to a future date. ‘NEPA requires consideration of the potential impacts of an action *before* the action takes place.’” *Neighbors*, 137 F.3d at 1380 *quoting City of Tenakee Springs v. Clough*, 915 F.2d 1308, 1313 (9<sup>th</sup> Cir. 1990) (emphasis in original).

The DEA fails to adequately identify the numerous cumulative projects and does not meaningfully analyze the cumulative impacts to resources in the California desert from the many proposed projects (including renewable energy projects and others). Moreover, because the initial identification and analysis of impacts is incomplete, the cumulative impacts analysis cannot be completed.

## Conclusion

Thank you for your consideration of these comments. In light of the shortcomings in the DEA, we urge the BLM to revise and re-circulate the DEA before making any decision regarding

the proposed plan amendment and right-of-way application. In the event BLM chooses not to revise the DEA and provide adequate analysis, the BLM should reject the right-of-way application and the plan amendment. Please feel free to contact us if you have any questions about these comments or the documents provided.

Sincerely,



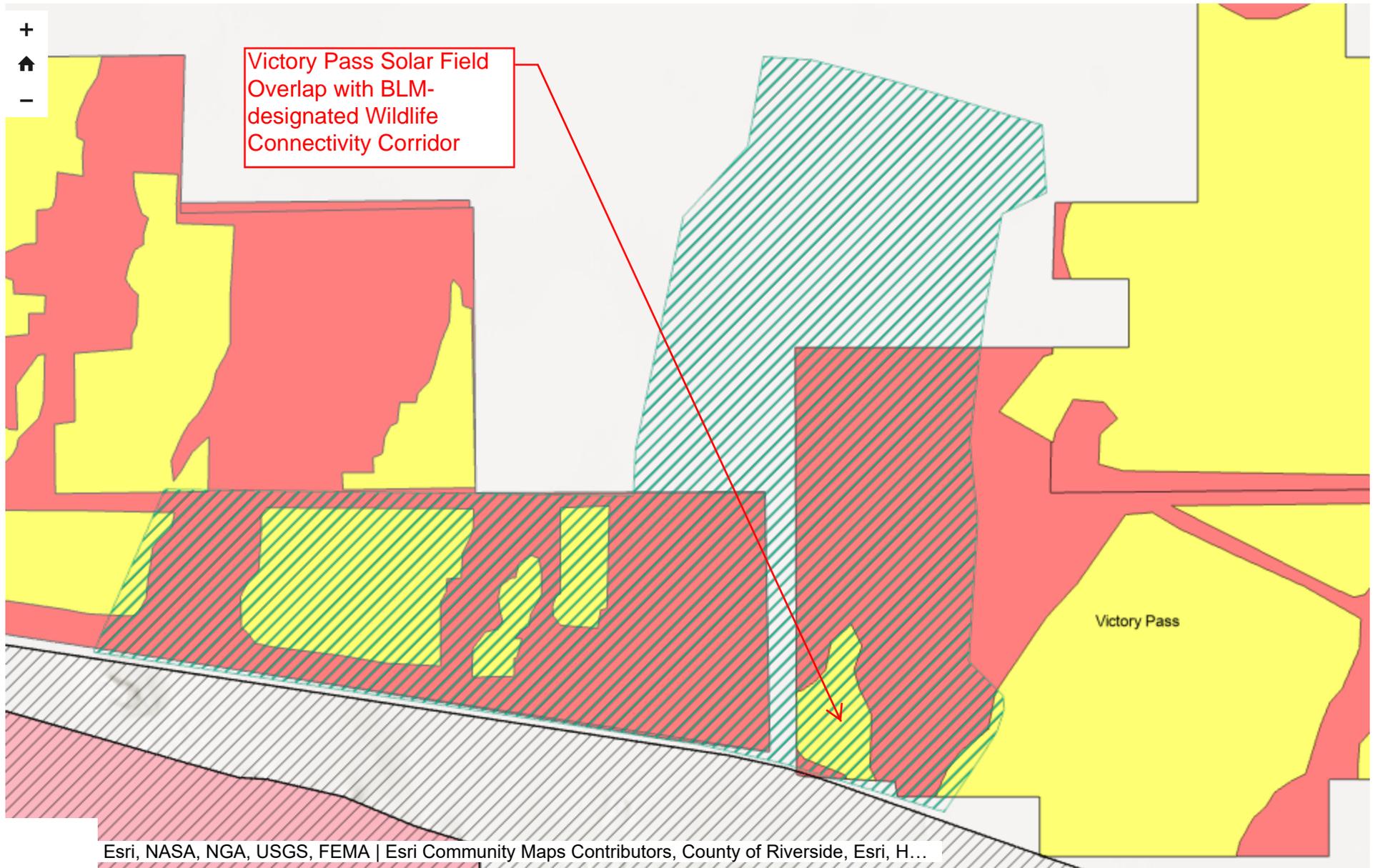
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**Reference:** Attachment 3

Barrows, C.W., M.F. Allen and J.T. Rotenberry 2006. Boundary processes between a desert sand dune community and an encroaching suburban landscape. *Biological Conservation* 131: 486-494.  
<https://pdfs.semanticscholar.org/574f/b229ffcf6f8d19d7dba74349c6fb40530d3b.pdf>



# Solar In The Desert



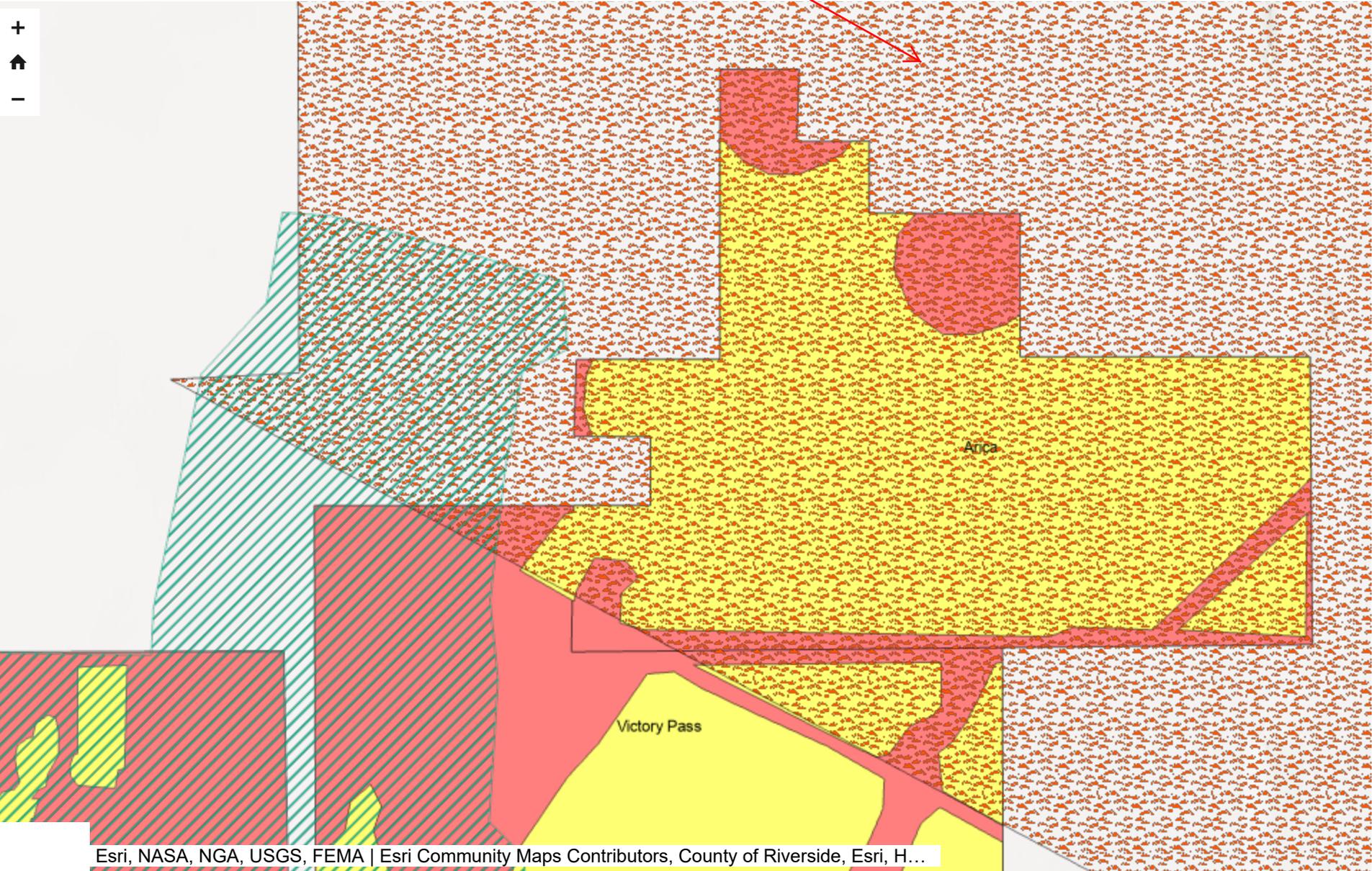
Attachment 1. Victory Pass Overlap with BLM-Designated Wildlife Connectivity Corridor



# Solar In The Desert



BLM-designated  
Wildlife Habitat  
Management Area  
(NECO LUPA)



Esri, NASA, NGA, USGS, FEMA | Esri Community Maps Contributors, County of Riverside, Esri, H...

Attachment 2. Arica Overlap with BLM-Designated Wildlife Habitat Management Area

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# Boundary processes between a desert sand dune community and an encroaching suburban landscape

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## ARTICLE INFO

### Article history:

Received 3 September 2005

Received in revised form

6 December 2005

Accepted 20 December 2005

Available online 8 June 2006

### Keywords:

Edge effect

Anthropogenic boundary processes

Desert aeolian sand community

Flat-tailed horned lizard

Loggerhead shrike: Predation

## ABSTRACT

In contrast to the body of work in more mesic habitats, few studies have examined boundary processes between natural and anthropogenic desert landscapes. Our research examined processes occurring at boundaries between a desert sand dune community and an encroaching suburban habitat. We measured responses to an anthropogenic boundary by species from multiple trophic levels, and incorporated measures of habitat suitability, and temporal variation, at multiple spatial scales. At an edge versus core habitat scale the only aeolian sand species that demonstrated an unambiguous negative response to the anthropogenic habitat edges was the flat-tailed horned lizard (*Phrynosoma mcallii*). Conversely loggerhead shrikes (*Lanius ludovicianus*) demonstrated a positive response to that edge. At a finer scale, species that exhibited a response to a habitat edge within the first 250 m included the horned lizards along with desert kangaroo rats (*Dipodomys deserti*). The latter species' response was confined to 25 m from the edge. For the flat-tailed horned lizard, edge effects were measured up to 150 m from the habitat boundary. Three potential causal hypotheses were explored to explain the edge effect on horned lizards: (1) invasions of exotic ant species reducing potential prey for the lizards; (2) road avoidance and road associated mortalities; and (3) predation from a suite of avian predators whose occurrence and abundance may be augmented by resources available in the suburban habitat. We rejected the exotic ant hypothesis due to the absence of exotic ants within the boundary region, and because native ant species (prey for horned lizards) did not show an edge effect. Our data supported the predation and road mortality hypotheses. Mechanisms for regulating population dynamics of desert species are often "bottom-up," stochastic processes driven by precipitation. The juxtaposition of an anthropogenic edge appears to have created a shift to a "top-down," predator-mediated dynamic for these lizards.

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## 1. Introduction

Primary mechanisms that distinguish processes at habitat boundaries include: (1) abiotic gradients unique to those boundaries, (2) access to spatially separated resources and

(3) species interactions (Wiens et al., 1985; Murcia, 1995; Laurance et al., 2002; Ries et al., 2004). Collectively these mechanisms create a conceptual framework for understanding ecological boundary responses. Additionally, understanding factors that control the occurrence and dynamics of popula-

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doi:10.1016/j.biocon.2005.12.024

tions in relatively unfragmented habitat provide a context from which to evaluate how those drivers are impacted at boundaries. In arid ecosystems highly variable and unpredictable precipitation often regulates biological processes (Noy-Meir, 1973). Support for this axiom can be found across a broad range of taxa and regions (Mayhew, 1965, 1966; Pianka, 1970; Ballinger, 1977; Whitford and Creusere, 1977; Seely and Louw, 1980; Dunham, 1981; Abts, 1987; Robinson, 1990; Brown and Ernest, 2002; Germano and Williams, 2005). Population dynamics of desert species are often characterized as being regulated from the bottom-up, by resource availability mediated by annual rainfall (Brown and Ernest, 2002). In contrast, Faeth et al. (2005) described a shift in the processes controlling population dynamics in a suburban desert environment. There irrigated landscapes regulated productivity and resulted in a predation controlled, top-down community. These different population regulating processes meet at the boundary between natural desert and anthropogenic habitats. The extent to which processes generated by anthropogenic habitats encroach on the natural desert and impact components of that community is the subject of this paper.

In contrast to the body of work in more mesic habitats, few studies have examined boundary processes between natural and anthropogenic desert landscapes (e.g., Germaine et al., 1998; Germaine and Wakeling, 2001; Boal et al., 2003; Gutzwiller and Barrow, 2003). Here we examined processes and species occurring at boundaries between an aeolian sand landscape and encroaching suburban and abandoned agricultural field habitats. Distinguishing between variance in abundance imposed by the heterogeneity of the available habitats and what if any effects the proximity of an edge has on the distribution of native species is critical in determining the ecological importance of those edges (Bolger et al., 1997; Fagan et al., 2003). We incorporated measures of habitat suitability and temporal variation at multiple spatial scales to identify whether components of an aeolian sand community have altered their distributions in response to the presence of anthropogenic habitat edges.

Much of the previous research on edges has focused on temperate and tropical habitats (Janzen, 1983; Wilcove, 1985; Laurance, 1991; Murcia, 1995; Laurance et al., 2002; Watson et al., 2004) where boundary-mediated ecological flow processes extend from 10 to 400 m into interior habitats (i.e., Kapos, 1989; Camargo and Kapos, 1995; Laurance et al., 2002). Fewer studies have investigated edge effects in semi-arid environments, with much of that work focusing on coastal sage scrub in southern California (Bolger et al., 1991; Bolger et al., 1997; Kristan et al., 2003). In this habitat, moisture gradients at suburban-natural community boundaries have limited the invasion of non-native ants to 100 m or more into the natural communities from mesic refuges in the suburban landscape, with a corresponding negative cascade affecting overall native species richness (Suarez et al., 1998). Increased predation is another factor identified at sage scrub boundaries (Bolger et al., 1991; Bolger et al., 1997; Crooks and Soulé, 1999; Suarez et al., 2000; Suarez and Case, 2002; Unfried, 2003). Collectively these findings define the range of anthropogenic boundary impacts described to date. Our objective was to determine whether any of these impacts also influence the distribution and abundance of species in desert habitats.

## 2. Methods

### 2.1. Study area

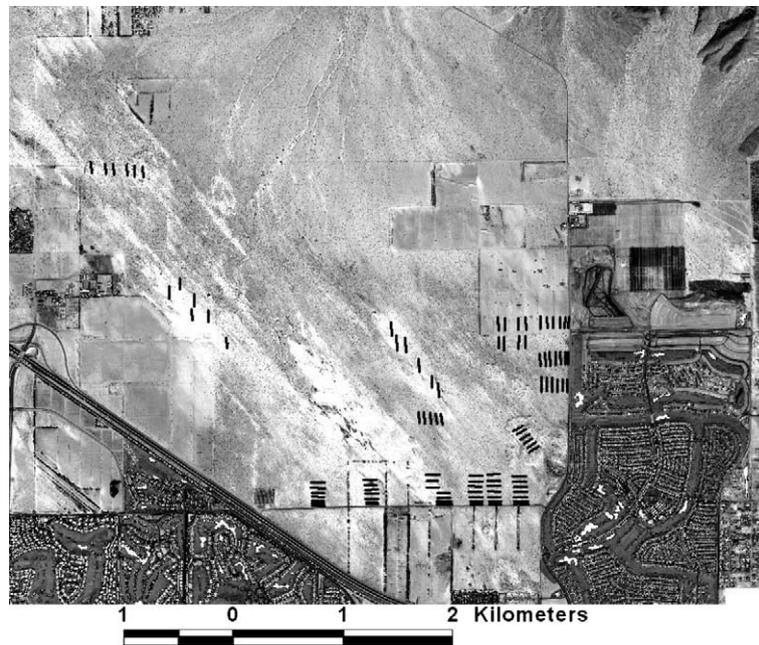
Aeolian sand habitats were studied within the Thousand Palms Preserve (33°47'N, 116°20'W) in the Coachella Valley near Palm Desert, Riverside County, California. The Preserve includes approximately 1300 ha of contiguous sand dunes and hummocks. The Coachella Valley is an extremely arid shrub desert with a mean annual rainfall of 79–125 mm (most recent 60 year means, Western Regional Climate Center, Palm Springs and Indio reporting stations). The lowest rainfall year occurred in 2002, with just 4–7 mm recorded across the valley floor. Temperatures range from a low approaching 0 °C in the winter to highs exceeding 45 °C commonly recorded during July and August.

Study plots were designed to enable analyses at both a coarse scale (edge versus interior plots) and at a finer scale along the habitat edges (within plot distance from the habitat edge). Additionally, study plots were established to identify effects from two separate edge types. Fourteen study plots were established within the Preserve: three were located along a 2.4-km boundary with a suburban golf course community, six were located along a 3.2-km boundary with an abandoned agricultural area and sparse rural housing (Fig. 1), and five control plots were centrally located in “core” habitat, greater than 500 m from roads. There was a four-lane paved road separating the Preserve from the suburban habitat and a two-lane paved road separating the Preserve from an area of abandoned agriculture. All study plots were located in a stratified random manner. Plots were stratified so as to include both active sand dune and sand hummock habitat in a proportion corresponding to the aerial extent of those different habitat types. Edge plots were established adjacent to paved roads, but randomly located along the roadway.

Each of the 14 study plots consisted of a cluster of 5–8, 10 m × 100 m belt transects. Edge plots included seven transects, with the first centered on a barbed wire boundary fence and running parallel to the fence and adjacent paved road. A second transect was established parallel to the first, but was 25 m interior from the edge. Additional parallel transects were placed at 50, 100, 150, 200, and 250 m from the edge. Core plots consisted of similar clusters of belt transects with the same dimensions as the edge sites. Core plots were >500 m from any roadway, residence, or habitat discontinuity and included five to eight parallel belt transects separated by 50–150 m. Each transect was marked with a short wooden stake at the beginning, middle, and end so that their position with respect to the boundaries of the belt transect could be readily determined. Each study plot covered approximately 2.5 ha. Surveys were repeated six times at each plot between June and July each year from 2002 through 2004. Data collected in 2002 focused on flat-tailed horned lizards, *Phrynosoma mcallii*. Data collected in 2003 and 2004 included all species encountered.

### 2.2. Survey protocol

The fine aeolian sand of the Thousand Palms Preserve presented an opportunity unique to sand dunes to quantify the



**Fig. 1 – Satellite image depicting distribution of plots, extent of aeolian sand habitat, juxtaposition of suburban golf course development and abandoned agricultural fields, and roads.**

occurrence and abundance of all terrestrial species occurring along transects with more or less equal detectability. Each vertebrate species could be identified to species and age class by their diagnostic tracks left in the sand. Ground-based species left easily identifiable tracks, and so their ability to avoid detection by differences in activity times, cryptic coloration, or stealthy behavior was nullified. Because late afternoon and evening breezes would wipe the sand clean the next day's accumulation of tracks could not be confused with those from the previous day. On those days when the wind did not blow, tracks from the current day could be distinguished from those from previous days by whether or not the tracks of nocturnal arthropods crossed over the vertebrate's track. Lizard track identification criteria were developed by spending several weeks prior to surveys, following tracks until animals were located and the species and age class was confirmed. Tracks from other diurnal vertebrates were confirmed as they were encountered during pre-survey field work. Nocturnal or otherwise cryptic species' tracks were confirmed by comparisons with foot sizes and configurations from museum specimens.

Surveys would begin after the sand surface temperature had risen sufficiently so that diurnal reptiles were observed to be active, usually  $\geq 35^\circ\text{C}$ . Surveys continued until late morning when the high angle of the sun reduced the observer's ability to distinguish and identify tracks. One or two observers working in tandem completed a survey on a given study plot in 30–45 min, recording all fresh tracks observed within the 10-m wide belt of each 100 m transect. Tracks were followed off transect if it was necessary to confirm a species' identification and to insure that the same individual was not crossing the same transect repeatedly, thus avoiding an inflated count of the individuals active on that transect. Data for separate transects were considered independent for most

species. In addition to tracks, we recorded any sightings of animals along transects and recorded any bird vocalizations heard during a survey. Wide ranging predators such as coyotes (*Canis latrans*), greater roadrunners (*Geococcyx californianus*), American kestrels (*Falco sparverius*), and loggerhead shrikes (*Lanius ludovicianus*), had ranges much larger than the transect dimensions, and so were recorded as present on a study plot, rather than on individual transects.

Harvester Ants (*Pogonomyrmex* spp.) were sampled using dry pitfall traps in April of each year. Previous arthropod sampling efforts (Barrows, unpublished data) have indicated that in most years ant numbers reached peak numbers in April. This was also the period when lizards eating ants would be consuming the resources necessary for egg production in the ensuing months. Three pitfall traps were placed on each transect; one at both ends and another at the transect middle. The traps were collected within 24 h of being set out to avoid any mortality of vertebrates that happened into the traps. Ant data were presented as the total count per transect.

### 2.3. Habitat measures

Vegetation density and plant species composition were measured on each transect each year. All perennial shrubs were counted within the 10-m  $\times$  100 m belt transects. Annual plants were counted and cover estimated in a 1 m<sup>2</sup> sampling frame placed at 12 locations along the midline of the belt transect.

Sand compaction has been described as a key habitat variable for Coachella Valley fringe-toed lizards, *Uma inornata*, (Barrows, 1997), and may be important for other psammophilic species. Sand compaction was measured at 25 points, approximately four m apart, along the midline of each belt transect

using a hand-held penetrometer with an adapter foot for loose soils (Ben Meadows Company, Janesville, WI, USA).

#### 2.4. Data analysis

A one-way analysis of variance (ANOVA) was employed to conduct coarser scale analyses, examining edge versus core differences, and to include wider ranging bird species. Here edge plots adjacent to the preserve edge (including transects ranging from 0 to 250 m from that edge) were compared with core plots (>500 m from the preserve edge). A two-way ANOVA was conducted to partition finer scale variance in species abundance between the treatment (distance from the preserve edge) and variance associated with habitat heterogeneity between each of the edge plots.

For the nine edge plots, data for those species that showed statistically significant variation with respect to distance to edge (0–250 m) were then subjected to multiple linear regression to determine whether environmental variation coincident with the edge distance could explain that observed variance. All variables were tested for normality and transformed with natural logs when necessary. Dependent variables were means of the six surveys on each transect per year for each species. Independent variables included measures of sand compaction ( $\text{kg}/\text{cm}^2$ ) for each year, shrub density ( $\text{shrubs}/\text{m}^2$ ), and linear distance from the Preserve edge. Total observations equaled 63 (seven transects/plot over nine plots), and since one or two variables were included in the regression analyses, model over fitting was avoided. Linear regression analyses were performed using SYSTAT 10.0 (SYSTAT, Wilkinson, 1990). A threshold of  $\alpha = 0.05$  for statistical significance was used throughout this paper.

### 3. Results

Of the nine species tested with ANOVAs at the edge versus core scale, only the flat-tailed horned lizard and the loggerhead shrike showed a statistically significant effect, although their responses were opposite (Table 1). Shrikes were more common along the edge whereas the horned lizards were more abundant in the core. At the finer scale, for those nine plots situated along the Preserve boundary, distance from the Preserve edge was found to be a significant source of variance for the flat-tailed horned lizard, and the desert kangaroo rat, *Dipodomys deserti* (Table 2).

These statistical results are corroborated by the patterns of temporal and spatial species' abundance for the seven sand dune occurring species included in our analysis (Fig. 2a–g). There were no consistent responses to proximity of the habitat boundary for Coachella Valley round-tailed ground squirrels (*Spermophilus tereticaudus chlorus*), sidewinders (*Crotalus cerastes*), western shovel-nosed snakes (*Chionactis occipitalis*), and harvester ants (*Pogonomyrmex* spp., including *Pogonomyrmex californicus* and *Pogonomyrmex magnacanthus*). The abundance of both fringe-toed lizards and desert kangaroo rats appeared to be reduced along the immediate habitat edge in both 2003 and 2004, but not at distances  $\geq 25$  m from that boundary in either year. In contrast, abundance of flat-tailed horned lizards was reduced at distances from the habitat edge of 150 m in 2002, and 100 m in 2003 and 2004.

For the nine edge plots, Pearson's correlations were calculated for distance from the habitat edge and sand compaction and shrub density. Edge distance was not correlated with sand compaction ( $r = -0.001$  to  $-0.135$ , all  $P = 0.0335$ – $0.995$ ), and was only moderately negatively correlated with shrub

**Table 1 – Analysis of variance (ANOVA) of the abundance of nine species at the larger, edge versus core, scale**

Species	Source of variation	SS	df	MS	F	P-value
Coachella Valley fringe-toed lizard	Edge effect	1.404	1	1.404	0.871	0.361
	Error	33.850	21	1.612		
Flat-tailed horned lizard	Edge effect	1.294	1	1.294	8.464	0.007
	Error	3.975	26	0.153		
Sidewinder	Edge effect	0.008	1	0.008	0.564	0.465
	Error	0.208	14	0.015		
Shovel-nosed snake	Edge effect	0.032	1	0.032	0.211	0.650
	Error	3.344	22	0.152		
Round-tailed ground squirrel	Edge effect	0.302	1	0.302	3.941	0.063
	Error	1.379	18	0.077		
Desert kangaroo rat	Edge effect	0.078	1	0.078	0.125	0.727
	Error	11.781	19	0.620		
Harvester ants	Edge effect	13.209	1	13.209	0.551	0.467
	Error	455.486	19	23.973		
Greater roadrunner	Edge effect	0.009	1	0.009	0.096	0.760
	Error	2.169	22	0.099		
Loggerhead shrike	Edge effect	1.131	1	1.131	18.871	0.0002
	Error	1.558	26	0.060		

The error term represents variation among plots. P-values  $\leq 0.05$  indicate a statistically significant amount of the variance in the distribution of that species is explained by that treatment (edge effect).

**Table 2 – Two-way ANOVAs were employed to determine sources of variance at a smaller, within edge plot, scale**

Species	Source of variation	SS	df	MS	F	P-value
Coachella Valley fringe-toed lizard	Edge effect	11.569	6	1.928	1.629	0.150
	Within group (error)	91.107	77	1.183		
Flat-tailed horned lizard	Edge effect	1.549	6	0.258	9.545	0.007
	Boundary type	0.319	1	0.319	11.810	0.014
	Error	0.162	6	0.027		
Sidewinder	Edge effect	0.008	6	0.001	0.585	0.735
	Boundary type	<0.0001	1	<0.0001	0.010	0.923
	Error	0.014	6	0.002		
Shovel-nosed snake	Edge effect	0.109	6	0.018	2.073	0.198
	Boundary type	0.005	1	0.004	0.550	0.486
	Error	0.053	6	0.009		
Round-tailed ground squirrel	Edge effect	0.075	6	0.013	1.345	0.364
	Boundary type	0.197	1	0.197	21.085	0.004
	Error	0.056	6	0.009		
Desert kangaroo rat	Edge effect	2.683	6	0.447	15.529	0.002
	Boundary type	3.323	1	3.323	115.400	<0.0001
	Error	0.173	6	0.029		
Harvester ants	Edge effect	8.789	6	1.465	1.890	0.229
	Boundary type	13.114	1	13.114	16.921	0.006
	Error	4.650	6	0.775		

Here variance is partitioned between edge effects and between plots occurring along two boundary types. Coachella Valley fringe-toed lizards did not occur along the boundary that included the four-lane road, so only a one-way ANOVA was calculated for edge effect. P-values  $\leq 0.05$  indicate a statistically significant amount of the variance in the distribution of that species is explained by that treatment (edge effect or boundary type).

density ( $r = -0.235$ ,  $P = 0.043$ ). However, sand was consistently more compacted along the immediate Preserve boundary than it was 25 m interior of that boundary (paired t-test,  $P = 0.048$ ).

Multiple regression models were run for the two species for which the within-plot ANOVAs indicated significant edge correlations. Shrub density did not explain a significant amount of the variance in abundance for either species, and so was not included in the models. For flat-tailed horned lizards, a model including edge distance and sand compaction was highly significant ( $F = 27.204$ ;  $df = 2/46$ ;  $P < 0.0001$ ), accounting for over 50% of the total variation in lizard abundance ( $R^2 = 0.542$ ). Both sand compaction and edge distance contributed significantly to the overall model ( $P = 0.004$ / $<0.0001$ ). For desert kangaroo rats, however, the overall regression was not statistically significant ( $F = 2.116$ ;  $df = 2/53$ ;  $P = 0.131$ ,  $R^2 = 0.074$ ).

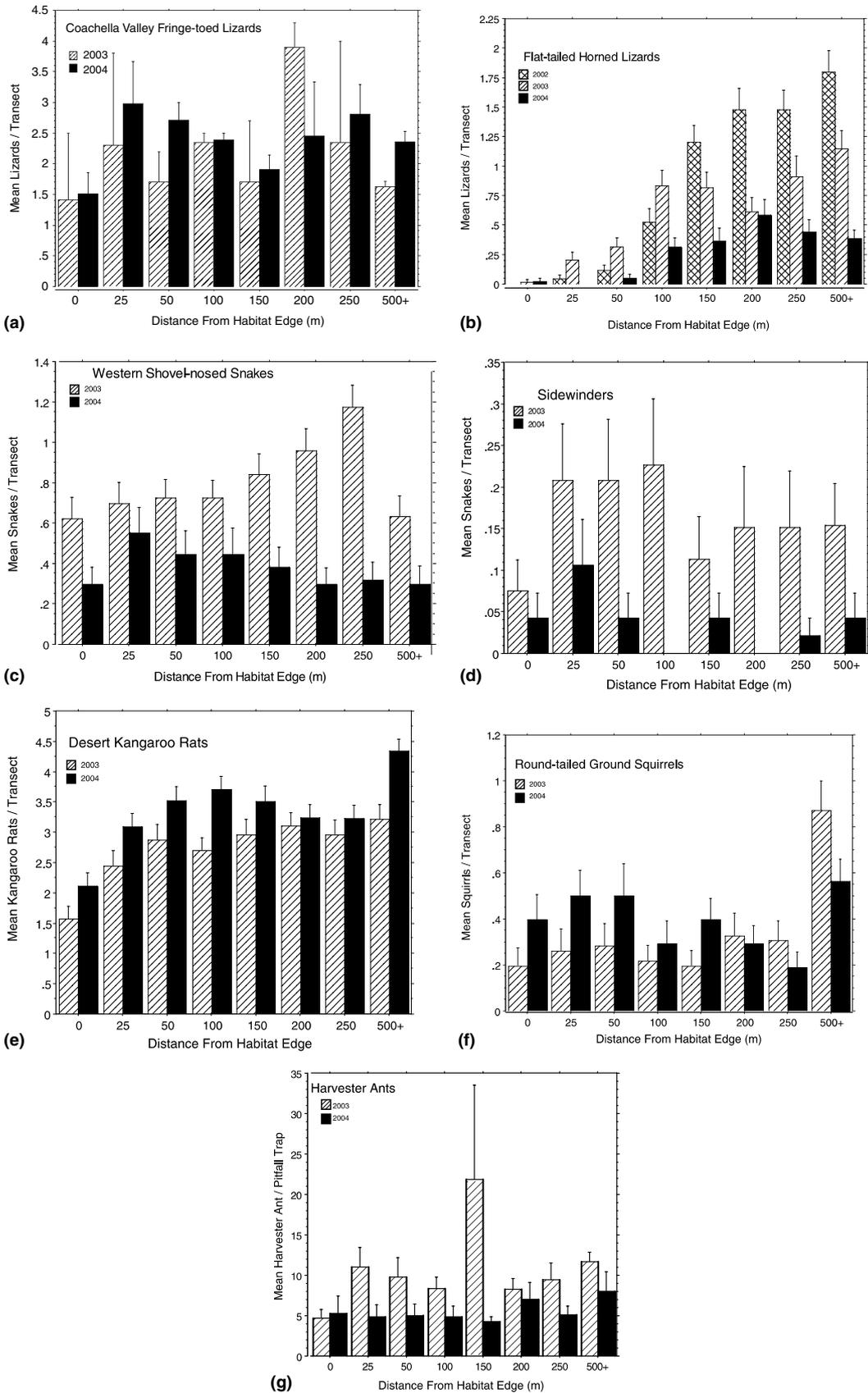
Boundaries between the natural desert and anthropogenic landscapes evaluated here were of two types. One was adjacent to a suburban golf course community, but separated by a well used four-lane road with curbs. The other boundary was adjacent to abandoned agricultural fields with tree rows surrounding each parcel, and was separated by a low use, two-lane road without curbs. The abundance of flat-tailed horned lizards, round-tailed ground squirrels, desert kangaroo rats and harvester ants differed between habitats adjacent to the two boundary types (Table 2). For species other than horned lizards, abundances within boundary types were not statistically different on transects extending away from the preserve edge; no difference in their response to the edge

was detected. For the horned lizards there were differences in abundance with respect to the preserve edge. No horned lizards were located closer than 100 m from the boundary adjacent to the suburban landscape; here lizard abundance did not reach an apparent asymptote until 200 m from the preserve edge (Fig. 3). Some horned lizards were located right to the edge of the boundary along the abandoned agricultural fields. Abundance appeared asymptotic 100 m from the preserve edge.

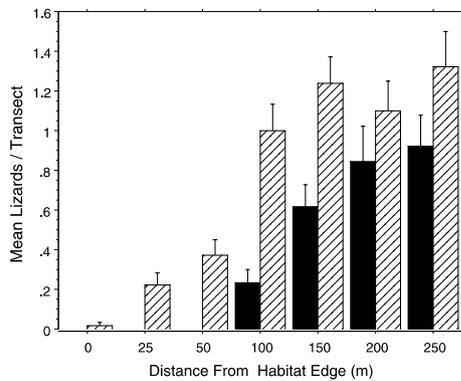
#### 4. Discussion

We identified negative responses to anthropogenic boundaries for flat-tailed horned lizards, and desert kangaroo rats. Data for the horned lizards were the most consistent from the standpoint of different scales (edge versus core plots and within-plot edge distances) and linear regression results. For the kangaroo rat, edge effects were apparent only at the finer scale, within-plot analyses and relatively weak regression results. This pattern may be explained by environmental variation associated with preserve habitat boundary. Historic road grading created low berms along the road-preserve boundaries. Rare flood events create pooled standing water and silt deposition along those berms, resulting in significantly more compacted sediments within 10–20 m of that boundary. The edge effect for desert kangaroo rats appeared to be confined to  $<25$  m from the preserve boundary, coincident with the effects of roadside berms.

Flat-tailed horned lizards typically occupy sand compaction conditions found throughout the nine edge plots. Edge



**Fig. 2 – (a–g) Mean counts and one standard error (indicated by the error bar) of species occurring on sand dunes and sand hummocks in the Coachella Valley at various distances from an anthropogenic habitat edge. Data for each year are the combined means for the plots on which the species occurred, with six repetitions per transect per plot. Data collected at >500 m represent the combined core plots.**



**Fig. 3 – Mean counts and one standard error (indicated by the error bar) of flat-tailed horned lizards at distances from two boundary types. Solid black bars represent data summarized from three plots adjacent to a four-lane road, with curbs, bounded by a suburban golf course community. Diagonally lined bars represent data summarized from five plots adjacent to a two-lane curbsless road, bounded by abandoned agricultural fields and tree-row windbreaks. Both summaries include data combined from 2002 and 2003. Data for each year are the combined means for the plots on which the species occurred, with six repetitions per transect per plot.**

effects for this species were measured up to 150 m from the habitat boundary, well beyond the impact of the roadside berms. This lizard's range has been reduced and fragmented in recent years (Turner and Medica, 1982) and this preserve may represent the only remaining habitat for flat-tails in the northern one-third of their original distribution. Deciphering causal factors for the flat-tail's absence along the preserve boundary may provide important directions for future management and preserve design strategies. Three non-exclusive hypotheses were evaluated to explain this edge effect.

(1) *Road mortality – road avoidance hypothesis.* Like many reptiles, flat-tailed horned lizards will use the margins of paved roads, most likely for thermoregulation (Norris, 1949; Turner and Medica, 1982). We did observe the horned lizards occasionally cross the two lane road, indicating that the road itself was not a barrier. Impacts of roads on wildlife populations include direct mortality and road avoidance (Forman and Alexander, 1998). If there is a road impact here we would expect the response from the lizards to be stronger adjacent to larger, busier roadways. In fact, we found consistent differences in lizard-edge relationships between edges adjacent to a busy four-lane road and a less used two-lane road. While edge effects were apparent along each road type, lizards adjacent to the four-lane road demonstrated a more pronounced and abrupt edge effect than those along the two-lane road, and so the data are consistent with a road effect hypothesis. No statistical difference in shrike abundance was found between plots along the two-lane and four-lane roads, eliminating shrike predation as a confounding variable. The lack of an edge effect in any of the three nocturnal species included in our analysis may be in part a reflection of reduced vehicle traffic during the night.

(2) *Invasive alien ant hypothesis.* Flat-tailed horned lizards' prey is almost exclusively harvester ants (Pianka and Parker, 1975; Turner and Medica, 1982). The reduction in harvester ants from 2003 to 2004 in the aeolian sand habitat, which coincided with a similar reduction in flat-tails, supports a hypothesis that the population dynamics of these two taxa are linked.

Suarez and Case (2002) and Fisher et al. (2002) have identified the invasion of non-native Argentine ants (*Linepithema humile*) as a leading factor in the disappearance of coast horned lizards (*Phrynosoma coronatum*) from fragmented habitats in coastal southern California. Suarez et al. (1998) described Argentine ants being able to invade up to 100 m into semi-arid natural habitats, greatly reducing native ant populations within that same 100 m belt. Coast horned lizards that were limited to Argentine ants for prey had negative or zero growth rates, and so could not maintain populations unless native ant populations were present (Suarez et al., 2000; Suarez and Case, 2002).

Argentine ants were known to occur invade mesic habitats (Holway, 2005) including suburban golf courses in the Coachella Valley. Similarly, introduced fire ants (*Solenopsis invicta*) have also been identified in the Coachella Valley and elsewhere are associated with roads, suburban development and edges (Forys et al., 2002). No non-native ant species were collected within any plots on the Thousand Palms Preserve. The extreme aridity of this habitat may be a barrier to invasion of ant species otherwise problematic to more mesic habitats. These data, and the lack of any edge effect apparent in the native harvester ants, indicate that alien ant invasions are not a cause for the observed edge effect in the horned lizard population

(3) *Enhanced predation hypothesis.* Increased predation along habitat edges is often identified as a causal factor for reducing nesting success for birds along forest edges (Andrén et al., 1985; Wilcove, 1985; Angelstam, 1986; Andrén and Angelstam, 1988; Burkey, 1993; Estrada et al., 2002; Maina and Jackson, 2003; Aquilani and Brewer, 2004). If increased levels of predation along the habitat margins are responsible for reduced flat-tail numbers there, then increased numbers of predators should be evident.

Comparing edge versus core plots, counts of loggerhead shrikes were consistently higher on the edge of aeolian sand habitat. The higher numbers of shrikes at edge plots versus core locations in our study area was consistent with an enhanced predator hypothesis. However, if predation rates are an important causal factor, then why were other species not similarly impacted? Of the six vertebrate species measured, three are primarily nocturnal and so would not be subjected to predation pressure from the diurnal shrikes; however Daley et al. (2000) did record shrike predation on four kangaroo rats. Of the diurnal potential prey species, the ground squirrels' large size puts them outside of the prey range of shrikes. The two lizards are within the shrikes' prey size, and flat-tailed horned lizards are regularly preyed on by shrikes (Young et al., 2004). Whereas both lizards are cryptically colored, flat-tailed horned lizards are slower moving and often respond to threats by remaining motionless (Norris, 1949). Fringe-toed lizards respond to threats by running extremely fast or diving into the loose sand (Stebbins, 1944).

Although predators were not quantified in 2002, flat-tailed horned lizards were commonly observed being preyed upon by American kestrels during site visits that year. Carcasses of marked horned lizards that had disappeared from study plots were located 0.7 km away in a palm tree planted on the edge of a golf course and frequented by kestrels. In 2003 and 2004 when predator occurrence was quantified, there were few observations of kestrels, but shrike observations were common. While kestrels and shrikes are native to the deserts of southern California, their abundance in the sand dune habitats of the Coachella Valley is likely enhanced by suburban development. In a pre-development landscape there were no trees growing in or around the Coachella Valley sand dunes. American kestrels are obligate hole or ledge nesters. Whereas there were once no nest sites for kestrels within 10 km of the dunes, today palm trees and other exotic vegetation planted in the neighboring suburban developments provide abundant nest sites on ledges formed by the large leaf petioles and in the thick “skirts” of dead palm leaves. While shrikes nest in native desert shrubs, trees in suburban areas as well as tree windbreaks planted at the margins of agricultural fields provide more sheltered nest sites. Power poles bordering the preserve provide elevated perch sites for both the kestrels and shrikes to see prey and then launch their hunting sorties. Flat-tailed horned lizards may be subjected to levels of predation along edges that they would not likely have experienced in a pre-development landscape.

By collecting data on multiple species from multiple trophic levels we have rejected the alien ant hypothesis and found support for both the predation and road affect hypotheses. Dynamics of the flat-tailed horned lizard population occupying a 100–200 m boundary region of the available habitat appears to have shifted from a bottom-up process where the lizard numbers are regulated by native ant abundance, to a top-down process where the lizards are limited by predation, and possibly road mortality. This shift in regulatory processes may contribute to a habitat “sink” (Pulliam, 1988) along the preserve boundary. For 2003 and 2004 combined, the horned lizards’ mean reproductive success ranged from 0 to 0.2 hatchlings/adult at distances from 0 to 150 m from the habitat edge; at 200 m from the edge and in core plots, mean reproductive success averaged 0.8 hatchlings/adult (Barrows, unpubl. data). Without immigration from the preserve core, flat-tailed horned lizards may not be able to sustain populations in the boundary region.

These results demonstrate the utility of community based research designed to evaluate hypotheses regarding processes that regulate the abundance of species (Barrows et al., in press). Rather than having broad impacts from indeterminate causes, boundary effects here were found to have a narrow scope and likely causes were identified. These findings can allow managers to focus adaptive management strategies aimed at reducing the boundary effect for flat-tailed horned lizards and so improve the viability of this remnant population. In the face of increasing suburban expansion into natural desert communities in the southwestern US and elsewhere in arid regions of the world, managers otherwise face decisions with little or no baseline from which to predict species responses.

## Acknowledgement

Funding was provided by the Coachella Valley Association of Governments, the County of Riverside, and the California Department of Fish and Game. We particularly thank James Sullivan, Kim Nicol and Eric Loft. Donna Thomas, Marisa Sripracha, Thomas Prentice, Brandon Mutrux, Darrell Hutchinson, Kathleen Fleming, and Monica Swartz provided essential support in collecting and summarizing data. Invaluable editorial suggestions were provided by Katherine Barrows. Research on flat-tailed horned lizards was conducted under California Department of Fish and Game Scientific Collecting Permit 801015-01.

## REFERENCES

- Abts, M.L., 1987. Environment and variation in life history traits of the chuckwalla, *Sauromalus obesus*. *Ecological Monographs* 57, 215–232.
- Andrén, A., Angelstam, P., 1988. Elevated predation rates as an edge effect in habitat islands: experimental evidence. *Ecology* 69, 544–547.
- Andrén, A., Angelstam, P., Lindström, E., Widen, P., 1985. Differences in predation pressure in relation to habitat fragmentation: an experiment. *Oikos* 45, 273–277.
- Angelstam, P., 1986. Predation on ground-nesting birds’ nests in relation to predator densities and habitat edge. *Oikos* 47, 365–373.
- Aquilani, S.M., Brewer, J.S., 2004. Area and edge effects on forest songbirds in a non-agricultural upland landscape in northern Mississippi, USA. *Natural Areas Journal* 24, 326–335.
- Ballinger, R.E., 1977. Reproductive strategies: Food availability as a source of proximal variation in a lizard. *Ecology* 58, 628–635.
- Barrows, C.W., 1997. Habitat relationships of the Coachella Valley fringe-toed lizard (*Uma inornata*). *Southwestern Naturalist* 42, 218–223.
- Barrows, C.W., Swartz, M.B., Hodges, W.L., Allen, M.F., Rotenberry, J.T., Li, B., Scott, T.A., Chen, X., in press. A framework for monitoring multiple species conservation plans. *Journal of Wildlife Management*.
- Boal, C.W., Estabrook, T.S., Duerr, A.E., 2003. Productivity and breeding habitat of loggerhead shrikes in a southwestern urban environment. *Southwestern Naturalist* 48, 557–562.
- Bolger, D.T., Alberts, A.C., Soulé, M., 1991. Occurrence patterns of bird species in habitat fragments: sampling, extinction, and nested species subsets. *The American Naturalist* 137, 155–166.
- Bolger, D.T., Scott, T.A., Rotenberry, J.T., 1997. Breeding bird abundance in an urbanizing landscape in coastal southern California. *Conservation Biology* 11, 406–421.
- Brown, J.H., Ernest, S.K.M., 2002. Rain and rodents: complex dynamics of desert consumers. *Bioscience* 52, 979–987.
- Burkey, T.V., 1993. Edge effects in seed and egg predation at two neotropical rainforest sites. *Biological Conservation* 66, 139–143.
- Camargo, J.L.C., Kapos, V., 1995. Complex edge effects on soil moisture and microclimate in a central Amazonian forest. *Journal of Tropical Ecology* 11, 205–211.
- Crooks, K.R., Soulé, M.E., 1999. Mesopredator release and avifaunal extinctions in a fragmented system. *Nature* 400, 563–566.
- Daley, M., Behrends, P.R., Wilson, M.I., 2000. Activity patterns of kangaroo rats–granivores in a desert habitat. In: Halle, S., Stenseth, N.C. (Eds.), *Activity Patterns of Small Mammals: An Ecological Approach*. Springer, Berlin, Germany, pp. 145–158.

- Dunham, A.E., 1981. Populations in a Fluctuating Environment: The Comparative Ecology of the Iguanid Lizards *Sceloporus merriami* and *Urosaurus ornatus*, vol. 158. Misc. Publ. Museum of Zoology, Univ. of Michigan, pp. 1–62.
- Estrada, A., Rivera, A., Coates-Estrada, R., 2002. Predation of artificial nests in a fragmented landscape in the tropical region of Los Tuxtlas, Mexico. *Biological Conservation* 106, 199–209.
- Faeth, S.H., Warren, P.S., Shochat, E., Marussich, W.A., 2005. Trophic dynamics in urban communities. *Bioscience* 55, 399–407.
- Fagan, W.F., Fortin, M., Soycon, C., 2003. Integrating edge detection and dynamic modeling in quantitative analyses of ecological boundaries. *Bioscience* 53, 730–738.
- Fisher, R.N., Suarez, A.V., Case, T.J., 2002. Spatial patterns in the abundance of The coast horned lizard. *Conservation Biology* 16, 205–215.
- Forman, R.T.T., Alexander, L.E., 1998. Roads and their major ecological effects. *Annual Review of Ecological Systems* 29, 207–231.
- Forys, E.A., Allen, C.R., Wojcik, D.P., 2002. Influence of the proximity and amount of human development and roads on the occurrence of the red imported fire ant in the lower Florida Keys. *Biological Conservation* 108, 27–33.
- Germaine, S.S., Wakeling, B.F., 2001. Lizard species distributions and habitat occupation along an urban gradient in Tucson, Arizona, USA. *Biological Conservation* 97, 229–237.
- Germaine, S.S., Rosenstock, S.S., Schwweinsburg, R.E., Richardson, W.S., 1998. Relationships among breeding birds, habitat, and residential development in greater Tucson, Arizona. *Ecological Applications* 8, 680–691.
- Germano, D.J., Williams, D.F., 2005. Population ecology of blunt-nosed leopard lizards in high elevation foothill habitat. *Journal of Herpetology* 39, 1–18.
- Gutzwiller, K.J., Barrow, W.C., 2003. Influences of roads and development on bird communities in protected Chihuahuan Desert landscapes. *Biological Conservation* 113, 225–238.
- Holway, D.A., 2005. Edge effects of an invasive species across a natural ecological boundary. *Biological Conservation* 121, 561–567.
- Janzen, D.H., 1983. No park is an island: Increase in interference from outside as park size decreases. *Oikos* 41, 402–410.
- Kapos, V., 1989. Effects of isolation on the water status of forest patches in the Brazilian Amazon. *Journal of Tropical Ecology* 5, 173–185.
- Kristan, W.B., Lynam, A.J., Price, M.V., Rotenberry, J.T., 2003. Alternative causes of edge abundance relationships in birds and small mammals of California coastal sage scrub. *Ecography* 26, 29–44.
- Laurance, W.F., 1991. Edge effects in tropical forest fragments: application of a model for the design of nature reserves. *Biological Conservation* 57, 205–219.
- Laurance, W.F., Lovejoy, T.E., Vasconcelos, H.L., Bruna, E.M., Didham, R.K., Stouffer, P.C., Gascon, C., Bierregaard, R.O., Laurance, S.G., Sampaio, E., 2002. Ecosystem decay of Amazonian forest fragments: a 22 year investigation. *Conservation Biology* 16, 605–618.
- Maina, G.G., Jackson, W.M., 2003. Effects of fragmentation on artificial nest predation in a tropical forest in Kenya. *Biological Conservation* 111, 61–169.
- Mayhew, W.W., 1965. Reproduction in the sand-dwelling lizard *Uma inornata*. *Herpetologica* 21, 39–55.
- Mayhew, W.W., 1966. Reproduction in the arenicolus lizard *Uma notata*. *Ecology* 47, 9–18.
- Murcia, C., 1995. Edge effects in fragmented forests: implications for conservation. *Trends in Ecology and Evolution* 10, 58–62.
- Norris, K.S., 1949. Observation on the habits of the horned lizard, *Phrynosoma mcallii*. *Copeia* 1949, 176–180.
- Noy-Meir, I., 1973. Desert ecosystems: environment and producers. *Annual Review of Ecology and Systematics* 4, 25–51.
- Pianka, E.R., 1970. Comparative autecology of the lizard *Cnemidophorus tigris* in different parts of its geographic range. *Ecology* 51, 703–720.
- Pianka, E.R., Parker, W.S., 1975. Ecology of horned lizards: a review with special reference to *Phrynosoma platyrhinos*. *Copeia* 1975, 141–162.
- Pulliam, R.H., 1988. Sources, sinks and population regulation. *The American Naturalist* 132, 652–661.
- Ries, L., Fletcher Jr., R.J., Battin, J., Sisk, T.D., 2004. Ecological responses to habitat edges: mechanisms, models and variability explained. *Annual Review of Ecology, Evolution and Systematics* 35, 491–522.
- Robinson, M.D., 1990. Comments on the reproductive biology of the Namib dune lizard, *Aporosaura anchietae*, during two years of very different rainfall. In: Seely, M.K. (Ed.), *Namib Ecology, 25 Years of Namib Research*. Transvaal Museum Monograph No. 7, Transvaal Museum, Pretoria, South Africa, pp. 163–168.
- Seely, M.K., Louw, G.N., 1980. First approximation of the effects of rainfall on the ecology and energetics of a Namib Desert dune ecosystem. *Journal of Arid Environments* 3, 25–54.
- Stebbins, R.C., 1944. Some aspects of the ecology of the iguanid genus *Uma*. *Ecological Monographs* 14, 311–332.
- Suarez, A.V., Case, T.J., 2002. Bottom-up effects on persistence of a specialist predator: ant invasions and horned lizards. *Ecological Applications* 12, 291–298.
- Suarez, A.V., Bolger, D.T., Case, T.J., 1998. Effects of fragmentation and the invasion on native ant communities in coastal southern California. *Ecology* 79, 2041–2056.
- Suarez, A.V., Richmond, J.Q., Case, T.J., 2000. Prey selection in horned lizards following the invasion of Argentine ants in southern California. *Ecological Applications* 10, 711–725.
- Turner, F.B., Medica, P.A., 1982. The distribution and abundance of the flat-tailed horned lizard (*Phrynosoma mcallii*). *Copeia* 1982, 815–823.
- Unfried, T.M., 2003. Effects of adjacent land use on coastal sage scrub birds. Masters thesis, University of California, Riverside, CA.
- Watson, J.E.M., Whittaker, R.J., Dawson, T.P., 2004. Habitat structure and proximity to forest edge affect the abundance and distribution of forest-dependent birds in tropical coastal forests in Madagascar. *Biological Conservation* 120, 311–328.
- Wiens, J.A., Crawford, C.S., Grosz, J.R., 1985. Boundary dynamics: a conceptual framework for studying landscape ecosystems. *Oikos* 45, 421–427.
- Wilcove, D.S., 1985. Nest predation in forest tracts and the decline of migratory songbirds. *Ecology* 66, 1211–1214.
- Wilkinson, L., 1990. SYSTAT: The System for Statistics. SYSTAT, Inc., Evanston, IL.
- Whitford, W.G., Creusere, F.M., 1977. Seasonal and yearly fluctuations in Chihuahuan lizard communities. *Herpetologica* 33, 54–65.
- Young, K.V., Brodie Jr., E.D., Brodie III, E.D., 2004. How the lizard got its horns. *Science* 304, 65.