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WINTERING ECOLOGY OF SHRUBLAND BIRDS: LINKING LANDSCAPE AND HABITAT

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EXECUTIVE SUMMARY

- The objectives of this study are to investigate for shrubland birds: 1) habitat associations on the wintering grounds, 2) climate influences on wintering distributions, and 3) breeding-wintering ground connectivity using stable isotopes.
- The Annual Report is a summary of the data collected during the first field season of winter 2005/06 and therefore, all results reported in this document should be viewed as preliminary.
- This study was conducted on eight DoD installations: Barry M. Goldwater Range - East, Edwards Air Force Base, Fort Bliss, Fort Irwin, Fort Huachuca, Naval Weapons Center China Lake – North Range, White Sands Missile Range, and Yuma Proving Grounds.
- We delineated the study boundary according to wintering shrubland species distributions, derived from long-term Christmas Bird Count data (delivered to DoD Legacy in 2005), which overlapped with five TNC ecoregions (Fig. 1).
- We developed a new vegetation spatial data set based on the SWReGap and cross-walked CAGap vegetation spatial data sets. The new vegetation spatial data set consisted of 90 ecological systems of which 27 are found on the eight DoD installations (Table 1). Ecological system richness followed a longitudinal gradient with DoD installation in the eastern part of the southwestern U.S. having higher richness compared to installations in the western region. The extent of ecological systems within DoD installations is dominated by the Sonora-Mojave Creosotebush-White Bursage Desert Scrub, the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe, and the Sonoran Paloverde-Mixed Cacti Desert Scrub. The North American Warm Desert Riparian Mesquite Bosque and Colorado Plateau Pynion-Juniper Woodland cover the least area on DoD installations (Table 1).
- Within each DoD installation, we delineated 1km-transects randomly stratified by the extent of the 27 ecological systems. Overall, we sampled 143 transects, of which 131 were within the boundaries of the DoD installations (Table 2) and detected a total of 3638 individuals in 71 species (Table 3). The most frequently detected species were the Brewer's Sparrow (800 detections), Horned Lark (575 detections), Sage Sparrow (529 detections), Black-throated Sparrow (301 detections), and Black-tailed Gnatcatcher (127 detections). These data were used to investigate avian community and species habitat associations at two scales: Large scale (DoD installations and ecological systems) and intermediate scale (1km-transect).
- At the large scale, installations differed in mean shrubland and overall avian species richness with some installations ranking high in both richness indices (e.g., Fort Huachuca and Barry M. Goldwater Range), ranking high in avian richness but not shrubland species richness (Edwards Air Force Base), ranking low in avian richness but high in shrubland species richness (White Sands Missile Range), and ranking low in both richness indices (Naval Weapons Center China Lake - North Range and Fort Irwin) (Fig. 2). Mean shrubland species abundance also differed among DoD installations with Fort Huachuca ranking highest in mean abundance for three shrubland species (Brewer's Sparrow, Green-tailed Towhee, and Vesper Sparrow) and Edwards Air Force Base (Sage Sparrow) and the Barry M. Goldwater Range (Black-throated Sparrow) ranking highest for one species (Fig. 3). For shrubland species, we identified nine ecological systems (30%, n = 27 ecological systems) in which these species were detected most frequently

(Table 4). Of the nine ecosystems, six ranked high for two shrubland species: Apacherian-Chihuahuan Mesquite Upland Scrub, Chihuahuan Mixed Salt Desert Scrub, Chihuahuan Sandy Plains Semi-Desert Grassland, Chihuahuan-Sonoran Desert Bottomland and Swale Grassland, North American Warm Desert Riparian Mesquite Bosque, Sonora-Mojave Mixed Salt Desert Scrub.

- At the intermediate scale (1km-transect), preliminary analyses revealed that avian richness related positively to monsoon herbaceous cover and spring grass cover but negatively to shrub coefficient of variation and bare ground. Shrubland bird abundance related to herbaceous or grass cover and height in five species (we were not able to model the Sage Thrasher due to low detections), but shrub cover and height were included as variables only in two species models (Brewer's and Sage Sparrow). In contrast, all of these species require some shrub cover on the breeding grounds.
- At the locale scale, we captured 789 individuals in 30 species, 76% of which were shrubland birds (Table 5). The most frequently captured species were Brewer's sparrows, White-crowned Sparrows, Black-throated Sparrows, Sage Sparrows, and Sage Thrashers. For these species, adult-juvenile ratios differed among installations. Preliminary analyses suggested that body size correlated with wintering region for two of three species analyzed (Brewer's Sparrow and Sage Sparrow) with larger individuals wintered in the eastern portions of the southwestern U.S (Fig. 5). For the Black-throated Sparrow, neither latitude nor longitude related to body size (Fig. 5).
- During the winter of 2005/06 and the breeding season of 2006, we captured birds and collected feather samples for the isotope analyses at over 70 locations within the western United States (Fig 6). Preliminary analyses of the isotope data for the Brewer's Sparrow revealed that breeding populations do not segregate on the wintering grounds. For example, individuals breeding east of the Rocky Mountains in Wyoming wintered in New Mexico whereas populations breeding in the western portion of the Great Basin wintered in Arizona and California (Fig. 7). For the Sage Sparrow, preliminary analyses suggest that breeding populations separate on the wintering grounds (Fig. 8). For example, of the nine individuals caught on the wintering grounds in New Mexico and California, all had isotopic signatures resembling those of birds breeding in Wyoming. We are in the process of analyzing and additional 800 feathers to substantiate the preliminary analyses.
- During the next field season of winter 2006/07, we are planning to survey wintering birds on at least 140 of the 143 transects sampled last winter (3 transect may prove difficult to resample), add additional transects to improve sample sizes, capture birds on all 67 2005/06 capture locations, add additional capture locations to improve sample sizes, and last, measure vegetation on all transects and capture locations.
- We conclude with a discussion of how this study will benefit the military. Specifically, we provide for eight DoD installations four prototype distribution maps delineating 1) high abundance areas for two shrubland species (Fig. 9 and 10), 2) high abundance areas for shrubland species combined (Fig. 11), 3) high avian richness (Fig. 12), and 4) locations of transect that could be ultimately implemented into a monitoring strategy of wintering birds on DoD lands (Fig. 13).

INTRODUCTION

Landscapes dominated by sagebrush (*Artemisia* spp.) in the western United States represent one of the nation's most imperiled ecosystems due to extensive habitat loss and habitat degradation (Noss et al. 1995). Exotic grasses and forbs now dominate a large proportion of this once vast ecosystem and have altered disturbance regimes and ecosystem processes. Consequently, populations of many birds associated with shrubland habitats are declining (Sauer et al. 2003). Although habitat changes on breeding grounds are a significant cause of these declines (Knick and Rotenbery 2002), the additional contribution of influences on shrubland birds during migration and on wintering grounds remains unknown (Knick et al. 2003). Therefore, defining the key wintering areas and critical habitats and developing the linkages between breeding and wintering grounds that influence population dynamics will be critical for the long-term conservation of shrubland birds.

Events during the wintering period may contribute significantly to annual dynamics in shrubland birds because in most migratory bird species, the nonbreeding period is roughly three times longer than the breeding season. For Neotropical migrant birds, the few studies that have investigated population regulation during the non-breeding season, all suggest the potential of population regulation to occur outside of the breeding grounds; survival rates may be lowest during migration, and up to 85% of the annual mortality may occur outside of the breeding grounds (Marra and Holmes 2001; Sillett and Holmes 2002). However, baseline information for shrubland birds is not available on habitats used by wintering birds or the linkages to their breeding ranges. In addition, we do not know the relative influence of climate or habitat characteristics that influence inter- and intra-annual variation in areas used by wintering birds.

The extent to which multiple breeding populations concentrate during winter and their annual or seasonal fidelity to wintering areas is important to understanding the relative significance of local, large-scale, or climatic influences on wintering areas (Webster et al. 2002). Local factors, such as contaminants or habitat disturbance, might be important if birds consistently use the same areas on a seasonal or yearly basis. As such, lands managed by the DoD in the southwestern United States may provide critical and stable habitats for a significant proportion of birds breeding across large areas in the northern Intermountain West. Indeed, 11 southwestern DOD installations overlap with one or more wintering ranges of shrubland birds.

Climate or land use changes on wintering areas potentially influence bird populations across a wide distribution of breeding range if birds concentrate during winter. For example, El Nino oscillations influence winter survival rates of Neotroopical migrants (Sillett et al. 2001). Therefore, the extent to which breeding populations segregate and/or aggregate on the wintering grounds is paramount in the development of conservation strategies for wintering shrubland birds because populations that are fixed to certain wintering ranges do not have as much potential genetic flexibility to respond to habitat and climatic changes occurring within their wintering ranges or on their breeding grounds (Both and Visser 2001).

Traditionally, site fidelity and habitat use by wildlife has been studied employing methods such as radio tracking. However, such methods are not feasible because most shrubland species of birds are too small to carry a radio-transmitter. Similarly, capture-recapture methods fail because too few individuals have been banded and recapture rates are virtually nonexistent (Kelly and Finch 1998; Hobson 1999; Kelly 2000). We now can use an analysis of stable isotopes in feathers of birds captured on wintering areas to link wintering and breeding ranges. Ratios of stable isotopes in feathers reflect concentrations contained in foods eaten during the

summer period of feather growth (species breeding in shrublands grow new feathers on the breeding grounds). Because concentrations of stable isotopes vary along longitudinal and latitudinal gradients (Hobson and Wassenaar 1997), feathers of birds captured in winter contain a signature from the previous summer location where feathers were replaced.

This study has the following objectives: 1) Determine the contributions of environmental features to the presence, distribution, and abundance of migratory shrubland birds on DoD lands; 2) Connect wintering and breeding grounds of shrubland birds using stable isotopes and GIS analyses.

METHODS, RESULTS, AND THE NEXT FIELD SEASON

1. Study area and methods

We delineated the study area according to the abundance models of wintering shrubland species (n = 6) developed from Christmas Bird Count (CBC) data and a spatial vegetation data set delineating ecological systems generally occupied by shrubland birds (product delivered to DoD Legacy 12/1/2005). These six density maps were combined to derive an overall distribution map of wintering shrubland species. To delineate the study boundary according to an ecological criterion, we overlaid Nature Conservancy Ecoregions (The Nature Conservancy 2001) with the distribution map of wintering shrubland species resulting in a perfect fit of 5 ecoregions: Apache Highlands, Arizona-New Mexico Mountains, Chihuahuan Desert, Mojave Desert, and Sonoran Desert (Fig. 1).

Within the study boundary, we derived a vegetation map based on ecological systems (NatureServe, 2005) by combining the SWReGap (http://www.gis.usu.edu/docs/projects/swgap/index.html) with the cross-walked CAGap (http://www.biogeog.ucsb.edu/projects/gap/gap_home.html) vegetation spatial data sets. This new vegetation map included 90 ecological systems. Of the 90 ecological systems, 27 overlapped with DoD installations (Table 1). Among DoD Installations, richness of ecological systems differed along a longitudinal gradient with installations in the eastern part of the southwestern U.S. having higher ecological systems richness [White Sands Missile Range (n = 20) > Fort Bliss (n = 18) > Fort Huachuca (n = 16) > Barry M. Goldwater Range (n = 12) > Yuma Proving Grounds (n = 10) > Naval Weapons Center China Lake - North Range (n = 7) > Fort Irwin (n = 5) > Edwards Air Force Base (n = 4)]. The extent of ecological systems within DoD installations, starting with the largest extent, ranked as follows: Sonora-Mojave Creosotebush-White Bursage Desert Scrub (present on five installations: Barry M. Goldwater Range, Edwards Air Force Range, Fort Irwin, and Yuma Proving Grounds), Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (present on two installations: Forts Bliss and Huachuca and White Sands Missile Range), Sonoran Paloverde-Mixed Cacti Desert Scrub ecological system (present in Barry M. Goldwater Range and Yuma Proving Grounds). In contrast, the North American Warm Desert Riparian Mesquite Bosque (Colorado Plateau Pynion-Juniper Woodland ecological system (found only in the White Sands Missile Range) cover the least area on DoD installations (Table 1).

Within each DoD installation, we delineated 1km-transects randomly stratified by the extent of each ecological system. We placed at least 5 transects within most ecological systems, placed transect in areas with low-level DoD training activity, and separated transects by ≥ 2km to ensure statistical independence. Overall, we sampled 143 transects of which 131 were within the

boundaries of the DoD installations (Table 2). Most transect were placed in the White Sands Missile Range (n = 41), with the rest of the installations containing between 9 and 18 transects. The majority of ecological systems (61%) were sampled at least five times (range 5 – 22) with the Sonora-Mojave Creosotebush-White Bursage Desert Scrub ecological system, the ecosystem with the largest extent, being sampled most frequently (n = 22). The remaining 39% of ecological systems were sampled between 1 and 4 times. Some ecological systems were under sampled because they were either difficult to access (e.g., Madrean Encinal) or of such small extent that the 2km inter-transect distance could not be applied (Table 2). To overcome the sampling discrepancy we are planning to lump some of the ecological systems, such as ecologically similar systems (e.g., Pinyon-Juniper Woodlands; n = 6), and will place additional transects in the under sampled ecological systems during the next field season in the winter of 2006/07. However, some ecological system will prove difficult to sample. For example, we found that the North American Warm Desert Riparian Mesquite Bosque ecological system is mainly in private domain or converted to systems dominated by the invasive tamarisk (*Tamarix sp.*).

Each 1km-transect was visited once during the winter season (Dec. 1 – Feb. 29). We estimated distance to each individual bird allowing us to calculate densities for each species using the program distance (Buckland et al. 2004). On each transect we collected shrub (genera level) and herbaceous cover and height. The herbaceous cover was measured according to two life forms (grass versus forbs), senescence period (annual versus perennial), and three precipitation regimes (winter: November – May; monsoon: July – September; and early winter: November – February). We tested whether this vegetation sampling scheme adequately represents precipitation regimes. Indeed we found that monsoon rainfall correlated with warm-season grass height.

To substantiate the census bird work, we also captured and banded birds on the 1km transects and locations where birds were abundant to investigate wintering habitat use and site fidelity of shrubland birds among years. Each captured bird was banded and a feather sample was collected. Feather samples are being currently (n = 500/800) analyzed by the Northern Arizona University's Isotope Laboratory. The results of these analyses will be used to link wintering and breeding grounds of shrubland birds.

2. Results

2.1 Large spatial scale (DoD Installations and Ecological Systems)

Preliminary analyses of the 1km-transect data set are based on descriptive statistics. Overall, we detected a total of 3638 individuals in 71 species (Table 3). The most common species, those with detections > 100, were the Brewer's Sparrow (800 detections), Horned Lark (575 detections), Sage Sparrow (529 detections), Black-throated Sparrow (301 detections), and Black-tailed Gnatcatcher (127 detections). There were five species with detections ranging between 50 – 100 (House Finch, Mourning Dove, Dark-eyed Junco, Loggerhead Shrike, and Gambel's Quail), 25 species with detections ranging between 10 – 49, 11 species with detections ranging between 5- 9, and 24 species with < 5 detections (50% were only detected once).

Total bird detections per transect ranged from 0 to 409. At the installation level, average detection ranked from highest to lowest as follows: Barry M. Goldwater Range (mean = 45.2, se = 18.7) > Fort Huachuca (mean = 38.5, se = 7.3) > Edwards Air Force Base (mean = 30.7, se = 8.1) >White Sands Missile Range (mean = 26.0, se = 15.1) > Fort Bliss (mean = 23.8, se = 8.1) >

Naval Weapons Center China Lake - North Range (mean = 18.8, se = 4.6) > Yuma Proving Grounds (mean = 17.2, se = 8.7) > Fort Irwin (mean = 13.4, se = 4.9).

DoD installation scale – Installations differed in mean shrubland species and overall avian richness with some installations ranking high in both richness indices (e.g., Fort Huachuca and Barry M. Goldwater Range), ranking high in avian richness but not shrubland species richness (Edwards Air Force Base), ranking low in avian richness but high in shrubland species richness (White Sands Missile Range), and ranking low in both richness indices (Naval Weapons Center China Lake - North Range and Fort Irwin) (Fig. 2).

At the species level, DoD installations differed in shrubland species mean abundance (Fig. 3) where Fort Huachuca ranked highest in mean abundance for three shrubland species (Brewer's Sparrow, Green-tailed Towhee, and Vesper Sparrow) and Edwards Air Force Base (Sage Sparrow) and the Barry M. Goldwater Range (Black-throated Sparrow) ranked highest for one species. We found the Brewer's Sparrows to be highly abundant (mean detection/km > 9) in three installations (Barry M. Goldwater Range, Fort Huachuca, and White Sands Missile Range), to be low abundant (mean detection/km 1.9 – 5.9) in two installations (Fort Bliss and Yuma Proving Grounds), and absent in three installations (Edwards Air Force Base, Fort Irwin, and Naval Weapons Center China Lake - North Range) (Fig. 3). We detected the Black-throated Sparrow on seven of the eight DoD installations (not detected on Edwards Air Force Base) and found it to be highly abundant (mean detection/km > 4 detections/km) in two installations (Barry M. Goldwater Range and White Sands Missile Range), intermediate abundant (mean detection/km 1.0 – 2.6) in two installations (Fort Huachuca and Yuma Proving Grounds), and low abundant (mean detection/km 0.008-0.55) in three installations (Fort Bliss, Fort Irwin, and Naval Weapons Center China Lake - North Range). The Green-tailed Towhee was detected only in half of the installations (Fig. 3). Highest mean abundance (1.08 detection/km) was documented in Fort Huachuca. On the other three installations, Barry M. Goldwater Range, White Sands Missile Range, and Yuma Proving Grounds, we documented mean detections/km ranging between 0.06 and 0.16. Similar to the Black-throated Sparrow, the Sage Sparrow was detected on seven of the eight installations (Fig. 3); we did not detect any Sage Sparrows in Fort Huachuca. Highest mean abundance/km (18.1 detections/km) was found in Edwards Air Force Base, followed by Fort Bliss (7.2 detections/km), Naval Weapons Center China Lake - North Range (4.7 detections/km), White Sands Missile Range (4.0 detections/km), and Fort Irwin (2.4 detections/km). Both the Barry M. Goldwater Range and Yuma Proving Ground installation had mean abundance of < 1 detection/km. The Sage Thrasher was found only in low abundance on two installations: Naval Weapons Center China Lake - North Range (0.8 detections/km) and White Sands Missile Range (0.5 detections/km) (Fig. 3). Last, we detected the Vesper Sparrow only on three installations and found the highest mean abundance on Fort Huachuca (1.3 detections/km); mean abundance on the Barry M. Goldwater Range and Yuma Proving Grounds were 0.23 and 0.33 detections/km, respectively (Fig. 3).

Ecological Systems – Shrubland and avian mean species richness differed among ecological systems with some systems ranking high in both richness indices (e.g., North American Warm Desert Riparian Mesquite Bosque ecological system – note n = 1, Riparian), ranking high in avian richness but not shrubland species richness (Madrean Ecinal, Colorado Plateau Pynion-Juniper Woodland – please note n = 1), ranking low in avian richness but high in shrubland species richness (Chihuahuan Sandy Plains Semi-Desert Grassland), and ranking low in both

richness indices (Mojave Mid-Elevation Mixed Desert Scrub and North American Warm Desert Pavement) (Fig. 4).

At the shrubland species level, we identified 9 ecological systems (30%) in which we found the three highest mean detections per species (Table 4). Of these nine ecosystems, six ranked highest for two species: Apacherian-Chihuahuan Mesquite Upland Scrub, Chihuahuan Mixed Salt Desert Scrub, Chihuahuan Sandy Plains Semi-Desert Grassland, Chihuahuan-Sonoran Desert Bottomland and Swale Grassland, North American Warm Desert Riparian Mesquite Bosque, Sonora-Mojave Mixed Salt Desert Scrub.

We found the Brewer's Sparrow, to be most frequently detected (mean detections/km > 10) in three ecological systems: Apacherian-Chihuahuan Mesquite Upland Scrub, Chihuahuan-Sonoran Desert Bottomland and Swale Grassland, and Riparian (Table 4). The Apacherian-Chihuahuan Mesquite Upland Scrub ecological system is most commonly found in the White Sands Missile Range (2% of total area), followed by Fort Bliss (4% of total area), and Fort Huachuca (28% of total area) (Table 1); this ecological system also occurs in small areas in the Barry M. Goldwater Range and Yuma Proving Grounds. The Chihuahuan-Sonoran Desert Bottomland and Swale Grassland ecological system is restricted to three DoD installations and covers (arranged in decreasing total area) 6% of the White Sands Missile Range, 3% of Fort Bliss, and 8% of Fort Huachuca. There were 13 ecological systems in which we did not detect any Brewer's Sparrows.

We found Black-throated Sparrow to be most plastic in habitat use occurring in 19 ecological systems. It was most frequently detected (mean detections/km ≥ 5) in the Chihuahuan Mixed Desert and Thorn Scrub, Chihuahuan Creosotebush Xeric Basin Desert Scrub, Chihuahuan Mixed Salt Desert Scrub, and Chihuahuan Sandy Plains Scrub Semi-Desert Grassland ecological systems (Table 4). All four ecological systems are restricted to three DoD installations (arranged in decreasing total area): White Sands Missile Range (16%, 4%, 6%, and 2% of total area, respectively), Fort Bliss (20%, 1.4%, 0.4%, and 0.3 of total area, respectively), and Fort Huachuca (25%, 0.2%, 0.5%, and 0.01% of total area, respectively) (Table 1).

The Green-tailed Towhee was detected in seven ecological systems but was most common (mean detections/km ≥ 2) in the Apacherian-Chihuahuan Mesquite Upland Scrub and North American Warm Desert Riparian Mesquite Bosque ecological systems (Table 4). The Apacherian-Chihuahuan Mesquite Upland Scrub ecological system is most commonly found in the White Sands Missile Range, Fort Bliss, and Fort Huachuca (see Brewer's Sparrow above) (Table 1); this ecological system also occurs in small areas in the Barry M. Goldwater Range and Yuma Proving Ground. The North American Warm Desert Riparian Mesquite Bosque ecological system is restricted to five DoD installations (arranged in decreasing total area): Barry M. Goldwater Range (0.05% of total area), White Sands Missile Range (0.004% of total area), Yuma Proving Ground (0.004% of total area), Fort Bliss (0.003% of total area), and Fort Huachuca (0.01% of total area).

Trailing the Black-throated Sparrow in habitat use plasticity, the Sage Sparrow was detected in 15 ecological systems, but most commonly (mean detections/km ≥ 5) in four ecological systems (arranged in decreasing mean detections: Chihuahuan Sandy Plains Semi-Desert Grassland, Sonora-Mojave Mixed Salt Desert Scrub, North American Warm Desert Active and Stabilized Dune, and North American Warm Desert Wash) to contain abundance indices of ≥ 5 (Table 4). The Chihuahuan Sandy Plains Scrub Semi-Desert Grassland ecological system, containing the highest mean detections of this species, is restricted to three DoD installations (arranged in decreasing total area): White Sands Missile Range (2% of total area),

Fort Bliss (0.3 of total area), and Fort Huachuca (0.01% of total area) (Table 1). The Sonora-Mojave Mixed Salt Desert Scrub, found on five of the eight sampled DoD installations, covers between 41% and 0.03% of the installations (arranged in decreasing total area: Edwards Air Force Base 41%, Naval Weapons Center China Lake - North Range 10.4%, Barry M. Goldwater Range 0.4%, Fort Irwin 0.6%, and Yuma Proving Grounds 0.03%). The North American Warm Desert Active and Stabilized Dune is restricted to White Sands Missile Range (5.1% of total area), Fort Bliss (9.5% of total area), and Barry M. Goldwater Range (1.2% of total area). The North American Warm Desert Wash ecological system is found on all eight sampled DoD installations and covers from 1.1% in the Naval Weapons Center China Lake to 0.025% in the Yuma Proving Grounds.

The Sage Thrasher was only found in two ecosystem types (Table 4): Sonora-Mojave Mixed Salt Desert Scrub (arranged in decreasing total area: Edwards Air Force Base 41% of total area, Naval Weapons Center China Lake - North Range 10.4% of total area, Barry M. Goldwater Range 0.4% of total area, Fort Irwin 0.6% of total area, and Yuma Proving Grounds 0.03% of total area) and Chihuahuan Mixed Salt Desert Scrub (White Sands Missile Range 6% of total area, Fort Bliss 0.4% of total area, and Fort Huachuca 0.5% of total area) (Table 1).

The Vesper Sparrow, found in 5 ecological systems (Table 4), occurred most frequently (mean detections/km ≥ 1) in the Apacherian-Chihuahuan Mesquite Upland Scrub, North American Warm Desert Riparian Mesquite Bosque, and Chihuahuan-Sonoran Desert Bottomland and Swale Grassland. The Apacherian-Chihuahuan Mesquite Upland Scrub ecological system (see Green-tailed Towhee) is most commonly found in the White Sands Missile Range, Fort Bliss, and Fort Huachuca (Table 1); this ecological system also occurs in small areas in the Barry M. Goldwater Range and Yuma Proving Ground. The North American Warm Desert Riparian Mesquite Bosque ecological system is restricted to five DoD installations Barry M. Goldwater Range, White Sands Missile Range, Yuma Proving Ground, Fort Bliss, and Fort Huachuca. The Chihuahuan-Sonoran Desert Bottomland and Swale Grassland ecological system is restricted to three DoD installations White Sands Missile Range, Fort Bliss, and Fort Huachuca (see Brewer's Sparrow).

2.2. Intermediate spatial scale (Transect Data)

Preliminary analyses at the intermediate spatial scale were conducted using multiple regression analyses with species abundance or species richness as the dependent variable and rain fall [spring rainfall (November – May), monsoon (July – September), and early winter (November – February)], herbaceous cover and height (forbs and grasses responding to three precipitation patterns), grass cover and height (grasses responding to three precipitation patterns), shrub cover (mean), shrub height (mean and coefficient of variation), and bare ground as the independent variables.

We found that shrubland species richness related positively to spring rainfall and early winter grass height but negatively to shrub height coefficient of variation and bare ground. Avian species richness related positively to monsoon herbaceous cover and spring grass cover but negatively to shrub coefficient of variation and bare ground.

For the six shrubland bird species, abundance was related to herbaceous or grass cover and height in five species (we were not able to model the Sage Thrasher due to low detections) but shrub cover and height were included as variables only in two species models (Brewer's and Sage Sparrow). In contrast, all shrubland species require some shrub cover on the breeding grounds. Specifically, for the Brewer's Sparrow, abundance was positively related to monsoon

grass cover and shrub cover. Black-throated Sparrow abundance was positively related to monsoon grass height but negatively to monsoon grass cover. Green-tailed Towhee abundance was positively related to monsoon grass height. Sage Sparrow abundance was negatively related to spring grass height and shrub coefficient of variation but positively to spring herbaceous height, early winter herbaceous cover, and bare ground. Vesper Sparrow abundance was positively related to spring grass height and monsoon grass cover.

2.3 Local spatial scale (Capture Data)

At the locale scale, we collected effort adjusted capturing rates of shrubland and other species along with vegetation data (using the same protocol as for 1km-transect). Across the southwestern United States we established 67 mist net locations and captured a total of 1,336 individuals in 36 species; 70% of total captures were shrubland birds. Within DoD installations, we captured 789 individuals in 30 species, 76% of which were shrubland birds (Table 5). The most frequently captured species were Brewer's sparrows, White-crowned Sparrows, Black-throated Sparrows, Sage Sparrows, and Sage Thrashers.

For the five most frequently captured species, adult-juvenile ratios differed among installations. For the Brewer's Sparrow, age class ratios were adult biased on Fort Bliss (87%), juvenile biased on the Barry M. Goldwater Range (25%) and Fort Huachuca (37%), but were neutral on the White Sands Missile Range (52%). For the Black-throated Sparrow, age class ratios were adult biased on the Barry M. Goldwater Range (68%) and White Sands Missile Range (58%), but were juvenile biased on Fort Bliss (17%). For the Sage Sparrow, age class ratios were adult biased on the Barry M. Goldwater Range (57%) and Fort Bliss (100%), but were neutral in the Edwards Air Force Base (50%). For the Sage Thrasher, there was an adult biased age class ratio (64%) in the White Sands Missile Range (only installation with enough captures). Last, for the White-crowned Sparrow, age class ratios were slightly adult biased on Fort Bliss (54%), but were juvenile biased on Edwards Air Force Base (33%), White Sands Missile Range (33%), and Yuma Proving Grounds (9%).

Preliminary analyses suggest that body size correlates with wintering region in two of three species analyzed (Brewer's Sparrow and Sage Sparrow) (Fig. 5). For both species we found a longitudinal body size cline. In the Sage Sparrow, larger individuals are found in the eastern and northern portions of the southwestern U.S with the largest individuals found in the north-eastern region. For the Brewer's Sparrow, there is a longitudinal trend with larger individuals wintering in the easterly portion of the southwestern U.S. For the third species, the Black-throated Sparrow, neither latitude nor longitude related to body size.

2.4 Connecting wintering and breeding grounds

We collected feathers from shrubland species on both the breeding and wintering grounds enabling us to calculate a probability of an individual caught on the wintering grounds belonging to a certain breeding population. The results presented in this annual report are preliminary and are based on pilot data. We have collected over 800 feather samples from wintering shrubland birds and from 248 individuals on the breeding grounds (Fig. 6). These feather samples are currently being analyzed in the Stable Isotope Laboratory at Northern Arizona University.

Preliminary analyses of the isotope data for the Brewer's revealed that breeding population do not segregate on the wintering grounds. That is, individuals breeding east of the Rocky Mountains in Wyoming wintered in New Mexico whereas populations breeding in the western portion of the Great Basin wintered in Arizona and California (Fig. 7). However, one

individual breeding in Washington, two breeding in northeastern Nevada, and one breeding in west-central Nevada wintered also in New Mexico. For the Sage Sparrow, preliminary analyses suggest that of the nine individuals caught on the wintering grounds in New Mexico and California, all had isotopic signatures resembling those of birds breeding in Wyoming (Fig. 8). We are in the process of analyzing and additional 800 feathers to substantiate the preliminary analyses.

PLANS FOR NEXT FIELD SEASON

During the next field season of winter 2006/07, we are planning;

- To survey wintering birds on at least 140 of the 143 transects sampled last winter (3 transect may prove difficult to resample)
- Add additional transects to improve sample sizes
- Capture birds on all 67 capture locations established during the winter of 2005/06
- Add additional capture locations to improve sample sizes
- Measure vegetation on all transects and capture locations to capture inter-annual variation in precipitation.

BENEFITS TO MILITARY

- This study will develop habitat models that will allow DoD land managers to develop installation management plans guiding training activities and to rank the importance of DoD installations in providing habitat for wintering avian species. Specifically, we will develop models that will relate species richness or species density with habitat, climate, and abiotic factors such as elevation and topography. At the species level, preliminary analyses suggested that Brewer's Sparrows were most frequently detected in the Apacherian-Chihuahuan Mesquite Upland Scrub, Chihuahuan-Sonoran Desert Bottomland and Swale Grassland, and Riparian ecological systems. Using this information, we developed a prototype map for each DoD installation in which we delineated ecological systems providing important wintering habitat for this species (Fig. 9). According to the Brewer's Sparrow habitat maps, Fort Bliss, Fort Huachuca, and White Sands Missile Range contained most of the habitat for this species. Similarly, the first year of this study showed that the Sage Sparrow was most frequently detected in the Chihuahuan Sandy Plains Semi-Desert Grassland, Sonora-Mojave Mixed Salt Desert Scrub, North American Warm Desert Active and Stabilized Dune, and North American Warm Desert Wash ecological systems. Again, we delineated these ecological systems in each DoD installation and found that Edwards Air Force Base and Naval Weapons Center China Lake -North Range contained most of the habitat important for this species (Fig 10). Last we delineated ecological systems supporting highest shrubland and avian richness (Fig. 11 and 12). Ultimately, the final maps will show density distributions of wintering species and diversity indices across DoD installations.
- The results of this study will allow DoD to assign importance of installations in providing wintering habitat for wintering shrubland species at the population level. Preliminary analyses of the stable isotopes, collected from feathers of birds captured on both the wintering and breeding grounds, suggested that DoD installations in New Mexico may potentially provide habitat for Brewer's Sparrows that breed in Wyoming, whereas

installations in southwestern Arizona and California provide wintering habitat for populations that breed in Oregon, Nevada and Idaho. These findings are important because DoD lands may provide crucial wintering habitat within a matrix of rapidly expanding urban areas in the Southwest for shrubland and other wintering species that are potentially fixed to certain wintering ranges and do not have as much potential genetic flexibility to respond to climatic changes and habitat losses.

- The products of this study will enable DoD land managers to delineate habitat important for nomadic shrubland and other bird species on annual basis. Because precipitation regimes differ within and among installations on an annual basis, DoD land managers can use the products of this study to spatially adjust training activities annually according to productivity of habitats and therefore suitability to nomadic wintering songbirds. The data collected in the first year of this study showed that herbaceous and grass cover influences wintering bird distributions. In turn, grass cover and height correlated with precipitation.
- If the second year of our study identifies habitat that is consistently occupied by wintering shrubland birds, then DoD land managers can develop management strategies that minimize the impact of DoD training activities in these habitat types. The first year of our study showed that the highest shrubland bird species and overall avian richness was found in the North American Warm Desert Riparian Mesquite Bosque ecological system. This ecosystem is infrequently found on DoD installations covering between 0.05 – 0.003% in five DoD installations.
- Last, the study design of this project could be adapted into a monitoring strategy for wintering birds on DoD installations (Fig. 11). Each installation will be provided with a baseline data set, depending on funding spanning 2 – 3 years, on wintering bird densities, and a study design that is stratified across large (southwestern U.S.), as well as small scales (Installation).

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Table 1: Area (km^2) covered by 27 ecological systems surveyed for wintering and residential birds in eight DoD Installations (gray coloration indicates absence of an ecological system in an installation).

	Installation: Area (km^2)							
Ecological System	Barry M. Goldwater Range	Edwards Air Force Base	Fort Bliss [a]	Fort Huachuca	Fort Irwin	Naval Weapons Center China Lake - North Range	White Sands Missile Range	Yuma Proving Grounds
Apacherian-Chihuahuan Mesquite Upland Scrub	1.73		137.21	77.91			198.09	0.02
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe			1287.62	25.26			2286.36	
Barren Land (Non-Specific)	5.86							37.25
Chihuahuan Creosotebush Xeric Basin Desert Scrub			55.08	0.81			352.22	
Chihuahuan Gypsophilous Grassland and Steppe			1.78				626.59	
Chihuahuan Mixed Desert and Thorn Scrub			765.68	71.63			1397.19	
Chihuahuan Mixed Salt Desert Scrub			13.83	14.18			517.28	
Chihuahuan Sandy Plains Semi-Desert Grassland			9.61	0.04			148.25	
Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub			1101.49	0.42			1269.59	
Chihuahuan-Sonoran Desert Bottomland and Swale Grassland			112.00	23.56			533.6	
Colorado Plateau Pynion-Juniper Woodland							0.06	
Great Basin Pinyon-Juniper Woodland						150.01		
Inter-Mountain Basins Big Sagebrush Shrubland						356.47		
Inter-Mountain Basins Semi-Desert Shrub-Steppe			4.60				9.36	
Madrean Encinal			2.22	28.26			4.53	
Madrean Pynion-Juniper Woodland	0.23		51.56	39.37			541.7	
Mojave Mid-Elevation Mixed Desert Scrub					5.23	94.07		
North American Warm Desert Active and Stabilized Dune	51.15		376.2				441.08	
North American Warm Desert Pavement			0.03	0.03			30.57	
North American Warm Desert Riparian Mesquite Bosque	1.9		0.11	0.03			0.32	0.15
North American Warm Desert Volcanic Rockland				0.18			178.22	
North American Warm Desert Wash	0.01	0.96	2.86	1.18	18.78	24.82	9.66	0.09
Riparian	0.92		4.89	0.27			19.76	0.56
Sonora-Mojave Creosotebush-White Bursage Desert Scrub	3143.48	601.29			1777.37	1308.6		2745.69
Sonora-Mojave Mixed Salt Desert Scrub	16.52	420.24			11.35	223.39		0.96
Sonoran Mid-Elevation Desert Scrub	4.76							0.06
Sonoran Paloverde-Mixed Cacti Desert Scrub	1014.41							598.83
Total Area (km^2)	4240.97	1022.50	3926.77	283.13	1812.73	2157.37	8564.44	3383.60

[a] For Fort Bliss, the SWReGap vegetation spatial data set only includes the portion within New Mexico. There are currently no comprehensive vegetation spatial data sets available for the State of Texas.

Table 2: Location of bird and vegetation sampling transects in relation to 27 ecological systems and 8 DoD Installations [light-grey coloration = ecological system not present on installation, dark-grey coloration = not sampled but ecological system present on installation with area (km^2) added for reference].

Ecological System	Barry M. Goldwater Range	Edwards Air Force Base	Fort Bliss	Fort Huachuca	Fort Irwin	Naval Weapons Center China Lake -North Range	White Sands Missile Range	Yuma Proving Grounds	Outside DoD	Grand Total
Apacherian-Chihuahuan Mesquite Upland Scrub	1.7		1	3			1			5
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe			1	1			2		1	5
Barren Land (Non-Specific)	1							4		5
Chihuahuan Creosotebush Xeric Basin Desert Scrub			55.1	0.8			5			5
Chihuahuan Gypsophilous Grassland and Steppe			1.8				5			5
Chihuahuan Mixed Desert and Thorn Scrub			765.6	2			3			5
Chihuahuan Mixed Salt Desert Scrub			1	1			3			5
Chihuahuan Sandy Plains Semi-Desert Grassland			2	0.04			3			5
Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub			1	0.4			4			5
Chihuahuan-Sonoran Desert Bottomland and Swale Grassland			112.0	2			4			6
Colorado Plateau Pynion-Juniper Woodland							0.06		3	3
Evergreen Forest/Chihuahuan Mixed Desert and Thorn Scrub									1	1
Great Basin Pinyon-Juniper Woodland						2				2
Inter-Mountain Basins Big Sagebrush Shrubland						4	9.4		1	5
Inter-Mountain Basins Semi-Desert Shrub-Steppe			3				1			4
Madrean Encinal			2.2	3			541.7			3
Madrean Pynion-Juniper Woodland	0.2		51.6	39.37					1	1
Mojave Mid-Elevation Mixed Desert Scrub					2	2				4
North American Warm Desert Active and Stabilized Dune	3		2				3			8
North American Warm Desert Pavement			0.03	0.03			5	0.2		5
North American Warm Desert Riparian Mesquite Bosque	1.9		0.1	0.03			0.3		1	1
North American Warm Desert Volcanic Rockland				0.18			1	0.09		1
North American Warm Desert Wash	0.01	1	2.9	1.18	1	2	1	0.6		5
Riparian	0.92		4.9	0.27			19.8	2		2
Sonora-Mojave Creosotebush-White Bursage Desert Scrub	3	2			9	1		6	1	22
Sonora-Mojave Mixed Salt Desert Scrub	1	6			2	2		2	1	14
Sonoran Mid-Elevation Desert Scrub	2							0.06	2	4
Sonoran Paloverde-Mixed Cacti Desert Scrub	3							4		7
Grand Total	13	9	11	12	14	13	41	18	12	**143**

Table 3: Number of detections per species and DoD installation collected on 143 transects during the winter of 2005/06 (gray coloration = 0 detection).

Species	Scientific Name	Barry M. Goldwater Range	Edwards Air Force Base	Fort Bliss	Fort Huachuca	Fort Irwin	Naval Weapons Center China Lake - North Range	White Sands Missile Range	Yuma Proving Grounds	Outside DoD Installation	Total Detections Per Species
Abet's Towhee	*Pipilo aberti*								2		2
Acron Woodpecker	*Melanerpes formicivorus*				4						4
American Kestrel	*Falco sparverius*	2	2	2				1	2		9
Ash-throated Flycatcher	*Myiarchus cinerascens*	4							4		8
Audubon's Warbler	*Dendroica coronata*	5	2				1		23		31
Bewick's Wren	*Thryomanes bewickii*		2		1		2	5	3	1	14
Black Phoebe	*Sayornis nigricans*								1		1
Brewer's Sparrow	*Spizella breweri*	114		21	161			392	107	5	800
Black-tailed Gnatcatcher	*Polioptila melanura*	17		9	11			57	18	15	127
Black-throated Sparrow	*Amphispiza bilineata*	59		6	12	3	1	179	37	4	301
Burrowing Owl	*Speotyto cunicularia*								1		1
Bushtit	*Psaltriparus minimus*				9					7	16
Cactus Wren	*Campylorhynchus brunneicapillus*	5	1	2	1		4	5	1		19
Canyon Towhee	*Pipilo fuscus*				1			7		7	15
Canyon Wren	*Catherpes mexicanus*									1	1
Cassin's Sparrow	*Aimophila cassinii*				5						5
Curve-billed Thrasher	*Toxostoma curvirostre*	3		2				2			7
Chipping Sparrow	*Spizella passerina*				11			2	3	12	28
Chukar	*Alectoris chukar*					14					14
Cooper's Hawk	*Accipiter cooperii*	1	1		1						3
Costa's Hummingbird	*Calypte costae*								8		8
Common Raven	*Corvus corax*	1	3	1		2	9				16
Crissal Thrasher	*Toxostoma crissale*				1			13			14
Dark-eyed Junco	*Junco hyemalis*				6		42			15	63
European Starling	*Sturnus vulgaris*					1					1

Table 3: Continued

Species	Scientific Name	Barry M. Goldwater Range	Edwards Air Force Base	Fort Bliss	Fort Huachuca	Fort Irwin	Naval Weapons Center China Lake - North Range	White Sands Missile Range	Yuma Proving Grounds	Outside DoD	Grand Total
Gambel's Quail	*Callipepla gambelii*	16			18			5	3	12	54
Golden-crowned Kinglet	*Regulus satrapa*									4	4
Great Horned Owl	*Bubo virginianus*					1					1
Gilded Flicker	*Colaptes chrysoides*	4							1		5
Greater Roadrunner	*Geococcyx californianus*			1							1
Green-tailed Towhee	*Pipilo chlorurus*	2			13			5	1	5	26
Hairy Woodpecker	*Picoides villosus*									3	3
House Finch	*Carpodacus mexicanus*	5				1		74		3	83
Horned Lark	*Eremophila alpestris*		42	118		122	1	280		12	575
House Wren	*Troglodytes aedon*				1						1
Juniper Titimouse	*Parus ridgwayi*				1		2			18	21
Lark Bunting	*Calamospiza melanocorys*			1				31			32
Ladder-backed Woodpecker	*Picoides scalaris*	3		1	9		5	6	1	2	27
Le Conte's Thrasher	*Toxostoma lecontei*		1				5				6
Lewis's Woodpecker	*Melanerpes lewis*		1								1
Lincoln's Sparrow	*Melospiza lincolnii*			1	10			1			12
Loggerhead Shrike	*Lanius ludovicianus*	5	6	4	3	3	8	9	15	4	57
Mexican Jay	*Aphelocoma ultramarina*				13						13
Montezuma Quail	*Cyrtonyx montezumae*				6						6
Mountain Bluebird	*Sialia currucoides*		6			2				2	10
Mountain Chickadee	*Parus gambeli*						4			13	17
Mourning Dove	*Zenaida macroura*	34		8	20				2	1	65
Moutain Quail	*Oreortyx pictus*				8						8
Northern Cardinal	*Cardinalis cardinalis*									1	1
Northern Flicker	*Colaptes auratus*				4		2		1		7

Table 3: Continued

Species	Scientific Name	Barry M. Goldwater Range	Edwards Air Force Base	Fort Bliss	Fort Huachuca	Fort Irwin	Naval Weapons Center China Lake - North Range	White Sands Missile Range	Yuma Proving Grounds	Outside DoD	Grand Total
Northern Harrier	*Circus cyaneus*	1			2						3
Northern Mockingbird	*Mimus polyglottos*				1					3	4
Phainopepla	*Phainopepla nitens*	1			20				4	10	35
Prairie Falcon	*Falco mexicanus*		1								1
Red-tailed Hawk	*Buteo jamaicensis*		2								2
Rock Wren	*Salpinctes obsoletus*	8	1		1	4	1	16	8	2	41
Ruby-crowned Kinglet	*Regulus calendula*		3		1					7	11
Rufous-winged Sparrow	*Aimophila carpalis*									5	5
Sage Sparrow	*Amphispiza belli*	18	163	79		33	61	152	3	20	529
Sage Thrasher	*Oreoscoptes montanus*						1	2		1	4
Savannah Sparrow	*Passerculus sandwichensis*							1			1
Say's Phoebe	*Sayornis saya*	7			3		2	2	1		15
Short-eared Owl	*Asio flammeus*					1					1
Song Sparrow	*Melospiza melodia*							1	1		2
Spotted Towhee	*Pipilo maculatus*						12			1	13
Verdin	*Auriparus flaviceps*	3		2	3			9	9	3	29
Vesper Sparrow	*Pooecetes gramineus*	3			16				6	1	26
Western Meadowlark	*Sturnella neglecta*	5	3	4	3			9			24
Western Scrub Jay	*Aphelocoma californica*									4	4
White-breasted Nuthatch	*Sitta carolinensis*									4	4
White-crowned Sparrow	*Zonotrichia leucophrys*	2	37		82		82	61	43	33	340
Total detections per installation		328	277	262	462	187	245	1327	309	241	3638

Table 4: Mean (SE) shrubland bird species abundance in relation to 27 ecological systems surveyed during the winter of 2005/2006 (grey coloration = no detection).

	Shrubland birds: Target Species					
Ecological System	Brewer's Sparrow	Black-throated Sparrow	Green-tailed Towhee	Sage Sparrow	Sage Thrasher	Vesper Sparrow
Apacherian-Chihuahuan Mesquite Upland Scrub	21.2 (11.5)	1.0 (0.9)	2.0 (0.9)	1.2 (0.7)		1.40 (0.9)
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	2.6 (1.9)	3.4 (2.3)	0.6 (0.4)			
Barren Land (Non-Specific)	0.2 (0.2)	4.0 (2.2)				
Chihuahuan Creosotebush Xeric Basin Desert Scrub	1.0 (0.7)	5.4 (2.1)	0.2 (0.2)	1.2 (0.5)		
Chihuahuan Gypsophilous Grassland and Steppe		0.8 (0.7)		4.4 (1.8)		
Chihuahuan Mixed Desert and Thorn Scrub		5.0 (3.6)	0.8 (0.6)	0.4 (0.2)		
Chihuahuan Mixed Salt Desert Scrub	4.2 (2.3)	8.6 (7.0)		3.6 (3.2)	0.4 (0.4)	0.6 (0.5)
Chihuahuan Sandy Plains Semi-Desert Grassland	9.4 (3.6)	10.2 (8.5)		18.8 (5.4)		
Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	0.4 (0.4)	1.0 (0.6)		2.4 (0.7)		
Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	58.3 (46.8)	2.0 (1.6)		4.0 (2.2)		1.0 (0.7)
Colorado Plateau Pynion-Juniper Woodland						
Great Basin Pinyon-Juniper Woodland						
Inter-Mountain Basins Big Sagebrush Shrubland		0.4 (0.4)		4.8 (1.0)		
Inter-Mountain Basins Semi-Desert Shrub-Steppe	5.3 (3.5)			0.8 (0.6)		
Madrean Encinal						
Madrean Pynion-Juniper Woodland						
Mojave Mid-Elevation Mixed Desert Scrub				0.3 (0.2)		
North American Warm Desert Active and Stabilized Dune	2.0 (1.1)	1.0 (0.4)		9.0 (2.7)		
North American Warm Desert Pavement						
North American Warm Desert Riparian Mesquite Bosque	2.0	1.0	5.0			1.0
North American Warm Desert Volcanic Rockland		4.0				
North American Warm Desert Wash		0.2 (0.2)		5.0 (4.3)		
Riparian	38.5 (27.2)					
Sonora-Mojave Creosotebush-White Bursage Desert Scrub	4.0 (2.8)	0.6 (0.5)	0.05 (0.04)	4.1 (1.6)		0.4 (0.3)
Sonora-Mojave Mixed Salt Desert Scrub	3.9 (2.8)	2.5 (1.8)	0.1 (0.1)	10.5 (3.5)	0.1 (0.1)	
Sonoran Mid-Elevation Desert Scrub		0.5 (0.3)				
Sonoran Paloverde-Mixed Cacti Desert Scrub		3.9 (1.4)				

Table 5: Number of individuals captured per species and DoD installation at 48 locations during the winter of 2005/06 (gray coloration = 0 capture).

Species	Scientific Name	Barry M. Goldwater Range	Edwards Air Force Base	Fort Bliss	Fort Huachuca	Naval Weapons Center China Lake, North Range	White Sands Missile Range	Yuma Proving Grounds	Total captures per species
Audubon's Warbler	*Dendroica coronata*		1						1
Bewick's Wren	*Thryomanes bewickii*		1	2			1		4
Brewer's Sparrow	*Spizella breweri*	31	1	15	153		173	34	407
Black-tailed Gnatcatcher	*Polioptila melanura*	2		3			1		6
Black-throated Sparrow	*Amphispiza bilineata*	20		7	1		36	18	82
Cactus Wren	*Campylorhynchus brunneicapillus*		1				1		2
Canyon Towhee	*Pipilo fuscus*						1		1
Cassin's Sparrow	*Aimophila cassinii*				8				8
Curve-billed Thrasher	*Toxostoma curvirostre*			1					1
Chipping Sparrow	*Spizella passerina*						8		8
Crissal Thrasher	*Toxostoma crissale*			2					2
Dark-eyed Junco	*Junco hyemalis*						17		17
Field Sparrow	*Spizella pusilla*		1						1
Gambel's Quail	*Callipepla gambelii*							1	1
Green-tailed Towhee	*Pipilo chlorurus*						3		3
House Finch	*Carpodacus mexicanus*						3		3
Lark Bunting	*Calamospiza melanocorys*			6			4		10
Le Conte's Thrasher	*Toxostoma lecontei*	1				1			2
Lincoln's Sparrow	*Melospiza lincolnii*				1				1
Mourning Dove	*Zenaida macroura*	1							1
Pine Siskin	*Carduelis pinus*						1		1
Pyrrhuloxia	*Cardinalis sinuatus*			4			1		5
Rock Wren	*Salpinctes obsoletus*	1							1
Sage Sparrow	*Amphispiza belli*	9	26	6		3	1	5	50
Sage Thrasher	*Oreoscoptes montanus*	3	4				38		45

Table 5: Continued

Species	Scientific Name	Barry M. Goldwater Range	Edwards Air Force Base	Fort Bliss	Fort Huachuca	Naval Weapons Center China Lake, North Range	White Sands Missile Range	Yuma Proving Grounds	Total captures per species
Savannah Sparrow	*Passerculus sandwichensis*		1				2		3
Sharp-shinned Hawk	*Accipiter striatus*	1							1
Verdin	*Auriparus flaviceps*						1		1
Vesper Sparrow	*Pooecetes gramineus*	3			11			1	15
White-crowned Sparrow	*Zonotrichia leucophrys*		3	22	1		69	11	106
Total captures per installation		72	39	68	175	4	361	70	789

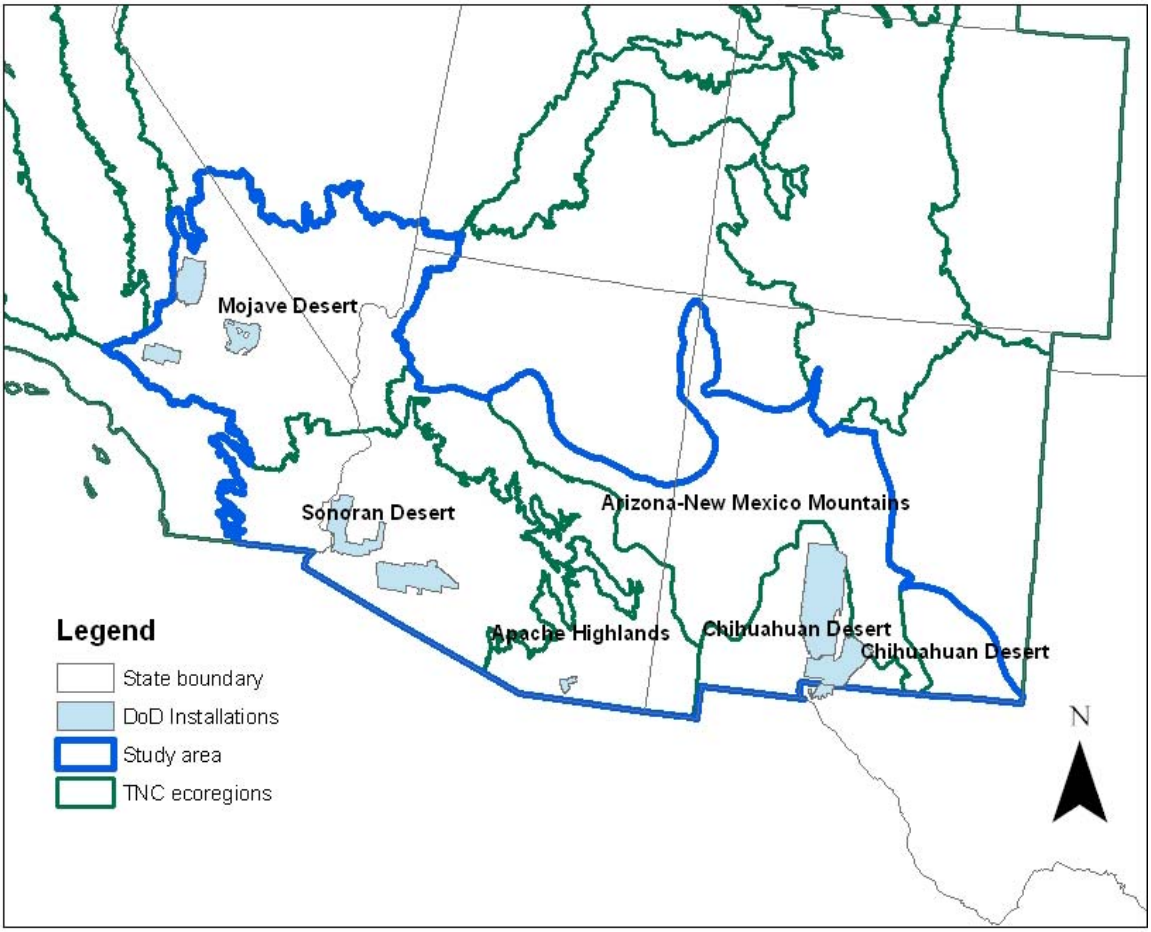

Fig 1. Delineation of study area derived from five Nature Conservancy Ecoregions overlapping with long-term wintering distributions of six shrubland species. DoD installations are shown light-blue.

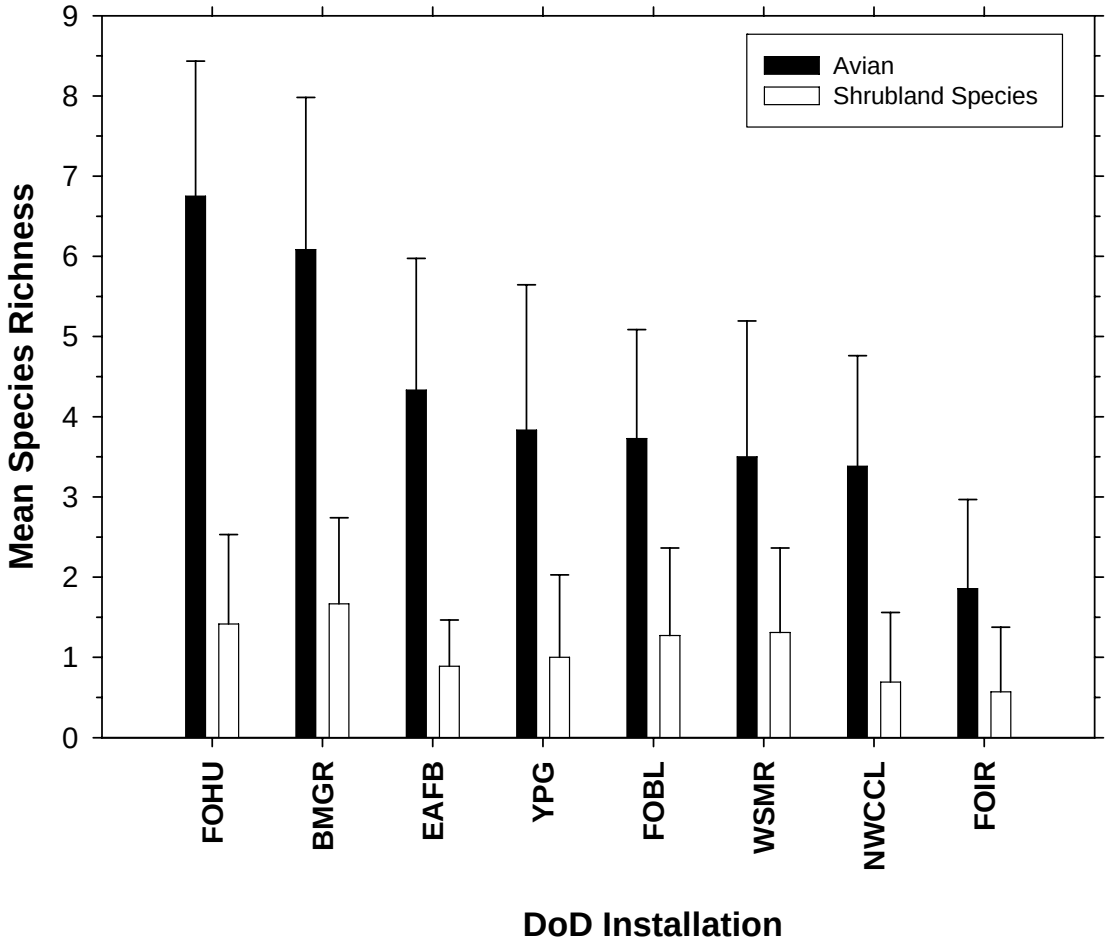

Fig. 2: Mean (+ se) avian and shrubland species richness derived from 131 transects located within eight DoD installations. DoD installations are ranked from highest to lowest avian richness (FOHU = Fort Huachuca, BMGR = Barry M. Goldwater Range, EAFB = Edwards Air Force Base, YPG = Yuma Proving Grounds, FOBL = Fort Bliss, WSMR = White Sands Missile Range, NWCCL = Naval Weapons Center China Lake - North Range, and FOIR = Fort Irwin).

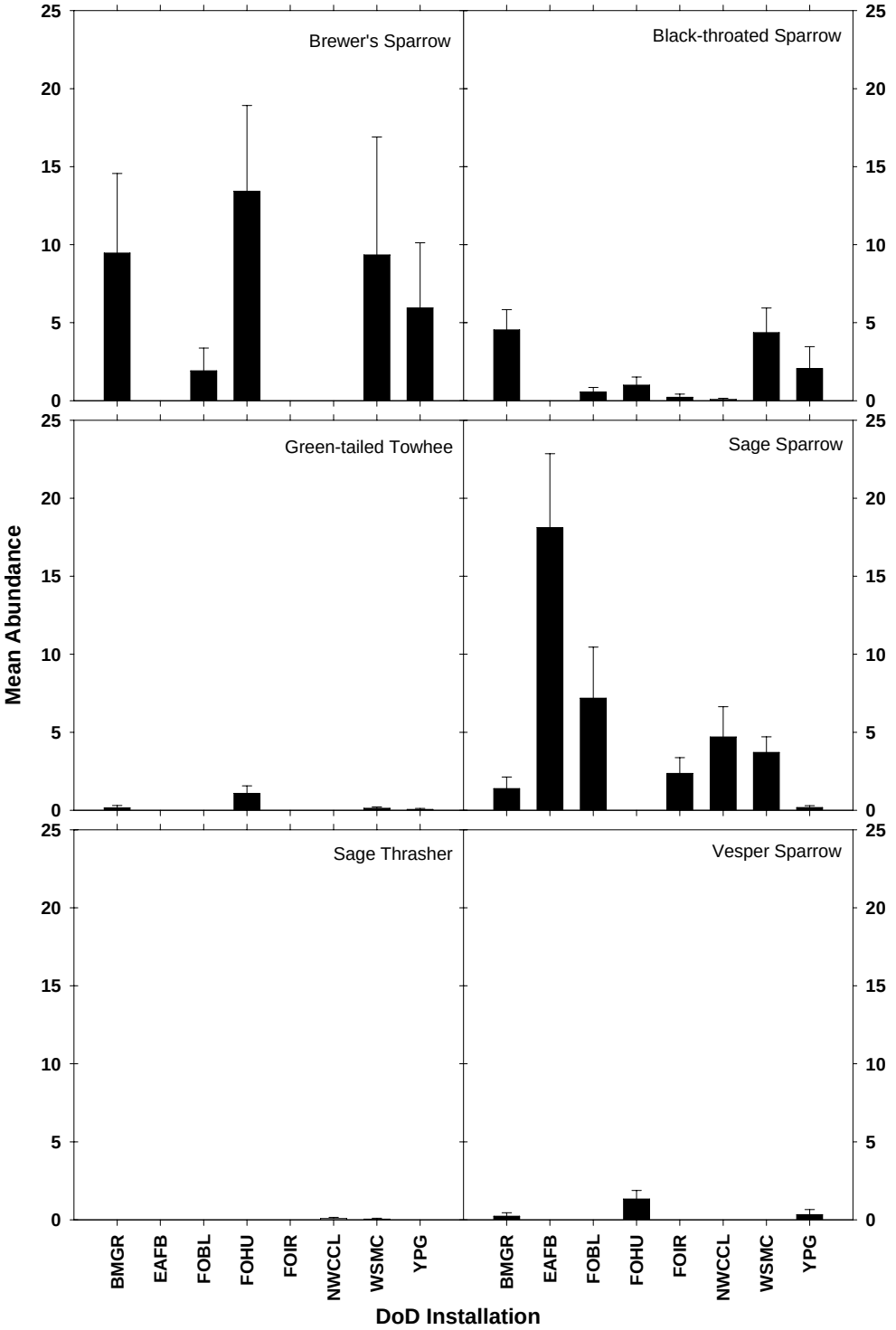

Fig. 3: Mean (+ se) shrubland species abundance surveyed in eight DoD installations (FOHU = Fort Huachuca, BMGR = Barry M. Goldwater Range, EAFB = Edwards Air Force Base, YPG = Yuma Proving Grounds, FOBL = Fort Bliss, WSMR = White Sands Missile Range, NWCCL = Naval Weapons Center China Lake - North Range, and FOIR = Fort Irwin).

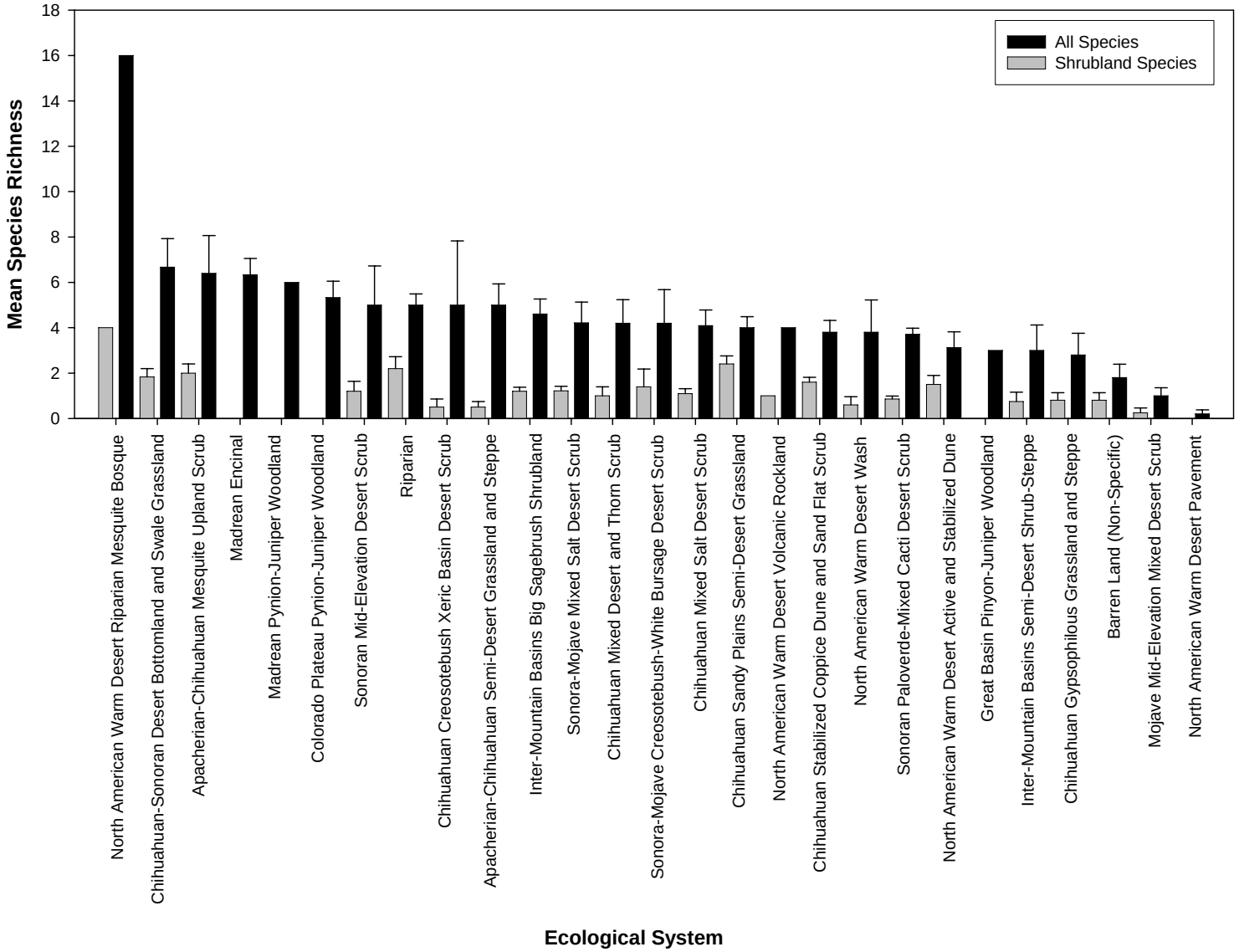

Fig. 4: Mean (+ se) avian and shrubland species richness in 27 ecological systems surveyed in eight DoD installations. Ecological systems are sorted from highest to lowest avian richness.

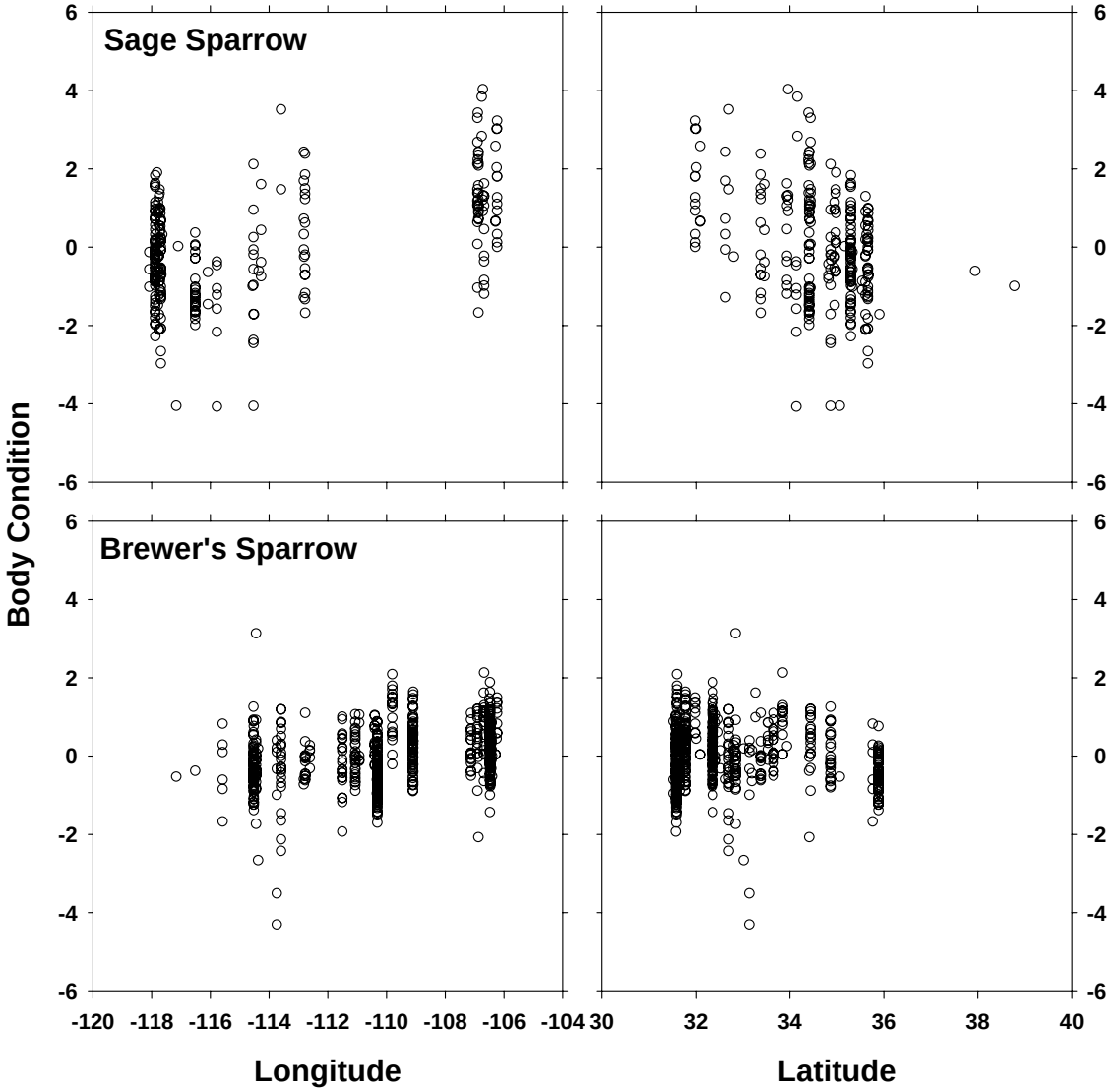

Fig. 5: Body weight adjusted for body size in relation to longitude and latitude for the Sage Sparrow (Top Panel) and the Brewer's Sparrow (Bottom Panel). In both species, heavier birds (positive value) are found in eastern regions of the southwestern U.S.

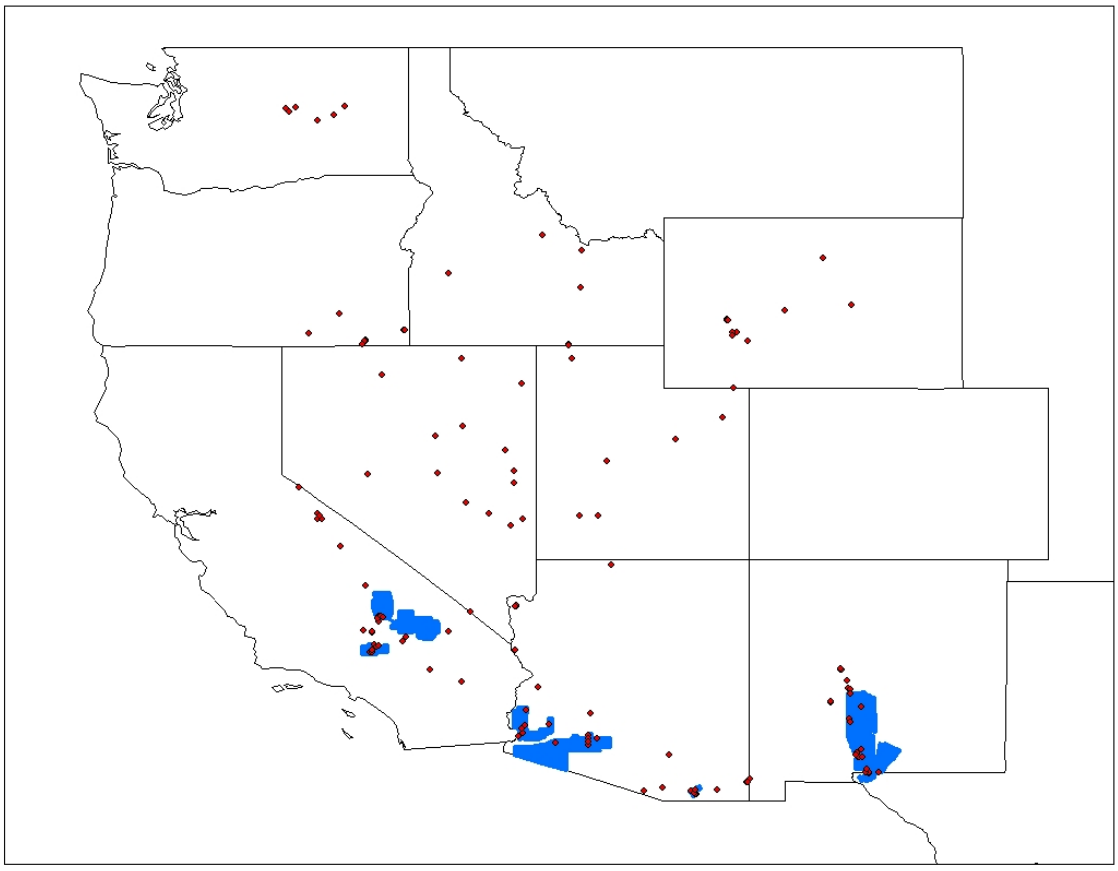

Fig. 6: Locations of feather samples collected on both the wintering and breeding grounds across the western U.S. DoD installations are shown in blue.

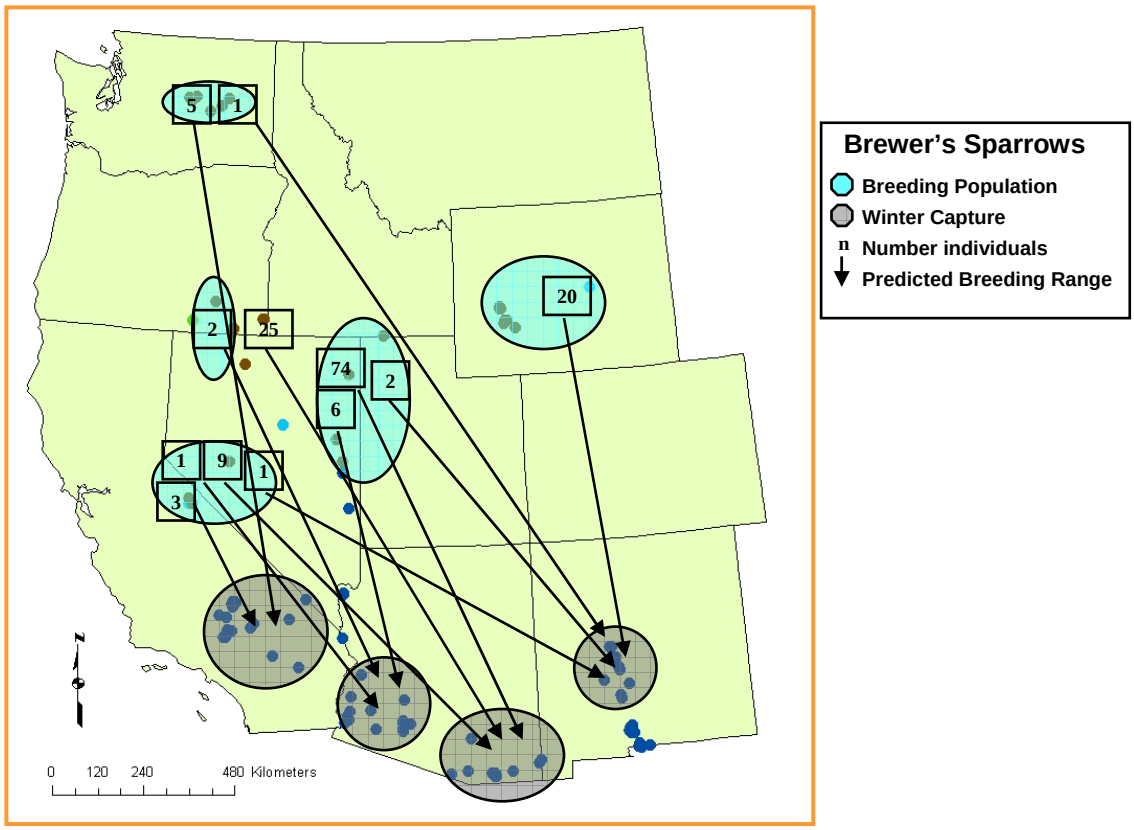

Fig 7: Breeding-wintering ground connectivity for the Brewer's Sparrow. Connectivity is based on isotopic analyses of feathers collected from birds on both the breeding and wintering grounds. Shown are number of individuals captured on the wintering grounds associated with a particular breeding population.

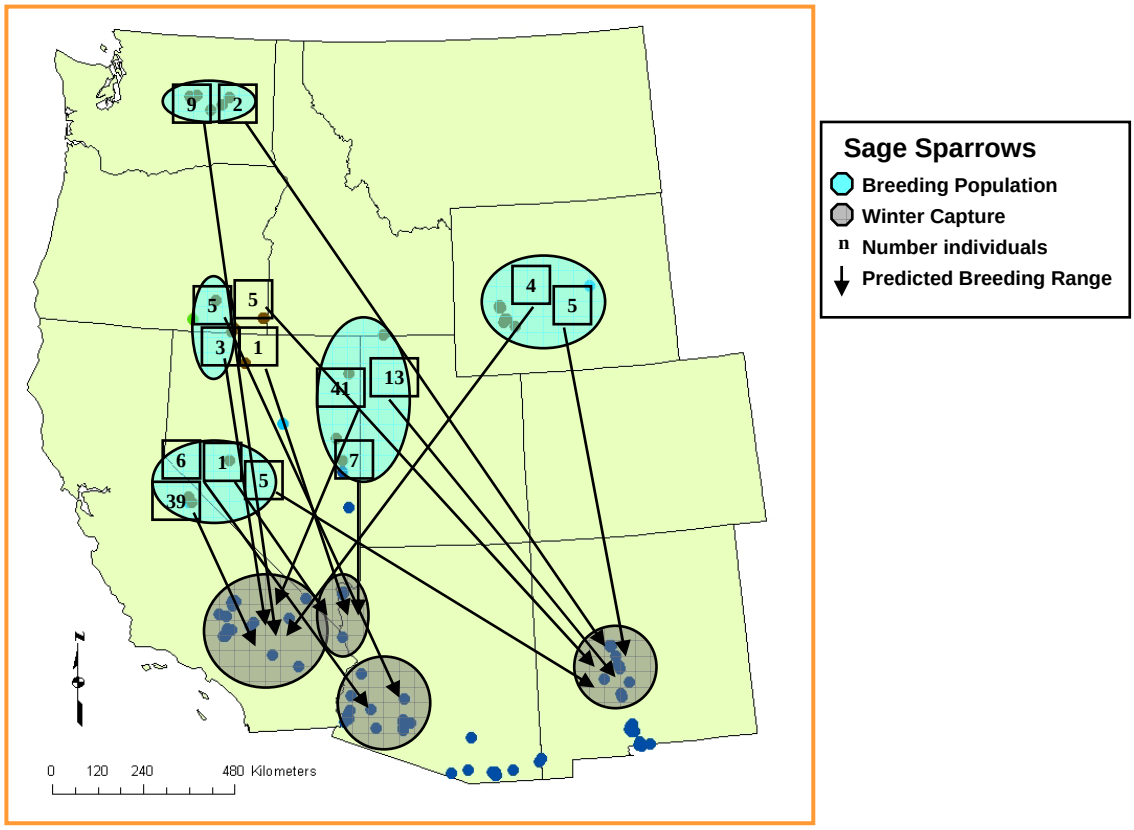

Fig. 8: Breeding-wintering ground connectivity for the Sage Sparrow. Connectivity is based on isotopic analyses of feathers collected from birds on both the breeding and wintering grounds. Shown are number of individuals captured on the wintering grounds associated with a particular breeding population.

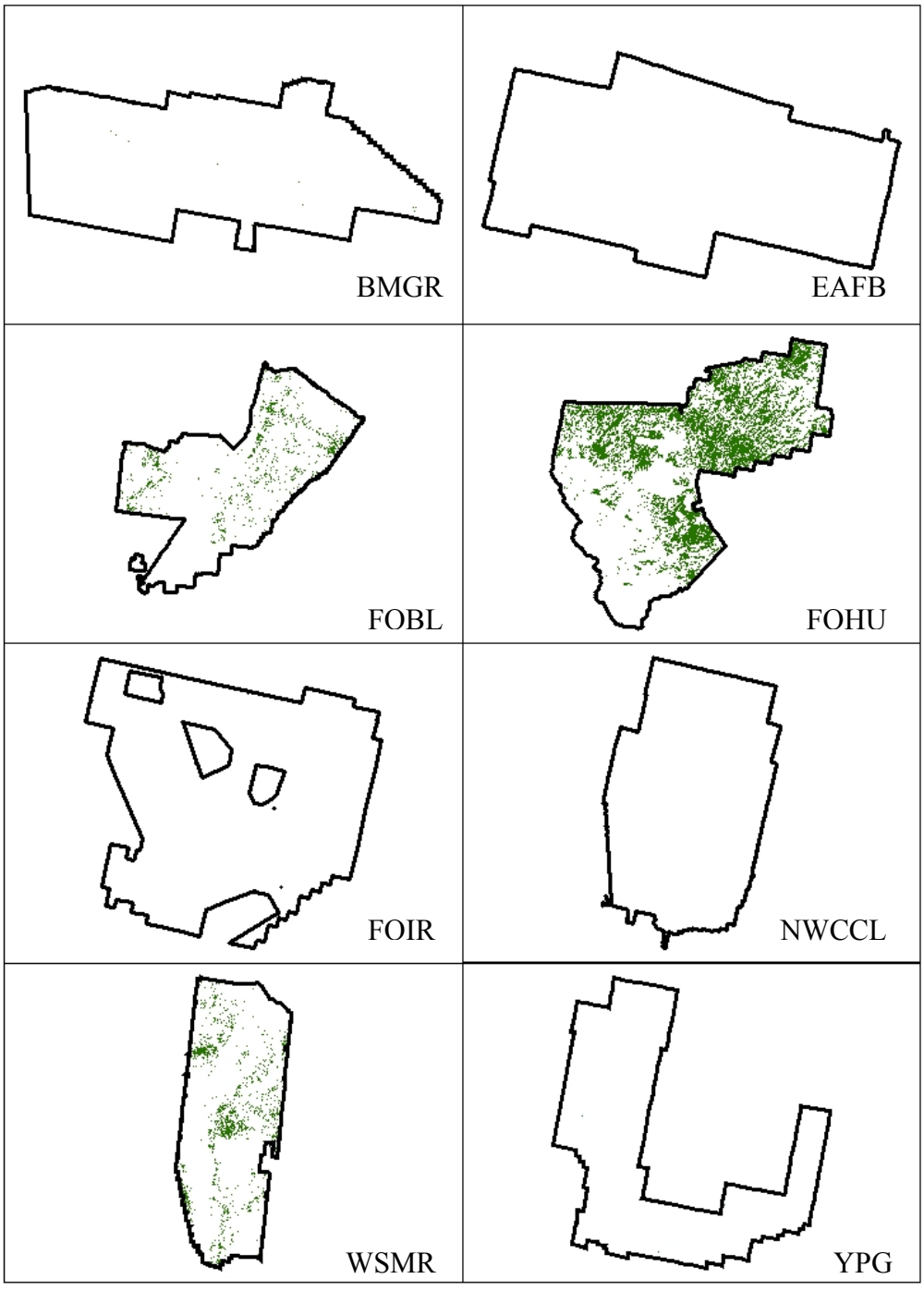

Fig. 9: Spatial distribution of ecological systems in which Brewer's Sparrows were most frequently detected for eight DoD installations (BMGR= Barry M. Goldwater Range, EAFB = Edwards Air Force Base, FOBL = Fort Bliss, FOHU = Fort Huachuca, FOIR = Fort Irwin, NWCCL = Naval Weapons Center China Lake - North Range, WSMR = White Sands Missile Range, and YPG = Yuma Proving Grounds).

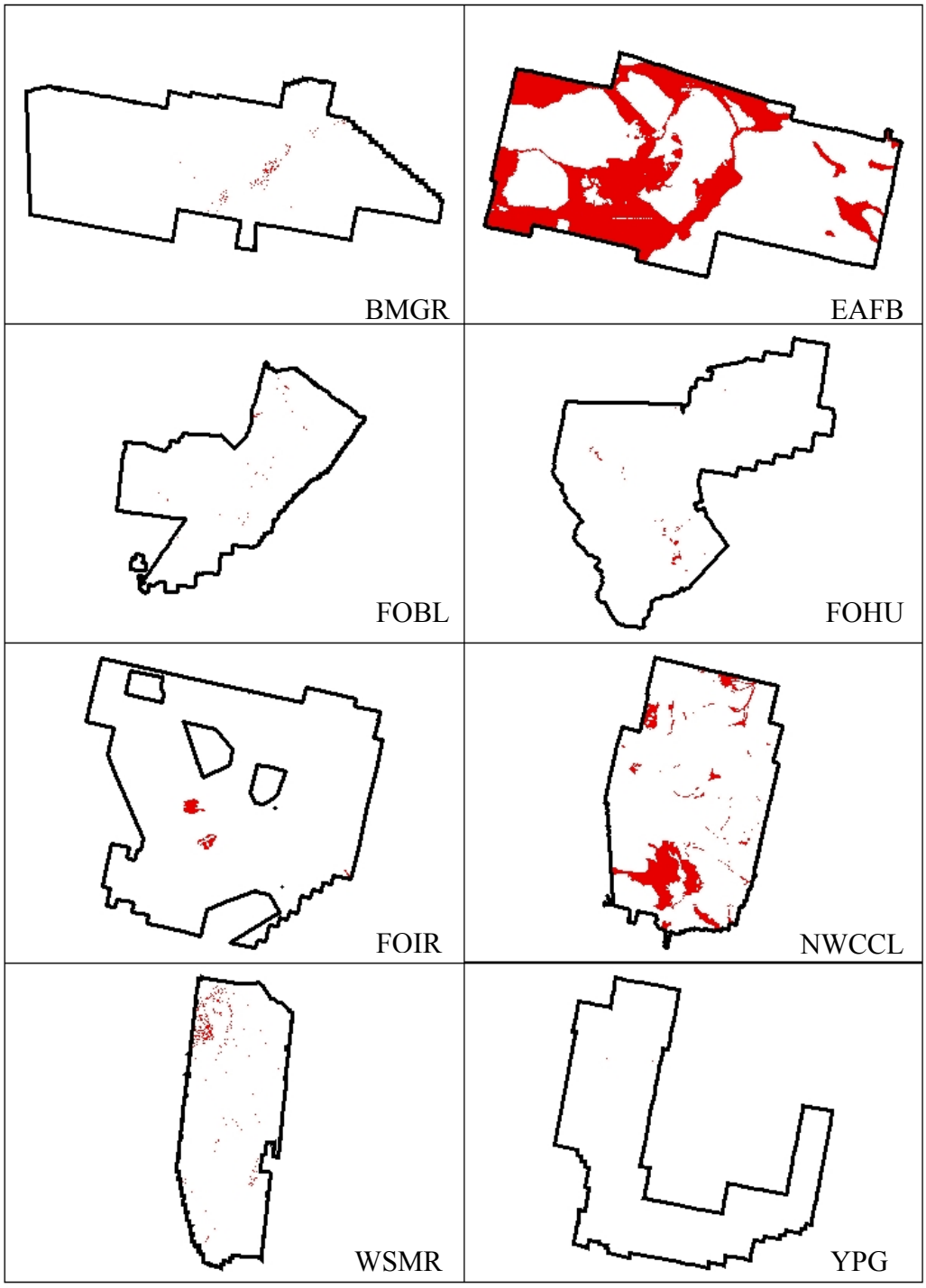

Fig. 10: Spatial distribution of ecological systems in which Sage Sparrows were most frequently detected for eight DoD installations (BMGR= Barry M. Goldwater Range, EAFB = Edwards Air Force Base, FOBL = Fort Bliss, FOHU = Fort Huachuca, FOIR = Fort Irwin, NWCCL = Naval Weapons Center China Lake - North Range, WSMR = White Sands Missile Range, and YPG = Yuma Proving Grounds).

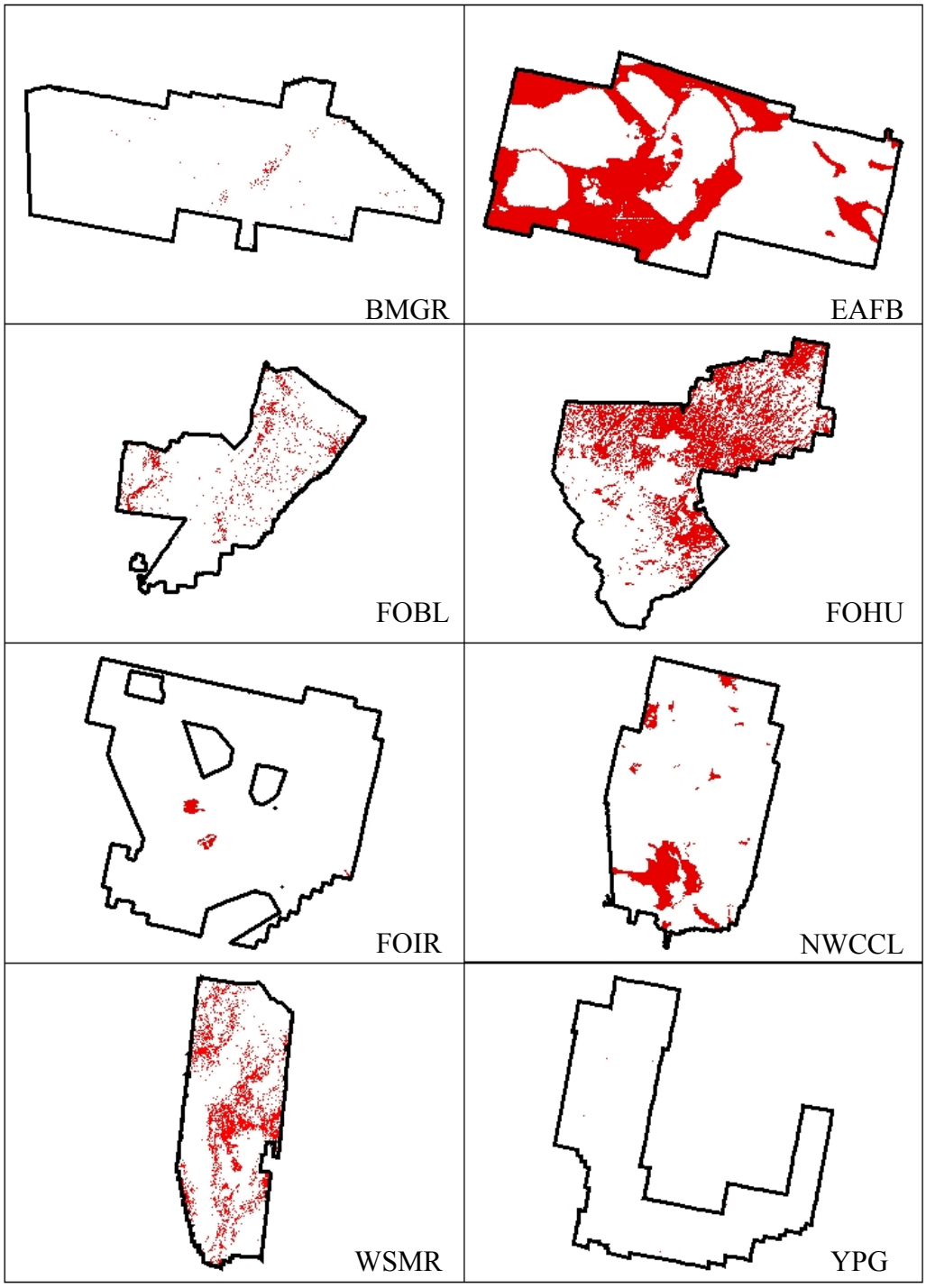

Fig. 11: Spatial distribution of ecological systems in which shrubland species were most frequently detected for eight DoD installations (BMGR= Barry M. Goldwater Range, EAFB = Edwards Air Force Base, FOBL = Fort Bliss, FOHU = Fort Huachuca, FOIR = Fort Irwin, NWCCL = Naval Weapons Center China Lake - North Range, WSMR = White Sands Missile Range, and YPG = Yuma Proving Grounds).

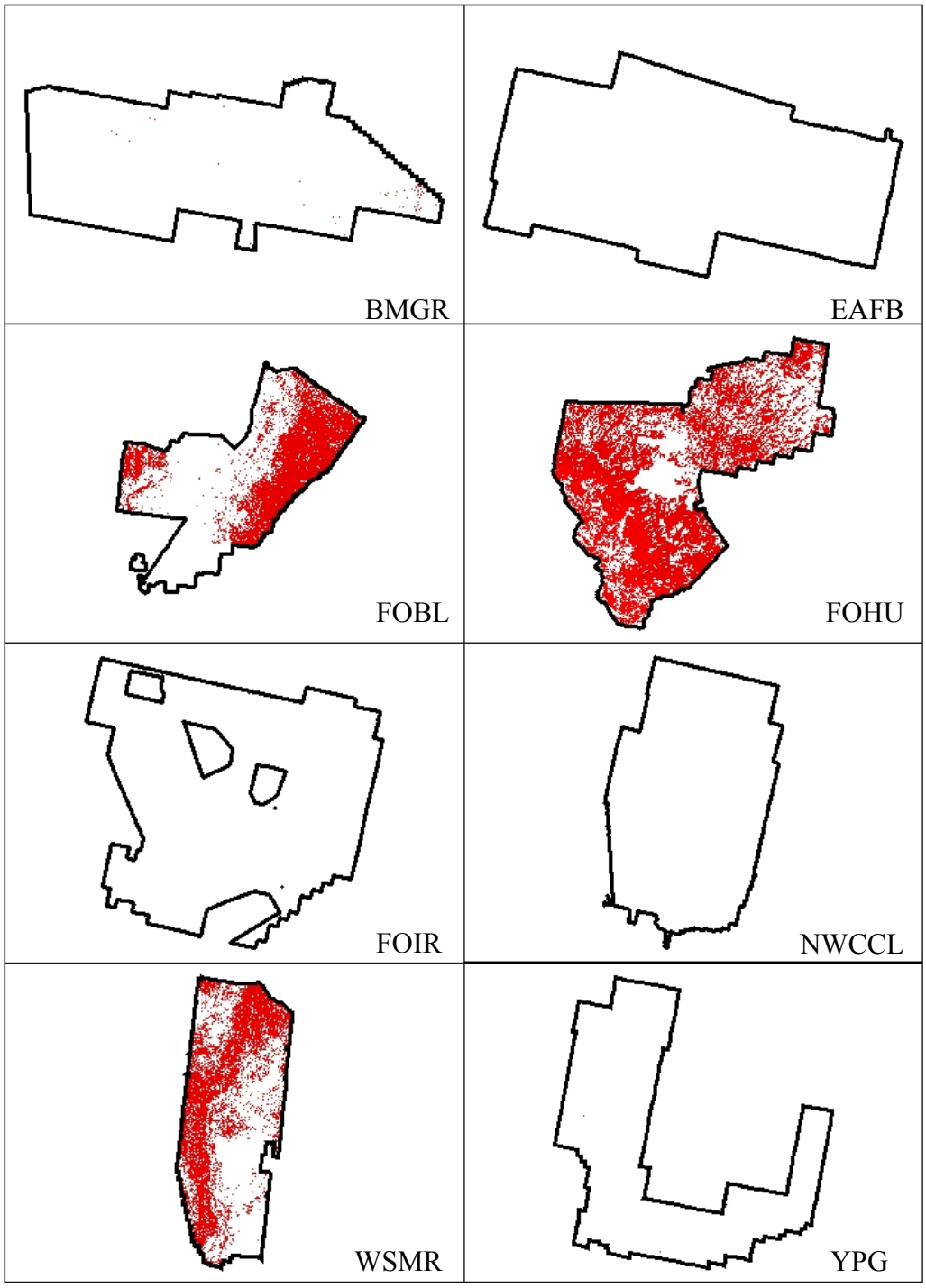

Fig. 12: Spatial distribution of ecological systems in which species richness was ≥ 5 species/transect for eight DoD installations (BMGR= Barry M. Goldwater Range, EAFB = Edwards Air Force Base, FOBL = Fort Bliss, FOHU = Fort Huachuca, FOIR = Fort Irwin, NWCCL = Naval Weapons Center China Lake - North Range, WSMR = White Sands Missile Range, and YPG = Yuma Proving Grounds).

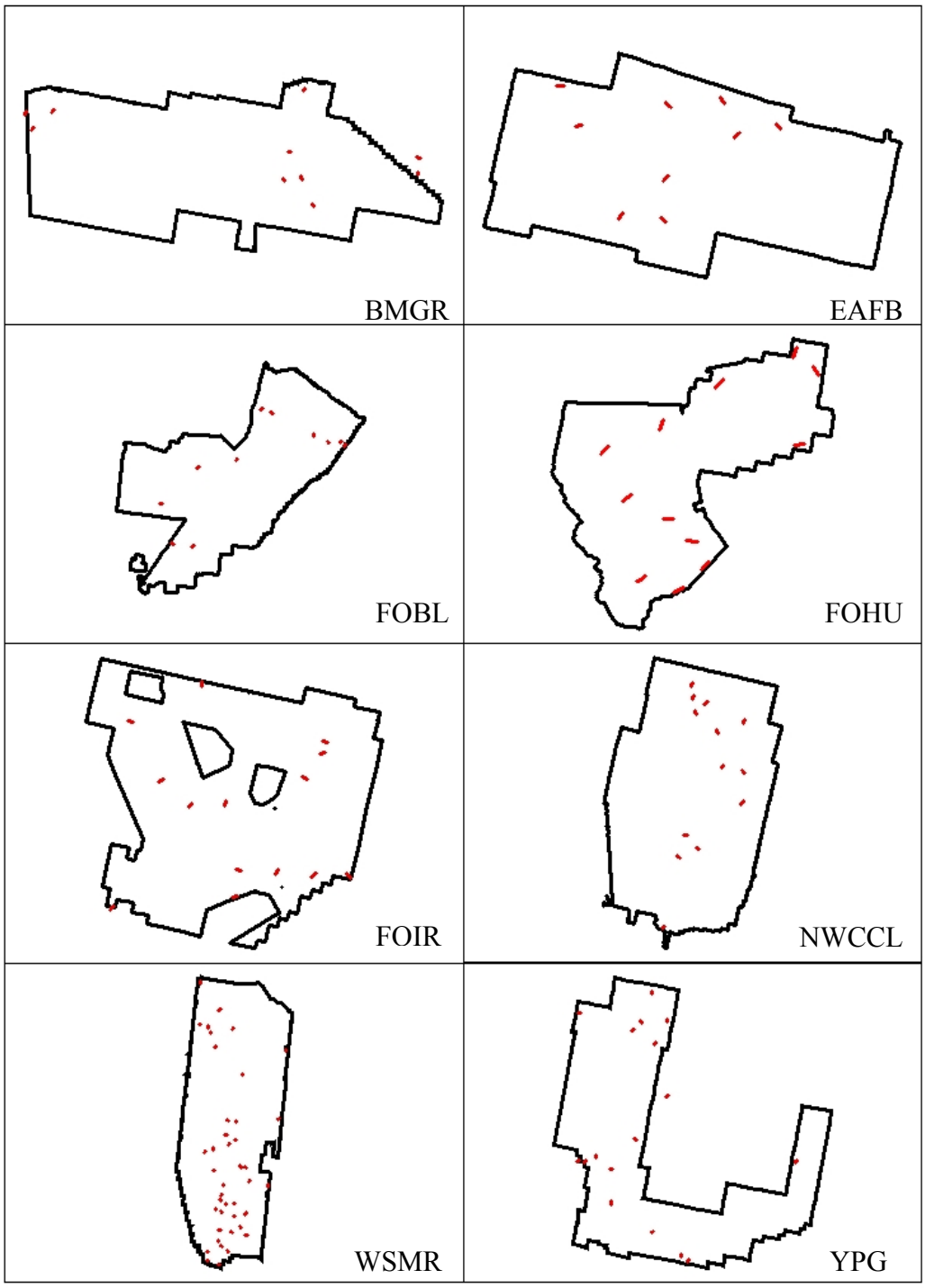

Fig. 13: Spatial distribution of 131 1km transects within eight DoD installations (BMGR= Barry M. Goldwater Range, EAFB = Edwards Air Force Base, FOBL = Fort Bliss, FOHU = Fort Huachuca, FOIR = Fort Irwin, NWCCL = Naval Weapons Center China Lake - North Range, WSMR = White Sands Missile Range, and YPG = Yuma Proving Grounds).