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Renewable Energy Development on Department of Defense Installations in the Desert Southwest: Identifying Impacts to Species at Risk – Journal Publication

Title: Challenges in Wildlife Conservation in the Presence of Solar Energy Development in Desert Ecosystems.

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Abstract

The deserts of the southwestern United States (U.S.) contain some of the highest biological diversity in the U.S. with many highly endemic species listed under some sensitive status designation. The impacts presented by solar development on the presence and distribution of small mammal and reptile communities must be examined to identify risk to both common and sensitive status species, in turn providing direction for future solar development. We designed a study to assess the presence and distribution of two taxa across three military installations in the southwestern U.S. through three primary objectives which address differences in both small mammal and reptiles communities across a gradient of distances from the photo-voltaic solar arrays. Our trapping efforts occurred from 7 November 2014 – 17 July 2015 from which we caught 10 species of small mammals and 15 species of reptiles. Results from these efforts indicated that species richness, species diversity, and abundance estimates are all highest at distance between 20 m and 400 m from the solar facility, suggesting that few individuals are utilizing solar arrays. The likely mechanism of this response is displacement into the surrounding habitat. We speculate that the construction and maintenance of these solar arrays creates unsuitable or low quality habitat for these small mammal and reptile communities. This is likely due to the fossorial nature of these communities in the Desert Southwest and their dependence on suitable low compaction soils for burrows. Based on these results, we detail recommendations on future solar development considerations, such as prioritizing solar development on disturbed lands.

Introduction

The high biodiversity of the Sonoran and Mohave deserts present an increased probability of conflict between at risk species management and renewable energy development (Lovich and Bainbridge 1999, Mittermeier et al. 2002, Randall et al. 2010, Lovich and Ennen 2011). Specifically, there is limited empirical information on the impact of renewable energy development on wildlife or at risk species. The limited work that has been conducted on the impact of renewable energy development has focused on wind facilities (Gill 2005, Kuvlesky et al. 2007). Thus, there is an absence of data on the impact of solar development on at risk species (Lovich and Ennen 2011; Turney and Fthenakis 2011; Northrup and Wittemyer 2013). While one model has been proposed to develop a wildlife centered suitability index for solar development (Stoms et al. 2013), it is based on broad scale habitat patterns rather than site specific data collection. Therefore, the site specific impacts of solar development exist only in compliance documents and other sources of “gray” literature (Lovich and Ennen 2011), and focus on hydrologic impacts and not at risk species (Duane and McIntyre 2011).

The majority of diversity in the Sonoran and Mohave deserts is made up of birds, mammals, and reptiles with many of the terrestrial at risk wildlife composed of small mammals and reptiles (Randall et al. 2010). Since many of the at risk species in the Sonoran and Mohave deserts are small mammals and reptiles (Randall et al. 2010) any evaluation of the impact of solar development on at risk species should be focused on these taxa. Small mammals are often used as indicators of ecosystem health across a variety of habitats (Chase et al. 2000, Pearce and Venier 2005). Thompson and Thompson (2005) suggest that reptiles are also indicators of ecosystem health. Thus, by monitoring these two taxa together we can better assess the impact of solar development on the landscape.

Sustaining and conserving suitable habitats and resources for at risk species allow military installations to manage potential risk and maintain compliance with federal regulations such as the Endangered Species Act (ESA). In addition, a memorandum of understanding between the Department of Defense (DoD) and the International Association of Fish and Wildlife Agencies directs the management of natural resources on military installations under provisions of the Sikes Act (USC 1960). Although many small mammal and reptile species on military lands are not currently protected under the ESA, they represent species that could affect DoD actions in the future if habitat degradation results in species listing under the ESA. Meeting federal compliance is vital to mission implementation and to maintaining military training activities across installations. Therefore, the impacts to small mammal and reptile communities presented by renewable energy development on DoD lands must be identified to avoid conflicts between wildlife at risk and military operations.

The qualitative term “Soft Footprint” has been used to suggest a low impact physical disturbance (Gatlin 2012). This is usually expressed as a surface maintenance similar to the surrounding landscape. This term suggests that if there is a “soft footprint” there are also “hard” and potential “intermediate” footprints. Although these terms are not specifically defined and prone to subjectivity, we define these terms as follows: soft footprint – surface maintenance similar to the surrounding landscape; intermediate footprint – surface maintenance is modified from surrounding landscape but is limited in vegetation composition and structure; and hard footprint – highly modified surface maintenance to eliminate and discourage vegetative growth and ground permeability often resulting from gravel or stone deposition. The types of footprints as defined above may have varying levels of effect on the surrounding wildlife community.

Mitigating the potential impacts that utility-scale solar energy developments may have on at risk species and communities requires that we identify the spatial extent at which the impacts occur. Only when the extent of the impacts is known can appropriate mitigation strategies be developed. The overall goal of this study was to answer the critical questions: 1) What impacts do solar developments have on wildlife communities and Species at Risk in the Desert Southwest; and 2) At what spatial-scale should mitigation occur? An opportunity to evaluate these questions arose with the installation of utility-scale solar developments on Department of Defense (DoD) managed lands in the Sonoran and Mohave deserts. The Sonoran Desert Military Ranges Conservation Partnership Team and collaborators at the Yuma Proving Ground (YPG), Davis-Monthan Air Force Base (DMAFB), and Edwards Air Force Base (EAFB) identified the evaluation of solar development impacts as a priority project to help implement their Net Zero Energy concept (Booth et al. 2010). Our specific objectives were: 1) quantify differences in reptile and small mammal diversity and abundance between solar development sites and un-impacted sites on DoD installations; 2) identify the spatial extent of solar development impacts on wildlife communities with application to Species at Risk; and 3) evaluate the mitigation value of “soft-footprint” solar development when compared to standard “hard-footprint” development. By interpreting the results of this study, we developed a set of data-driven management recommendations that can provide useful guidance on both existing and future solar developments.

Methods

Study Area – Our study areas consisted of three DoD installations within the Mohave and Sonoran deserts (Figure 1). Each installation had an existing photo-voltaic solar array.

DMAFB is located in Pima County within the city limits of Tucson, Arizona totaling approximately 43 km^2. DMAFB lie in an ecotone zone where the Arizona Upland subdivision of the Sonoran Desert intersects with Chihuahuan Desert grassland (Brown, 1994). Plant species that occur in this area include prickly pear (*Opuntia spp.*), cholla (*Cylindropuntia spp.*), and saguaro (Carnegiea gigantea) cacti, mesquite (*Prosopis spp*.), palo verde (*Parkinsonia spp.*), creosote bush (*Larrea tridentata*), acacia (*Acacia spp*.), yucca (*Yucca spp.*), as well as numerous species of native and exotic grasses. The Tucson basin is characterized by broad alluvial fans, dissected upland bajadas, and four major mountain ranges: the Santa Catalina, Tucson, Santa Rita, and Rincon mountains. DMAFB lies between 773 m and 891 m in elevation with average precipitation between 27.9 and 33.0 cm/yr. Average temperatures range from 4^0C for lows during the winter to 38^0C for highs during the summer.

YPG lies within La Paz and Yuma counties near Yuma, Arizona and totals approximately 3,450 km^2. The Lower Colorado River Subdivision of the Sonoran Desert is the predominate vegetative community. This vegetative community is the largest and most arid component within the Sonoran Desert and characterized by extremely drought-tolerant plant species such as creosote bush (*Larrea tridentata*), bursage (Ambrosia spp.), palo verde (*Parkinsonia spp.)* and cacti (*e.g*., prickly pear cacti [*Opuntia spp.*] and saguaro [Carnegiea gigantea]) (Olson and Dinerstein 2002, Brown 1994). The broad, flat, and sparsely vegetated desert plains of YPG are dissected by numerous incised washes that support ironwood (Olneya tesota), smoketree (*Psorothamnus spinosus*), acacia (*Acacia spp*.), mesquite (*Prosopis spp*.) and numerous shrub species. Elevated hills and mountain slopes within the Arizona Upland Subdivision of the Sonoran Desert are vegetated with, cacti and agave (*Agave spp.*). Elevation on YPG ranges from sea level to 878 m with average precipitation is approximately 3 cm/yr. Average temperatures range from 8°C for lows during the winter to 42°C for highs during the summer.

EAFB lies within Kern, Los Angeles, and San Bernardino counties near Lancaster, California and totals approximately 1,262 km². EAFB lies completely in the Mojave Desert. Dominant vegetation on our EAFB sites included creosote bush (*Larrea tridentata*), white bursage (*Ambrosia dumosa*), saltbush (*Atriplex confertifolia*), blackbrush (*Coleogyne ramosissima*), as well as numerous annual forbs and grasses (Brown, 1994). Elevation on EAFB ranges from 690 m to 1,039 m with average precipitation is between 15.2 and 17.8 cm/yr. Average temperatures range from 1°C for lows during the winter to 36°C for highs during the summer months.

Study Design – We developed a trap design to measure the ecological gradient of a small mammal and reptile communities from an anthropogenic disturbance by reviewing different trap designs, arrangements, and appropriate analyses to measure community effects. We reviewed literature on three different trapping designs: grid (Dice 1938, Pelikan et al. 1964, Southern 1973), web (Anderson et al. 1983), and transect (Read et al. 1988, Pearson and Ruggiero 2003). Each had advantages and disadvantages, but the assessment for this study related to understanding the dynamics of the small mammal and reptile communities in relation to disturbance. Therefore, we chose a hybrid design of grids and transects based on recommendations from the literature.

Our design included two super-transects on opposite sides of the solar facility and directed away from the source of disturbance within homogeneous habitat. Each super-transect originated at the fence line surrounding the solar facility (this appeared to be the most obvious and consistent barrier) and extended away from the facility. A super-transect consisted of up to 5 grids spaced with 100 m intervals. A grid consisted of up to 50 traps set in a 40 x 100 m rectangle with traps spaced 10 m apart. Our first grid was located within the solar fence boundary and extending along the super-transect line for 40 m at which a 100 m interval was measured before the placement of the next grid. This continued until a maximum of 5 trap grids were placed along both super-transect lines. The grids within the solar facility represented the "Treatment" (Figure 2) with grids 2 and 3 representing the potential "edge" and grids 4 and 5 representing the "control" or un-impacted site. The 100m interval between grids was based on a literature review of the primary taxonomic families home range sizes with average home range diameters of ~27.2 m for Heteromyidae (Maza et al. 1973, Schroder 1979, Braun 1985), ~55.6 m for Cricetidae (Cranford 1977, Thompson 1982, Lynch et al, 1994, Ribble et al. 2002, Shurtliff et al. 2005), ~152.9 m for Sciuridae (Bradley 1967, Drabek 1973, Ortega 1990, Boellstorff and Owings 1995), and ~84.2 m for Soricidae (Blair 1940, Hawes 1977, Kollars 1995) of small mammals found within our study area. With the exception of a few sciurid species, most small mammals have home ranges smaller than the 100 m interval distance. We assumed for comparison purposes that at least the furthest grids away from the solar facility on each of the super-transects were un-impacted by the disturbance associated with the facility. These "controls" were set as our baseline comparison for "treatment" effect. At each military installation we were able to sample areas at least three home ranges away from the solar facility as summarized in the literature review of home range sizes using the basic configurations of Figure 2.

Modification for reptile grids included 3 transects per grid while maintaining the super-transect design. Each grid was composed of 3 transects with 3 paired box traps (total of 6 traps) placed along each transect (identified by a drift fence with substrate along the bottom instead of a trench). No trenches were dug for the drift fence due to inconsistent digging requirement and potentially significant cultural areas at each installation. Complete independence between the two grids within the solar facility and the first grid along the super-transect was not be possible in all cases; however, for data analysis we will assume independence. For EAFB reptile trapping, we were not able to set complete grids for Super Transect B due to cultural sensitivity concerns. An archeologist was able to position at least a single transect of traps for grids 4 and 5.

We conducted three trapping sessions each for small mammals and reptiles. We trapped small mammals for eight consecutive days approximately once a month from mid-November 2014 through early April 2015. We conducted three similar trapping sessions for reptiles which consisted of a single 8-day trapping session with approximately one session each month from April through July 2015. All traps were individually marked with a unique number for identification purposes.

For small mammals, we used 600 folding Sherman Model LFATDG live traps (7.62 X 8.89 X 22.86 cm). Traps were baited with sweet feed as traps were opened. A handful of cotton batting or poly-fill was placed inside each trap to provide insulation. Traps were opened one hour prior to sunset and left open during the night. We began checking traps one hour prior to sunrise. Trap stations were marked no more than 1 m away with a pinflag. Trapped animals were identified to species, weighed, sexed, and had the following metrics taken: tail length, body length, length of the hind foot and pinnae (ear) length. Animals were placed in 1-gallon re-sealable bags to be weighed. Bags were discarded as they become soiled or developed holes. Each animal was marked using standard techniques (Silvy 2012) with a numeric ear tag and colored washer so we could identify individuals during subsequent trapping efforts. Application of ear tags included iodine to prevent possible infection (Silvy 2012). Animals were handled for no more than 5 minutes, using standard methods described in Wilson et al. (1996), so as to reduce stress and released promptly at the point of capture after all metrics were taken. All traps were sanitized between each trapping session with QUAT 128 disinfectant.

For reptiles (lizards and snakes) we utilized box traps with funnel entrances. These traps were built specifically for this project to maximize the breadth of species that may be captured. Box traps were constructed with a wood frame and 3.18 mm aluminum mesh and a funnel opening (~3.81 – 4.45 cm) on both ends of the box with an incline angle of ~ 20°. Traps had a removable insulated lid (to reduce heat exposure) which could be opened to remove specimens caught in the trap. Captured individuals were marked with either a toe-clip for small and potential juveniles (McDiarmid et al. 2012) or permanent marker for adults. Animals were released promptly at the point of capture after being measured and marked. Traps were checked daily between 0600 hrs and 1100 hrs.

Analyses – Spellerberg and Fedor (2003) suggest more rigorous use of the definitions between species richness and species diversity. For this reason we provided information for both the Shannon-Wiener index for diversity and providing species richness measurements as described in Kessler et al. (2001). For each installation, we pooled data between the two super-transects for each unique grid number to generate species diversity indices (Shannon–Weiner Index; Shannon and Weaver 1949, Magurran, 2004), species richness (Kessler et al. 2001) and relative abundance estimates using mark-recapture methods. These unique grid numbers represented generally similar distances from the solar facility. In this way, we increased our species representation and inferences by sampling more area along a similar distance from the facility.

By using the furthest grids as controls and comparison of each grid closer to the solar facility, we calculated changes across each of the super-transects to the treatment estimates. We compared the rate of change across this gradient and identified the extent of impact as defined by the "edge."

We evaluated species diversity and abundance based on the physical construction of each solar facility. Prior to this study, we identified three military installations with different types of solar installation ranging from "hard" to "soft" footprint design. DMAFB included 18.8 ha of solar development in our focus area and included both a "hard" footprint which included a graded surface compacted and leveled with coarse stone below the solar panels. The "soft" footprint design included a graded surface but revegetated with grasses to help control erosion. YPG is characterized by a 1.4 ha "hard" footprint design as it was graded and terraced with coarse stone. EAFB was compacted, but native soil was left in place and was likely more of a "soft" footprint design consisting of 3.2 ha.

Results

Our trapping efforts (Table 1) occurred from 7 November 2014 – 2 April 2015 for small mammals and 21 April 2015 – 17 July 2015 for reptiles. We successfully trapped 10 species of small mammals and 15 species of reptiles for all installations combined (Table 1). We captured a single individual small mammal (*Dipodomys merriami*) on the DMAFB solar array. This produced no measurable results on the treatment areas of either YPG or EAFB. For reptiles, we captured a total of 15 reptiles within the solar arrays at all installations combined (Table 1). DMAFB had the highest diversity, while YPG had the highest abundance (Figures 3 and 4). YPG reptile abundance consisted of a single species, *Uta stansburiana*. Our control sites indicated the inverse with YPG having the greatest diversity and DMAFB having the highest abundance of reptiles (Figure 3B). In all cases treatment sites resulted in lower metrics than controls. Species richness was highest at intermediate distances for both small mammals (Table 2) and reptiles (Table 3). This is represented by Grids 2-4 for each solar array.

Diversity and relative abundance metrics varied at each trapping distance for both small mammals and reptiles (Figures 5 and 6). Diversity of small mammals species using the Shannon-Wiener Diversity Index resulted in indices of H = 1.21, 1.77, and 0.52 for DMAFB, YPG, and EAFB respectively. Figure 5 displays the relationship between diversity and average distance from the solar array. Relative abundance measurements also indicate that numbers are highest at intermediate distances (Figure 6) with the highest recorded relative abundances at DMAFB and lowest at EAFB.

Our trapping efforts within the solar arrays resulted in a combined 17 captured individuals including both small mammals and reptiles. Only the intermediate type of footprint (DMAFB) captured any individuals within the solar array (Figure 7).

Discussion

This study was designed to quantify potential impacts solar energy development may have on species at risk in desert landscapes. We used small mammal and reptile communities to estimate the impact of three solar developments located on military lands. Our results suggest that the wildlife communities within the solar facility developments were displaced almost completely as hypothesized by Lovich and Ennen (2011) and Northrup and Wittemyer (2013). Our findings indicate that communities of these two taxa disperse into the nearest available habitat around the facility. We detected increased diversity and abundance in these taxa at 300-400m from the solar array. These results suggest that the physical footprint regardless of intensity (Hard, Intermediate or Soft) displaces the wildlife community completely. Our findings also indicate that the displacement of the wildlife community results in a halo of increased diversity and abundance at 300-400m from the solar facility. These results can inform wildlife management decisions while maintaining military missions. Developing highly disturbed areas for solar development may cause the least impact to existing wildlife communities (Stoms et al. 2013) with minimal displacement of existing animals. For this reason we encourage installations to assess existing disturbed lands for solar development which will reduce displacement risk to both small mammal and reptile communities.

We report on three different aspects of species composition; species richness, diversity and abundance. We used these three aspects to evaluate the impact of solar development to establish community assemblages of small mammals and reptiles. Our results concerning the solar array versus our control sites indicate that solar development eliminates area as potential habitat for small mammals and reptiles. Our findings also indicate that species richness, diversity and abundance of these two taxa were negatively correlated with the presence of the solar array (Figures 3-6). These findings also provide a baseline that can be used to compare richness, diversity and species abundance across time (Bejder et al. 2006). Our extensive trapping efforts detected so few individuals within the solar array that our species richness, diversity, and abundance estimates were functionally zero. Given that these three solar arrays have been established for several years (multiple species generations) enough time has passed to allow for recolonization if the habitat was suitable, yet no recolonization has occurred. These findings suggest that the development of these solar arrays lead to the loss of the site as wildlife habitat and quantify similar to observations by Lovich and Ennen (2011).

Our results suggest that both small mammals and reptiles avoided these solar arrays. In addition, species richness, diversity and abundance increased with distance from the solar array. This pattern is similar to the response of these taxa to road development (Findlay and Houlahan 1997, Fahrig and Rytwinski 2009) and land conversion (Findlay and Houlahan 1997). While, this pattern of response to development was observed by Lovich and Ennen (2011), other researchers found no consistent response of small mammals to anthropogenic disturbance (Rosa and Bissonette 2007). We found a consistent bell-shaped curve distribution across distance for species richness, diversity, and abundance for all three solar energy facilities. The tails of this curve occurred at the solar array and at the control. The peak of species richness, diversity and abundance was observed at an intermediate distance (300 to 400m) from the solar array (Tables 2 and 3; Figures 3-6). This was likely due to displacement and subsequent dispersal of these two taxa (Lidicker 1975) into the surrounding landscape. This halo of increased species richness, diversity and abundance at 300 to 400m from the solar array suggests that disturbance from the construction of the solar arrays may have altered the potential carrying capacity (Robbins 1973) in the adjacent landscape.

Comparison of “soft” and “hard” footprint designs does not generally suggest measureable differences. However, we conclude that in all cases species richness is ≤ to surrounding species richness (Tables 2 and 3), but we do not suggest direct comparisons due to the unique species composition at each facility. Figure 7 indicates that relative abundance is nearly non-existent as compared to the surrounding landscape in all cases. This contradicts previously held perceptions of “soft” footprint design and potential benefits for at risk species such as the Mohave ground squirrel (*Xerospermophilus mohavensis*; Gatlin 2012). It is possible that due to the construction of these solar arrays in these environments, the disturbance and displacement impacts may be permanent regardless of the surface maintenance. There are examples of small mammals avoiding areas of high soil compaction (Malizia et al. 1991; Ignacio et al. 2007) likely due to high energy costs adversely affecting thermoregulation (Vleck 1991). Considering that each of these sites was within either Sonoran or Mohave deserts, this may well be the case in our different footprint types. This has been laboratory tested with some species suggesting that high soil compaction results in little to no burrowing activity (Ducey et al. 1993). This question of soil compaction should be explored further to assess potential mitigation alternatives for this type of disturbance during the construction of solar arrays.

From this study we find that some general practices may be conducive to more effective placement and maintenance of solar facilities in desert landscapes but may be relevant to any landscape. Combined natural resource management in collaboration with successful development, operation, and maintenance of renewable energy sources are paramount to continued build-out and support of these renewable energy alternatives. It is important to note that these suggestions are specific to photo-voltaic solar arrays and may not be applicable to other types of solar energy generation technology such as concentrated solar power technology or heliostat power plants (a.k.a. power towers).

- New solar development should be focused on disturbed or recently disturbed landscapes. Prioritizing solar development on disturbed lands will likely expedite the process by reducing time associated with various compliance processes especially environmental by reducing potential impact to species at risk.
- Initial surveys should be conducted on a proposed solar development site to identify any potential sensitive status species. This should include identifying features that may attract or concentrate small mammals and/or reptiles.

- If at risk species are identified during an initial survey, monitor the immediate and adjacent areas (up to 400 m for the proposed solar development) to determine if any mitigation measures are warranted.
- A wildlife biologist should document any active burrows within the proposed solar development. Attempts should be made to relocated any individuals within the proposed solar development and relocate those individuals at least 400 m outside of the immediate impact area immediately prior to construction to reduce collapsing active burrows on existing wildlife. This will also reduce the level of dispersal into the adjacent landscape thus reducing stress on already limited resources within desert landscapes.
- As most solar arrays are typically fenced (chain-linked) for security purposes, we suggest installing low to the ground openings (during construction) to allow wildlife to move through the fence rather than digging under the fence. This can help maintain the integrity of the fence for a longer duration.

Conclusions

We conclude that the development and operations of a solar array does not produce “edge” as defined by Murcia (1995). However, the effect of this type of development on existing small mammal and reptile communities has measurable impacts. This effect is primarily observed as displacement (Lovich and Ennen 2011, Northrup and Wittemyer 2013) where the area physically developed for the solar array is generally considered non-habitat or low-quality habitat for these communities as measured by three metrics: species richness, species diversity, and relative abundance. On open desert landscapes, the development of solar arrays will likely create islands of non- or low-quality habitat increasing heterogeneity in the landscape. Furthermore, the increase in abundance adjacent to solar arrays may unbalance the equilibrium of that habitat beyond its carrying capacity. The results presented in the paper will need to be considered as solar generation continues to scale up and solar arrays become more prominent on desert landscapes.

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Figure 1. Overview of solar energy development on three military installations in the Desert Southwest, USA (inset) in 2014-2015.

Figure 2. Schematic of sampling design for small mammals (A) in proximity to solar development. Hashed line (encompassing "treatment") represents the solar facility as outlined by a physical fence barrier and vertical hashed boxes represent grids. For reptile trapping, small mammal grids were replaced by grid (B). All other dimensions remain the same.

Figure 3. Comparison of reptile diversity (A; Shannon-Wiener Index) and relative abundance (B) between treatment (solar field) and control (un-impacted) sites at three military installations across the Desert Southwest: Davis-Monthan Air Force Base (DMAFB), Yuma Proving Ground (YPG), and Edwards Air Force Base (EAFB) in 2015.

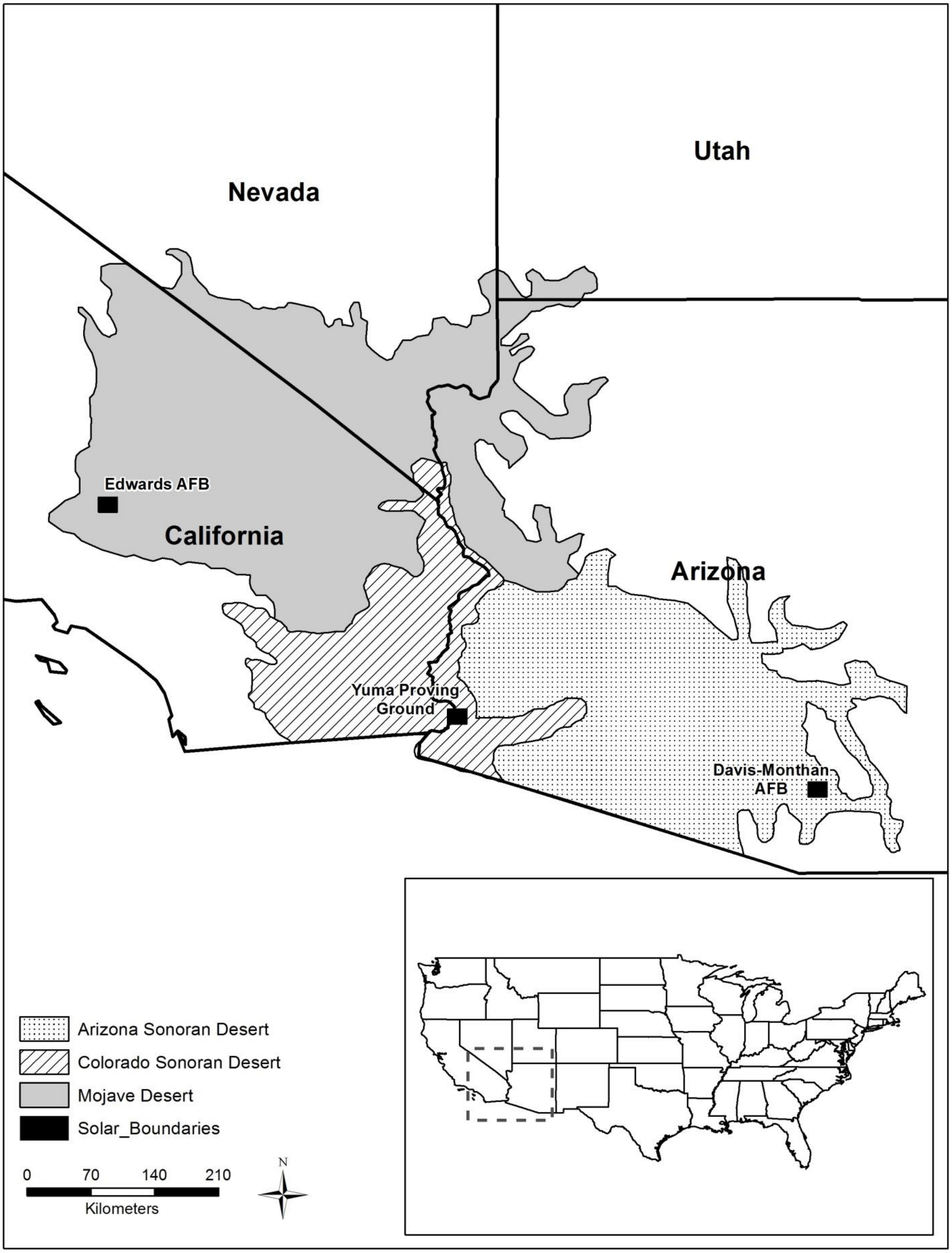
Figure 4. Comparison of small mammal diversity (A; Shannon-Wiener Index) and relative abundance (B) between treatment (solar field) and control (un-impacted) sites at three military installations across the Desert Southwest: Davis-Monthan Air Force Base (DMAFB), Yuma Proving Ground (YPG), and Edwards Air Force Base (EAFB) in 2014-2015.

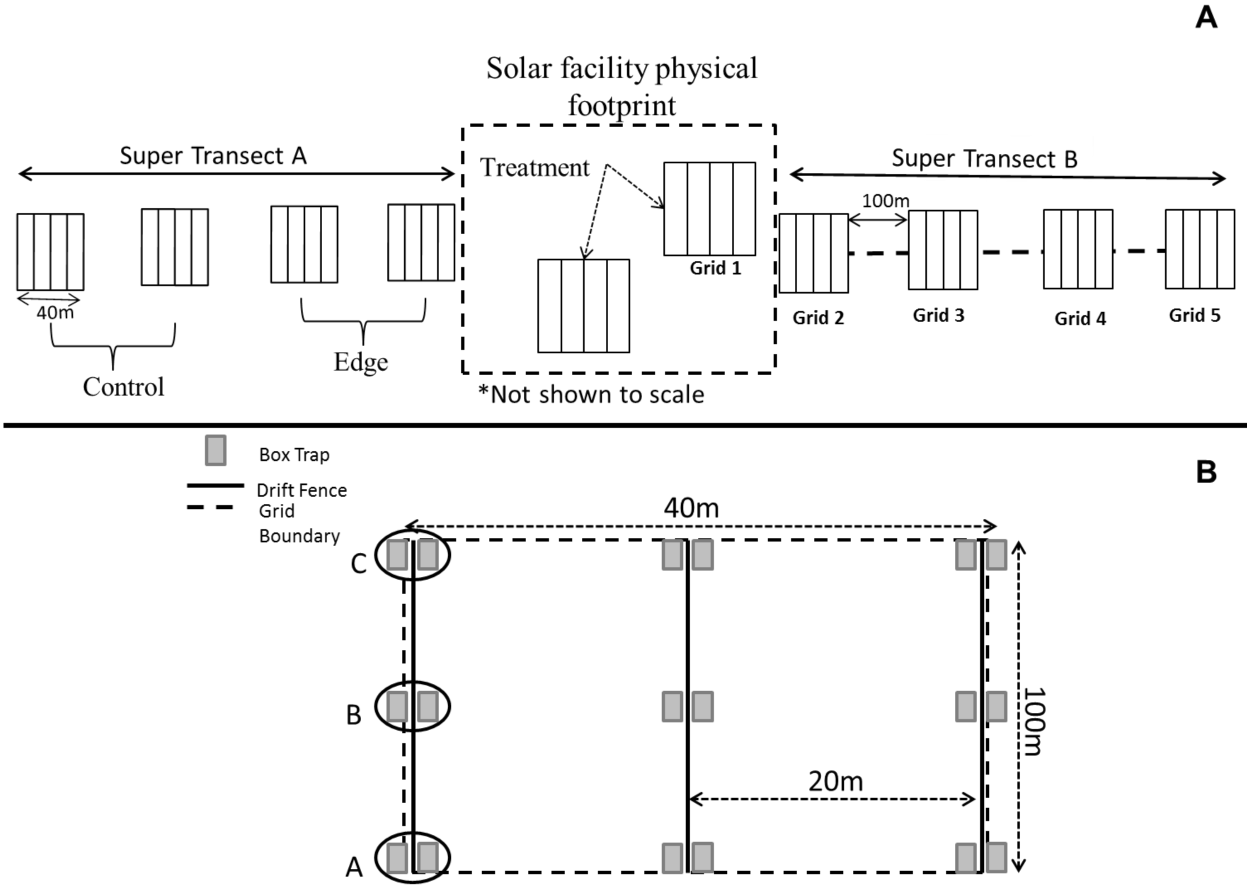
Figure 5. Diversity index of small mammals (A) and reptiles (B) at each of three military installations in the Desert Southwest during trapping efforts between November 2014 and July 2015.

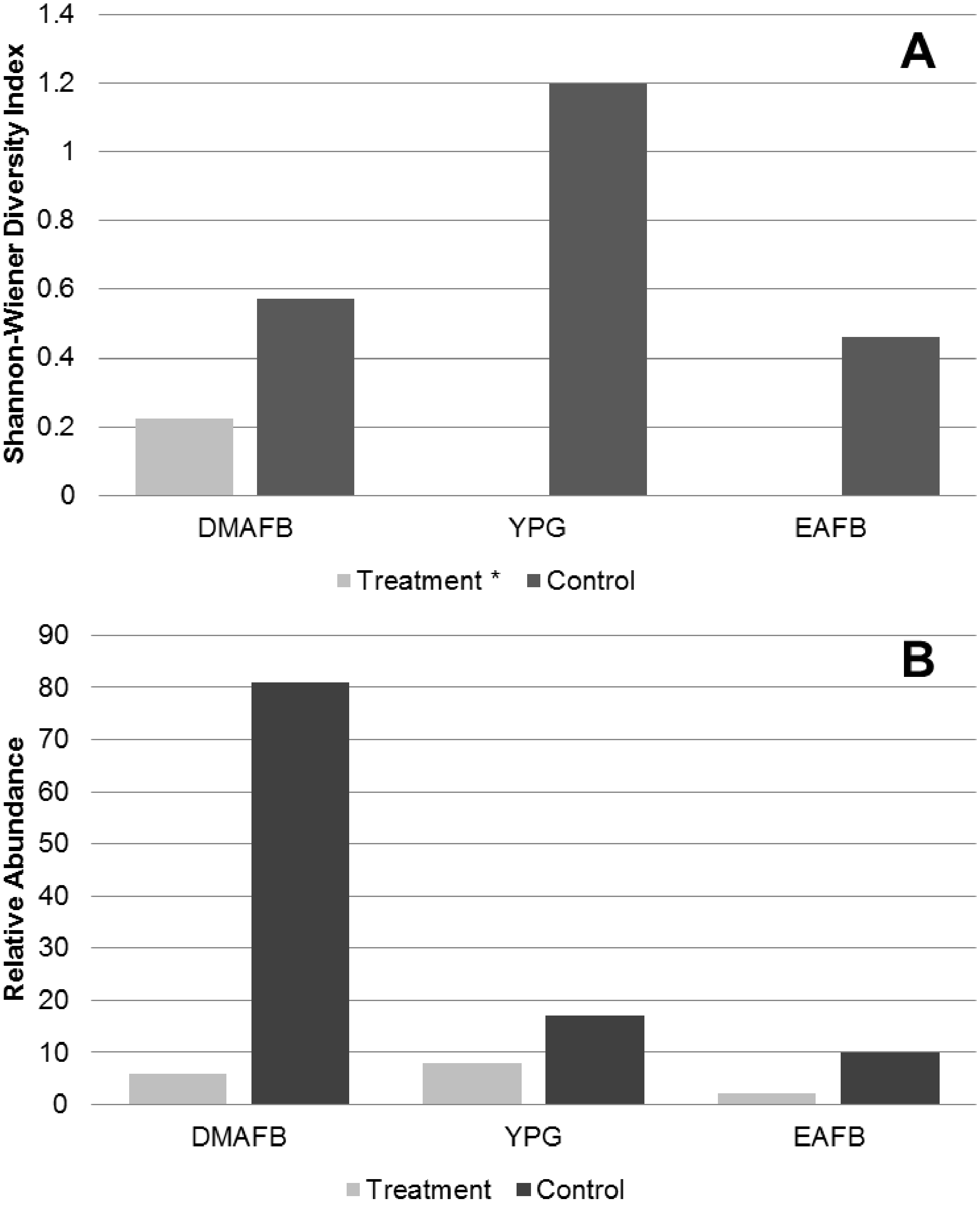
Figure 6. Relative abundance of small mammals (A) and reptiles (B) at each of three military installations in the Desert Southwest during trapping efforts between November 2014 and July 2015.

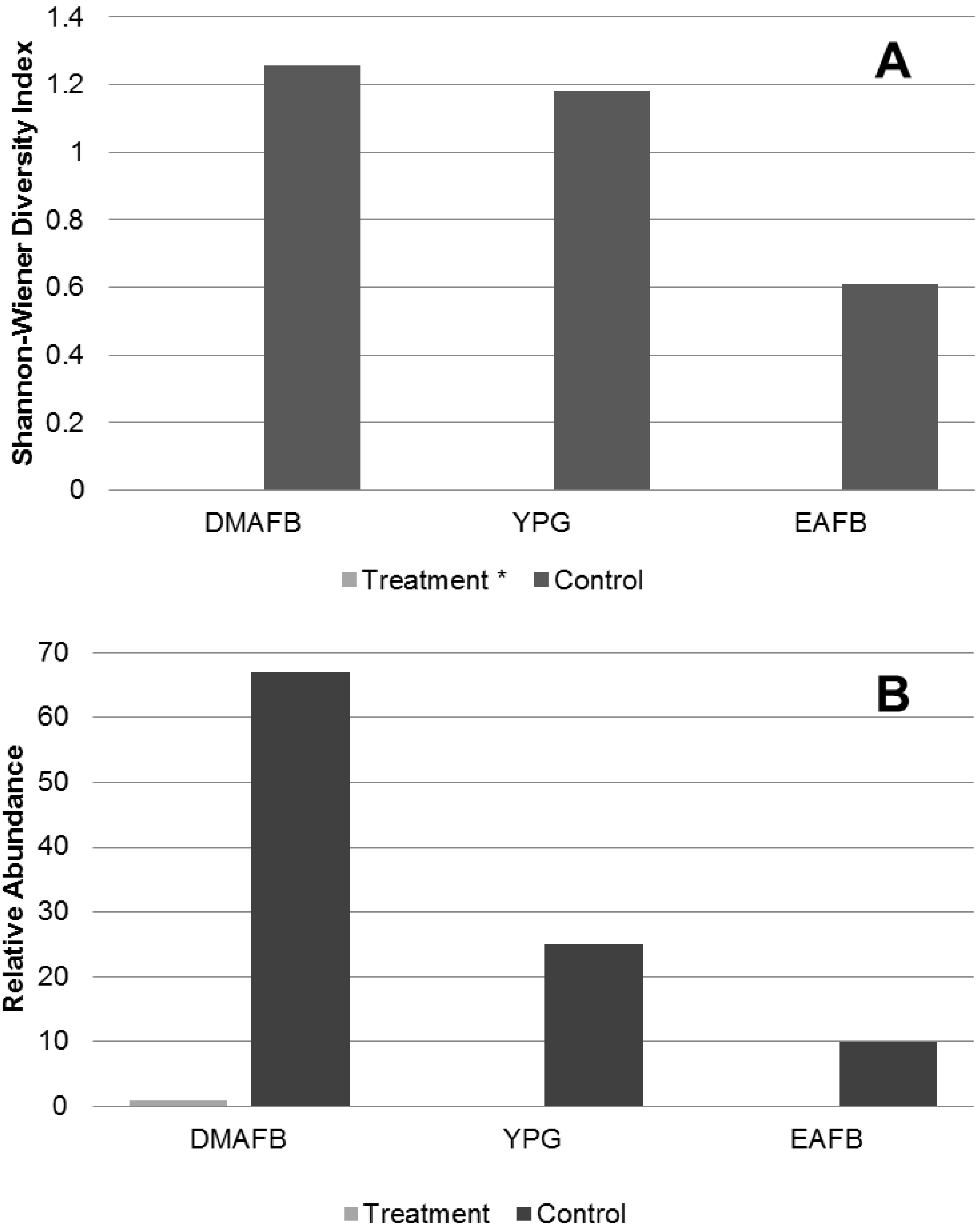
Figure 7. Comparison of captured individuals between traps located within the solar array and those beyond the solar array of three different solar footprint designs in three Desert Southwest,

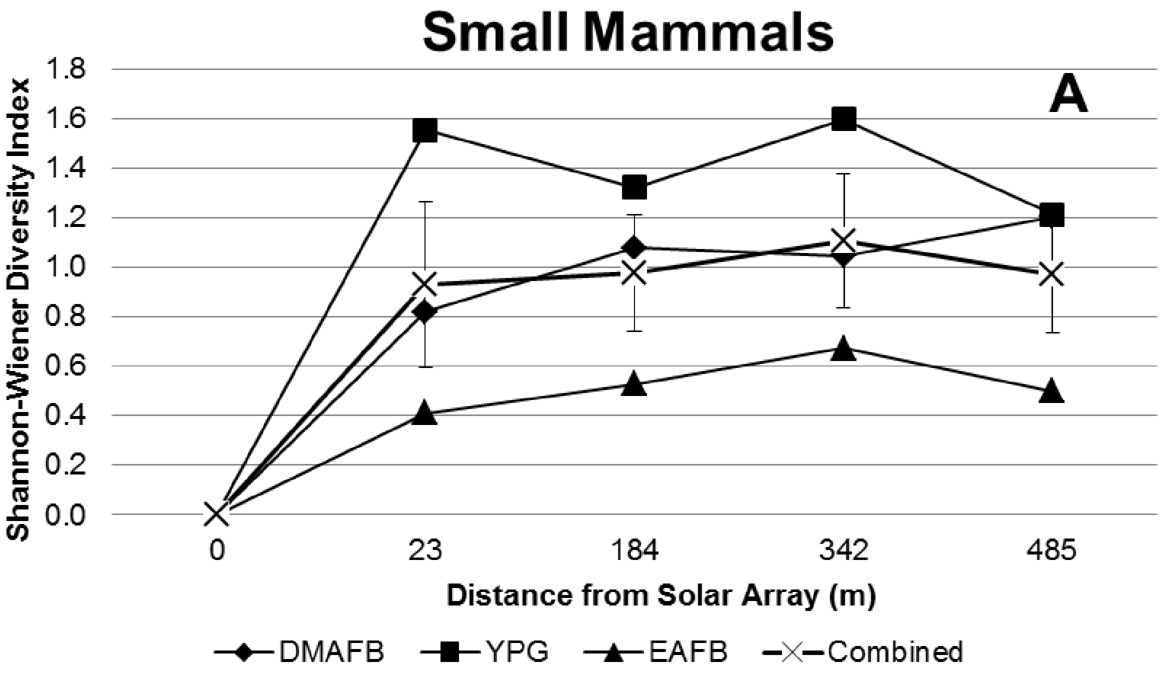
2014-2015. Relative abundance was measured as the average number of individuals captured per footprint type.

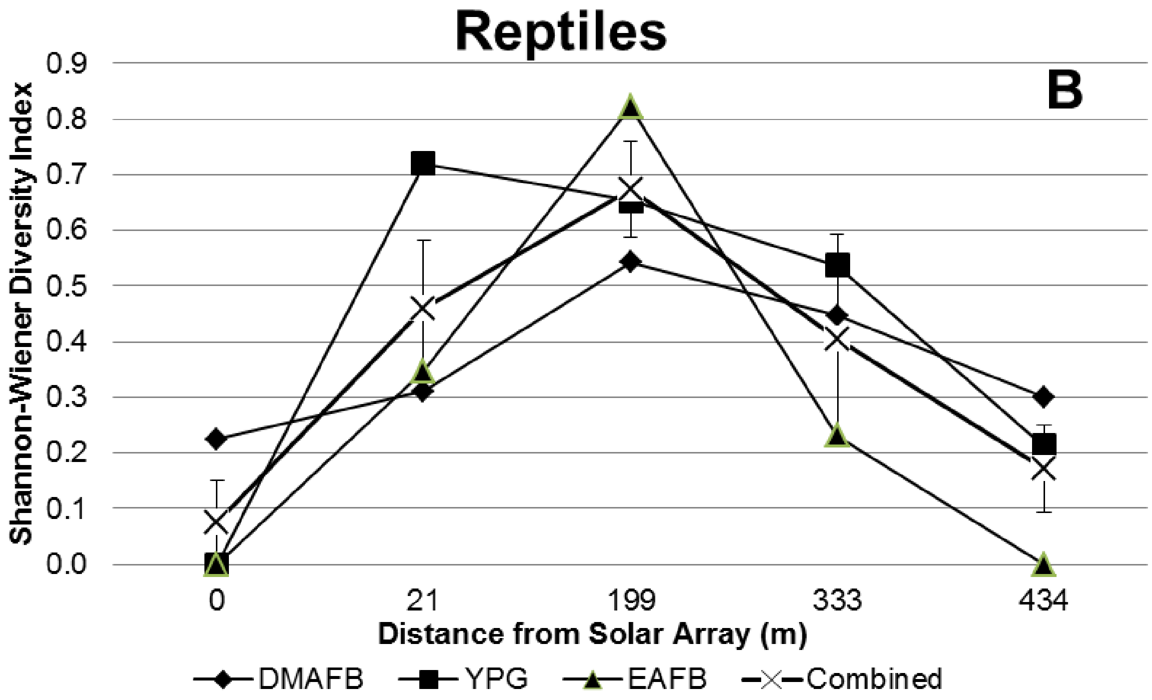

Utah
Nevada
Edwards AFB
California
Arizona
Yuma Proving Ground
Davis-Monthan AFB
Arizona Sonoran Desert
Colorado Sonoran Desert
Mojave Desert
Solar_Boundaries
0
70
140
210
Kilometers
N

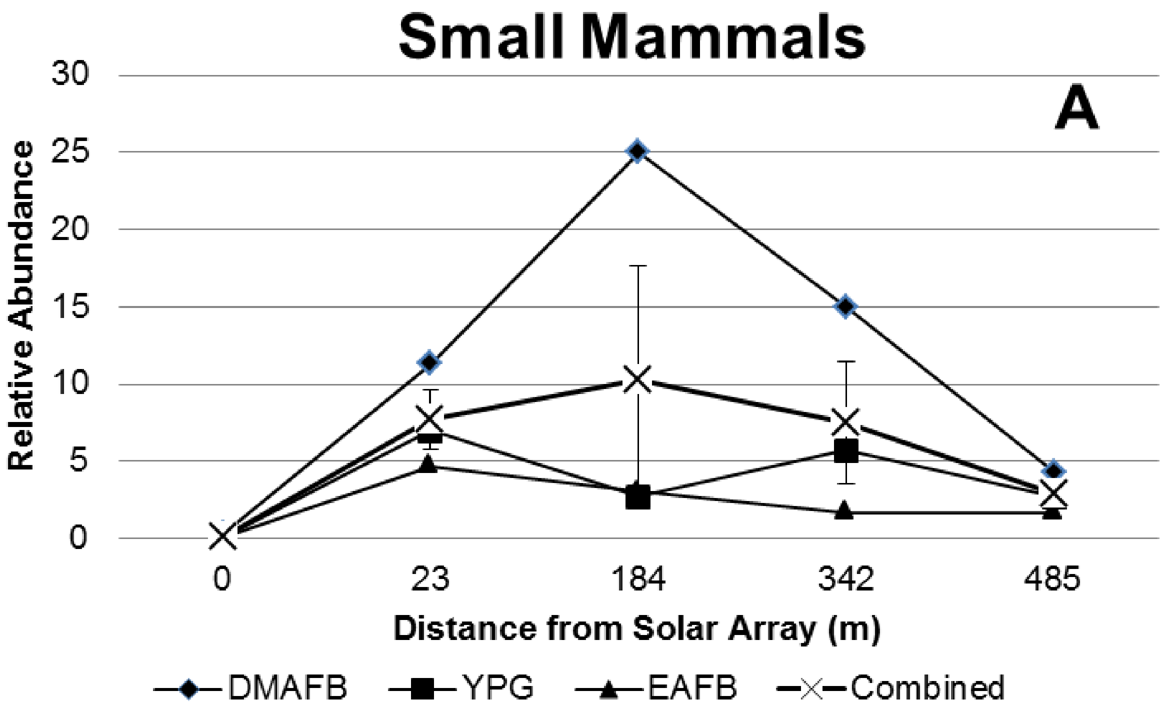

A
Solar facility physical footprint
Super Transect A
Treatment
Super Transect B
100m
Grid 1
40m
Grid 2
Grid 3
Grid 4
Grid 5
Edge
Control
*Not shown to scale
B
Box Trap
Drift Fence
Grid Boundary
40m
C
B
A
20m
100m

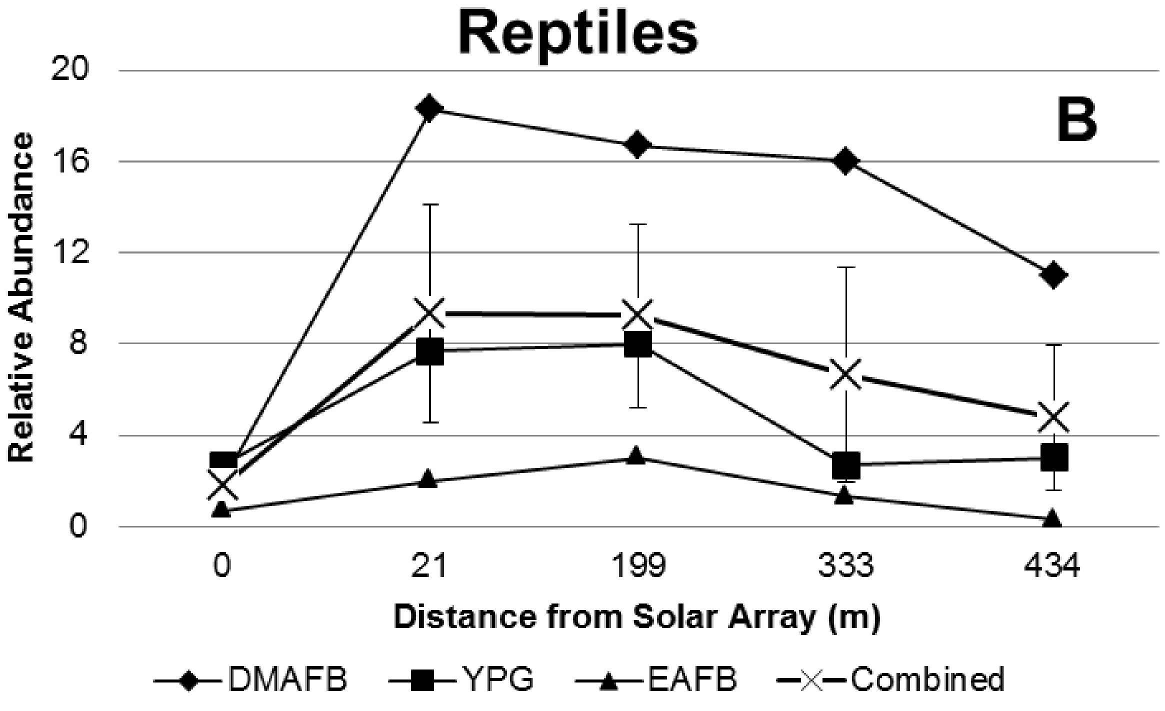

A
Shannon-Wiener Diversity Index
1.4
1.2
1
0.8
0.6
0.4
0.2
0
DMAFB
YPG
EAFB
▨ Treatment *
■ Control
B
Relative Abundance
90
80
70
60
50
40
30
20
10
0
DMAFB
YPG
EAFB
▨ Treatment
■ Control


A
Shannon-Wiener Diversity Index
1.4
1.2
1
0.8
0.6
0.4
0.2
0
DMAFB
YPG
EAFB
Treatment *
Control
B
Relative Abundance
70
60
50
40
30
20
10
0
DMAFB
YPG
EAFB
Treatment
Control


Small Mammals
A
Shannon-Wiener Diversity Index
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
23
184
342
485
Distance from Solar Array (m)
DMAFB
YPG
EAFB
Combined


Reptiles
B
Shannon-Wiener Diversity Index
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
21
199
333
434
Distance from Solar Array (m)
DMAFB
YPG
EAFB
Combined


Small Mammals
A
Relative Abundance
30
25
20
15
10
5
0
0
23
184
342
485
Distance from Solar Array (m)
DMAFB
YPG
EAFB
Combined


Reptiles
B
Relative Abundance
20
16
12
8
4
0
0
21
199
333
434
Distance from Solar Array (m)
DMAFB
YPG
EAFB
Combined

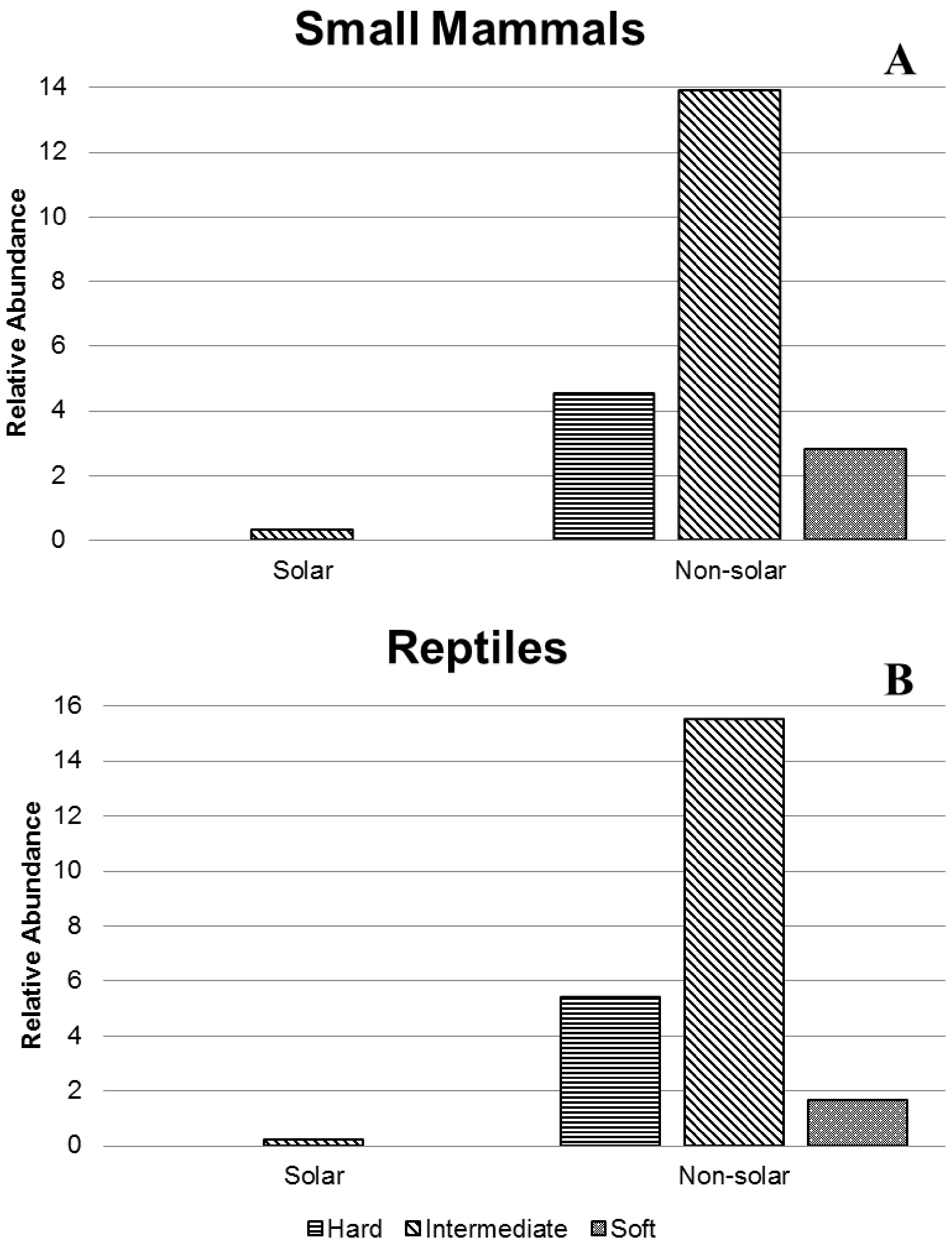

Small Mammals
A
Relative Abundance
14
12
10
8
6
4
2
0
Solar
Non-solar
Reptiles
B
Relative Abundance
16
14
12
10
8
6
4
2
0
Solar
Non-solar
▤Hard ▧Intermediate ▩Soft

Table 1. Trapping efforts across three military installations from 7 Nov. 2014 to 17 Jul. 2015. Military installations include: Davis-Monthan Air Force Base (DMAFB), Yuma Proving Ground (YPG), and Edwards Air Force Base (EAFB).

Cumulative Trapping Efforts

Small Mammals

	# Traps	# Trap-nights	# Captures	# Recaptures	# Species*
DMAFB	440	21,569	177	211	7
YPG	450	22,051	54	12	7
EAFB	500	24,500	33	12	2
Totals	1,390	68,120	264	235	10

Reptiles

	# Traps	# Trap-nights	# Captures	# Recaptures	# Species*
DMAFB	90	540	175	17	10
YPG	81	486	71	1	5
EAFB	69	414	21	1	6
Totals	240	1,440	267	19	15

* Cumulative number of species at each installation and overall.

Table 2. Small mammal species richness at each grid for three military installations in the Desert Southwest, 2014-2015.

	Small Mammal Species* Composition by grid Grid 1	Grid 2	Grid 3	Grid 4	Grid 5
DMAFB	DIME	CHIN DIME SIAR	AMHA CHIN DIME NEAL XETE	AMHA CHIN CHPE DIME SIAR XETE	CHIN DIME NEAL SIAR
YPG	N/A	AMHA CHBA CHIN CHPE DIME PEER	AMHA CHBA CHIN CHPE DIME	AMHA CHBA CHIN CHPE DIME XETE	AMHA CHBA CHIN CHPE
EAFB	AMLE DIME	AMLE DIME	AMLE DIME	AMLE DIME	AMLE DIME

* AMHA=*Ammospermophilus harrisii*; AMLE=*A. leucurus*; CHBA=*Chaetodipus baileyi*; CHIN=*C. intermedius*; CHPE=*C. penicillatus*; DIME=*Dipodomys merriami*; NEAl=*Neotoma albigula*; PEER=*Peromyscus eremicus; SIAR*=Sigmodon arizonae*;* XETE=*xerospermophilus tereticaudus*

Table 3. Reptile species richness at each grid for three military installations in the Desert Southwest, 2014-2015.

	Reptile Species* Composition by grid				
	Grid 1	Grid 2	Grid 3	Grid 4	Grid 5
DMAFB	ASTI PICA UROR	ASTI CRAT PHSO UTST	ASTI CADR COVA UTST	ASTI CADR COVA HYCH SCMA UROR	ASTI CADR UROR
YPG	UTST	ASTI CADR COVA UTST	ASTI DIDO UTST	ASTI CADR COVA DIDO UTST	ASTI UTST
EAFB	ASTI	ASTI COFL UTST XAVI	ASTI SAHE UTST XAVI	ASTI COFL CRSC	ASTI

* ASTI=*Aspidoscelis tigris*; CADR=*Callisaurus draconoides*; COVA=*Coleonyx variegatus*; COFL=*Coluber flagellum*; CRAT=Crotalus atrox*;* CRSC=*C. scutulatus*; DIDO=*Dipsosaurus dorsali*; HYCH=*Hypsiglena chlorophaea*; PHSO=*Phrynosoma solare*; PICA=*Pituophis catenifer*; SAHE=*Salvadora hexalepis*; SCMA=*Sceloporus magister*; UROR=*Urosaurus ornatus*; UTST=*Uta stansburiana*