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Department of Defense
Legacy Resource Management Program

Project: 17-818

Gopher Tortoises and Test Ranges: Developing an Understanding of the Wildlife-Habitat Relationships for this Novel Habitat

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10 September 2019
updated July 2021

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INTRODUCTION

Gopher Tortoises (*Gopherus polyphemus*) are considered a keystone species (Young and Goff 1939, Jackson and Milstrey 1989, Kent et al. 1997, Alexy et al. 2003, Dziadzio and Smith 2016) in Longleaf Pine (*Pinus palustris*) -dominated sandhill communities in the southeastern Coastal Plain of the United States (Auffenberg and Franz 1982). Through the creation of burrows, these tortoises provide shelter, habitat, and food for approximately 60 vertebrates and 300 invertebrate species (Young and Goff 1939, Jackson and Milstrey 1989, Kent et al. 1997, Alexy et al. 2003, Dziadzio and Smith 2016). However, Gopher Tortoises have declined due to causes including fire suppression, development, poor silvicultural practices, human collection and consumption, and road mortality (USFWS 2011). The Gopher Tortoise is currently considered federally threatened under the Endangered Species Act (ESA) in the western portion of its range, and a candidate for listing in the eastern portion of its range (USFWS 2011). The federal listing of Gopher Tortoises has stimulated applied studies aimed at informing habitat management practices (e.g., Hermann et al. 2002, Yager et al. 2017).

Eglin Air Force Base, in the panhandle of Florida where Gopher Tortoises are currently listed as state threatened and are a candidate for federal listing, has greater than 155,000 ha of potential habitat, much of which is high quality. The large size of Eglin represents an important landscape for both military activities and Gopher Tortoise conservation. Despite large expanses of suitable habitat and intensive habitat management on Eglin, Gopher Tortoises occur at low densities and are likely well below carrying capacity. Based on prior research and monitoring efforts (Printiss and Hipes 1999; Gorman et al. 2015), the population on Eglin is best characterized as patchily distributed and low-density with interlaying areas of low probabilities of occupancy. The low density is primarily attributed to previous human collection and consumption (Taylor 1982, Jeremy Preston, Eglin AFB Jackson Guard, pers. comm.) along with historic fire suppression and other potential factors affecting tortoise populations and habitat throughout Florida (FWC 2012; Mushinsky et al. 2006).

For decades, Gopher Tortoises have been established on Eglin test ranges, which range in size from a few dozen to over 4,000 ha. Test ranges vary in management histories and habitat conditions. Habitats can vary from minimal shrub cover and planted non-native grasses to high shrub and diverse native herbaceous cover. Small portions of these areas are directly impacted by military use, but the vegetation is cleared to support Air Force missions (e.g., line-of-sight) and buffer zones. Test ranges have open canopies that allow adequate sun exposure and the potential for – depending on types and levels of management or disturbance – moderate to high coverage of herbaceous vegetation, both of which are considered the primary requirements for suitable Gopher Tortoise habitat (FWC 2012). It appears that habitat characteristics on test ranges are meeting at least some of the life history requirements of Gopher Tortoises, but our previous results suggested there may be significant differences in the presence and number of burrows used by younger age classes (which could indicate production and survival of young tortoises) based on type and level of past and current habitat management regimes (Legacy Project 16-818).

Although the quality of forested sandhills adjacent to many test ranges has improved substantially over the last few decades through mechanical, herbicide, and ongoing fire management, emigration of tortoises from ranges into these more "natural" sites appears to be minimal. However, small to medium populations do exist sporadically in forested habitats across Eglin. Other studies have shown a relationship between characteristics of fire-maintained forested habitat (i.e., open canopy and midstory with dense herbaceous ground cover) and Gopher Tortoise presence, abundance (at least of burrows), and/or growth rates (Jones and Dorr 2004, Innes 2009, Kowal et al. 2014, Tuberville et al. 2014). The differences between habitat characteristics on occupied test ranges and forested sandhills though have not been explicitly examined.

Our past research indicates Gopher Tortoises are using test ranges at higher rates than sandhills (Gorman et al. 2015, Chandler et al. 2020), however, it is not well understood how the broader wildlife community responds to burrows created by tortoises on test ranges. The construction and maintenance of burrows contribute to a large wildlife community that occupies intact longleaf pine ecosystems (Jackson and Milstrey 1989), whereas the value of burrows on test ranges is mostly unknown. It is possible that some of the species that utilize Gopher Tortoise burrows, such as the federally threatened Indigo Snake (*Drymarchon couperi*), the federally petitioned Eastern Diamondback Rattlesnake (*Crotalus adamanteus*), and two species that are both Florida species of special concern as well as petitioned for federal listing, the Gopher Frog (*Lithobates capito*) and Florida Pine Snake (*Pituophis melanoleucus mugitus*), may not use test ranges as frequently and therefore would not benefit from tortoises exploiting these open canopy habitats.

Understanding the relationship of tortoises to available habitat on test ranges compared to forested sandhills is critical to making informed management decisions for Gopher Tortoises on Eglin and on DoD lands throughout the southeastern U.S. Likewise, understanding movement patterns across habitat types along with dispersal tendencies (including emigration/immigration patterns) and landscape permeability is essential to managing, in the long term, a healthy metapopulation of tortoises across a large landscape. As with other wildlife populations, habitat fragmentation has been reported to be a significant limitation on Gopher Tortoise dispersal (BenDor et al. 2009).

We investigated Gopher Tortoise and commensal use and viability on test ranges. To better understand the impacts of range management on these populations, we used area-constrained burrow and habitat surveys and deployed wildlife cameras. Additionally, we used Global Positioning System (GPS) tracking technology to attempt to determine movement patterns and habitat use.

For this project, we attempted to address the following objectives. However, our inability to obtain quantifiable historic information from the installation about management practices on test ranges limited our ability to address objectives 4 and 5.

1. Monitor tortoise movements throughout the year using GPS transmitters to (a) identify within-habitat movements and any movements between habitat types (e.g., between ranges and forested sandhills), (b) determine home range size and fine-scale habitat use in the different habitat types, and (c) collect baseline data that could be used to estimate survival rates and long-distance dispersal movements.
2. Using an online questionnaire, identify range management practices used at 10-15 other military installations that support Gopher Tortoise populations. If information is available, identify the status of Gopher Tortoise populations in testing and training areas at other installations.

3. Continue to investigate the habitat characteristics of test ranges versus forested sandhills by increasing site replication to better understand why Gopher Tortoises might be selecting (or remaining in) these sites. Understanding both the variation of habitat characteristics within ranges related to management practices along with differences between ranges and forested sandhills will help elucidate the habitat use of tortoises on Eglin.
4. Continue to compare age-size distributions and recruitment between test ranges and forested sites and between test range sites with different management regimes (roller drum chopping, mowing, herbicide, and/or fire).
5. Continue to compare commensal use (abundance, species richness, and presence of species of concern) between test ranges and forested occupied sites and between test range sites with different management practices through the deployment of wildlife cameras at tortoise burrow entrances.

METHODS

TEST RANGES VS. FORESTED HABITATS. —We conducted vegetation surveys from June-August at 11 sites (8 sites on 5 test ranges and 3 forested sites) in 2017 and 8 additional sites (4 test ranges and 4 forested sites) in 2018 (19 sites total, with the 12 range sites located on 9 separate ranges, and the 7 forested sites on 7 separate forest stands). We collected data at two scales: 1) Site-wide scale: to explore similarities and differences among sites and between forested and test range habitats with an emphasis on herbaceous groundcover. Also, to determine if habitat differences were related to differences in densities of Gopher Tortoise burrows, 2) Burrow scale (i.e., use vs. availability): to explore possible selection preferences for major vegetation cover types that may have influenced burrow site selection within each habitat type.

We compared species compositions and abundances of the herbaceous community among sites and between forested sites and test ranges using hierarchical cluster analysis and non-metric multidimensional scaling (NMDS). Bray-Curtiss dissimilarity coefficients were used as our distance metric for both approaches.

AGE-SIZE DISTRIBUTIONS AND RECRUITMENT. — Our survey goal for each study site in 2017 was to observe at least 10 active and/or inactive tortoise burrows. If we did not observe this number in the original 10 ha surveyed, we expanded the survey boundary until we did. In 2018, we relaxed our study site requirement in test ranges to observe 5-10 active/inactive burrows. In fall 2017, we surveyed seven of the new sites (4 test ranges, 3 forested) using a two-observer 10 m transect method with repeat surveys conducted by different observers (Gorman et al. 2015). In spring 2018, we surveyed the final forested site after locating the new population in winter 2018. Each site ranged between 10.0-19.7 ha. Upon detection of each burrow, we recorded the location (UTM) using a Garmin GPSMap78 (Garmin International, Inc., Olathe, KS), measured burrow tunnel width at 50 cm depth (McCoy et al. 2006), measured burrow aspect, and assigned burrow status as active, inactive, or abandoned (Gorman et al. 2015).

Tortoise shells are particularly soft at the juvenile stage, which, coupled with small body size, results in high levels of predation (Landers et al. 1982, Wilson 1991). Beginning at the early subadult stage (≥ 130 mm), the shell begins to harden, resulting in higher survival. The adult stage is typically reached at carapace measurements between 220-230 mm (Wilson 1991, Landers et al. 1982, Diemer 1992, Berish and Leone 2014, Rostal et al. 2014, Tuberville et al. 2014). Adults have few natural predators and experience high survival (Ernst and Lovich 2009). Given the above, we used three size classes, juvenile (<130 mm), subadult (≥ 130 mm < 230 mm), and adult (≥ 230 mm) to characterize burrow densities (i.e., burrow density was calculated for each site, broken down by burrow size class). Widths of Gopher Tortoise burrows are correlated with individual carapace lengths (Alford 1980) and size and age class (Landers et al. 1982). Thus, small burrows are likely indicative of the production of younger age classes, while the ratio of juvenile to adult, and sub-adult to adult burrows (i.e., small to large burrows) provide insight into the age structure of the population. To assess age structure we calculated the density of juvenile, subadult, and adult burrows, and the ratio of juvenile plus subadult to adult burrows.

COMMENSAL USE OF FORESTED SITES AND TEST RANGES. —In 2018, we deployed Moultrie M-990i (Gen2) camera traps at Gopher Tortoise burrows at eight sites (4 forested and 4 ranges) in the winter (13 January to 24 February), spring (24 March to 16 May), and summer (1 July to 7 September). Between 7-15 cameras were deployed at each site for a total of 4-5 days each during the spring and summer. Five cameras were deployed at each site during the winter season. Cameras were placed 1.5 m from burrow entrances atop 0.6 m stakes and angled to include within the viewing frame, the burrow entrance, most of the apron, and approximately 6–12 cm behind the burrow entrance. To maximize the capabilities of the camera model chosen (Moultrie M-990i Gen 2), and to maximize tortoise and burrow associate detections based on estimated seasonal activity periods, we programmed the cameras to record activity via time lapse during specified time periods (Table 1). When time-lapse was inactive, the cameras were programmed so that the motion detection function was active. Once deployed, cameras were checked after approximately 4 trap days (i.e., one trapping period) at which time the cameras were retrieved. Test range (n=4) and forested sites (n=4) were paired for each camera trapping period to minimize intra-seasonal differences. We documented commensal vertebrate richness and abundance, as well as any interesting behavior observed.

We reviewed all photos from the cameras and recorded the times at which tortoises exited and returned to burrows. A unique observation record (or bout) consisted of, at minimum, a burrow exit time and burrow entrance time. We calculated the per bout activity time across all seasons for all tortoises. For each season we were able to break down above-ground activity time into two components: the total time spent basking (hereafter basking time) and the total time spent foraging (hereafter foraging time). We defined basking time as the time spent by the tortoise at least halfway out of its burrow, but within the camera viewing frame. Basking time included tortoise emergence during rain events and burrow maintenance. However, the majority of time represented a stationary posture by the tortoise just outside the burrow entrance, presumably for basking purposes. Foraging time was defined as the time spent by the tortoise out of the camera view (i.e., approx. 1 m or more away from the burrow). Because by definition the cameras were unable to record what tortoises were doing during foraging time, this time may have included visits to other burrows, mating, and other behaviors. Basking time and foraging time were used to calculate combined activity time (i.e., time spent at least halfway out of the burrow). We also calculated the mean frequency of tortoise activity periods (i.e., number of observed activity periods per burrow per camera deployment) across sites and seasons.

While reviewing photos, we also recorded incidences of burrow associates (i.e., other species that use tortoise burrows). All vertebrate species observed entering the burrow, using any part of the apron, or observed within 6–12 cm behind the burrow were recorded as burrow associates. Of the vertebrate burrow associates observed, several have been reported as natural predators of Gopher Tortoises (Roosevelt 1917, Douglas and Winegarner 1977, Causey and Cude 1978, Landers et al. 1980, Maehr and Brady 1984, Butler and Sowell 1996, Mushinsky et al. 2006, Ernst and Lovich 2009, Aresco et al. 2010, Perez-Heydrich et al. 2012, and Smith et al. 2013), or as potential predators based on reports of predation on other turtle species, including those in the genus *Gopherus* (Nelson 1933, Hamilton 1951, Fordham et al. 2006, Fordham et al. 2008, Mayer and Brisbin 2009, Jolley et al. 2010, Holcomb and Carr 2013, Whytlaw et al. 2013, and Lovich et al. 2014). Gopher Tortoise predators primarily prey on eggs and/or juveniles as adults have few natural predators (Ernst and Lovich 2009).

For quality control and future reference, at least one representative photo was typically archived for each species encountered for each burrow during each trapping round.

When we tallied occurrences of each species of burrow associate, we made a conservative estimate within each trapping period. We considered an occurrence to be a unique individual determined either because we could see multiple individuals in a single camera frame (for example, 3 Gopher Frogs in a single camera frame would be counted as three occurrences) or observation of individuals of the same species that were clearly distinct. For example, a juvenile Eastern Coachwhip (*Masticophis flagellum*) and a large adult Eastern Coachwhip exiting and entering the burrow multiple times during a trapping period would count as two occurrences. Across burrows and across trapping periods, we summed occurrences, so it is possible that the same individuals were counted multiple times if they were using multiple burrows and/or were present in multiple seasons. We compared the mean number of occurrences and richness of all burrow associates combined, herpetofauna, and potential Gopher Tortoise predators for test ranges and forested sites across seasons. Our measures of occurrence and richness consider all burrow associates detected. Because we were unable to identify individual burrow associates, we acknowledge that our approach is not an accurate estimate of abundance and is more a measure of frequency.

MANAGEMENT STRATEGIES OF TESTING AND TRAINING AREAS. —In 2018, with the support of Chris Peterson (DoD Partners in Amphibian and Reptile Conservation), we developed and distributed a questionnaire to natural resource personnel at DoD properties where Gopher Tortoises are known to occur throughout the Southeast U.S. The purpose of this questionnaire was to identify common management practices used to maintain testing/training areas, airfields, and other human altered/disturbed/ruderal habitats potentially used by Gopher Tortoises. We have included a copy of this questionnaire at the end of this report (Appendix A).

GPS TELEMETRY. — We deployed 11 GPS transmitters (Lotek model PinPoint VHF 3600-L LiteTrack 'Turkey') over varying timespans between April and October of 2018. Data were collected for nine Gopher Tortoises over tracking periods lasting approximately 2 weeks – 5 months. Transmitters were equipped with very high frequency (VHF) capabilities for standard radio tracking, as well as remote download capabilities allowing us to retrieve GPS data in the field without recapturing tortoises.

Tortoises were captured via flap traps (see Appendix B in USFWS Gopher Tortoise Candidate Conservation Agreement for capture and processing procedures) checked twice daily. Tortoises were processed (measured, weighed, sexed, visually assessed for health, and uniquely marked via marginal scute drilling) and fitted with transmitters weighing approximately 90 g (approximately 100g with epoxy). Due to the large size of the transmitters, only large adult tortoises were included in this study to ensure transmitter to body weight ratios were minimized (<8%, see Herpetological Animal Care and Use Committee guidelines). Transmitters were attached to the anterior costal scutes (Figure 1) with the antenna trailing backwards, threaded through plastic tubing and attached at one or two locations on the posterior costal or vertebral scutes to minimize the overall profile of the unit and the potential for it to snag on vegetation or the burrow wall. This position also ensured that transmitters would not obstruct mating attempts. The length of the transmitter prevented us from positioning it on a single scute. Instead, prior to applying epoxy, we bridged growth plates with electrical tape and placed the transmitter so that it sat flush against the carapace. Transmitters were secured with epoxy putty or gel (Loctite or JB weld) and tortoises were returned to their burrows immediately once epoxy had sufficiently cured (typically 1-2 hours).

Transmitters were programmed to attempt a location fix every 15 minutes between 1000 and 1800. This period was chosen as a compromise between prolonging transmitter battery life and maximizing the likelihood we recorded tortoise activity outside of their burrows (e.g. foraging, social interactions, burrow changes, etc. Douglas & Layne 1978, McRae et al. 1981). A timeout occurred if the transmitter was unable to obtain a location within 70 seconds during a scheduled fix. Tortoises were tracked to their burrows and data were remotely downloaded weekly. To determine whether a transmitter remained attached post-deployment, camera traps (Moultrie Cam) were mounted at the burrow for remote monitoring. Occasionally, cable-mounted cameras were inserted down a burrow if a transmitter was suspected to have failed. For example, if we were unable to acquire a VHF signal or data download over multiple attempts we used this camera to determine the transmitter's fate.

The 11 transmitters were deployed among three forested sites (201E, Bull Creek, & Garnier Creek) and two test ranges (C62N & C62S). We deployed transmitters in two waves (five in the first, six more in the second). Of the original five tags, only three successfully collected data and all three stopped functioning prior to deployment of the second wave. There was no overlap in data collection between the two waves (see below). In total, data were collected for nine individual tortoises, five on test ranges (three females, two males) and four in forested sites (three females, one male, Table 2).

The first wave consisted of five transmitters, two of which were attached to tortoises on test ranges C62N (tortoise SG9) and C62S (tortoise BD2) on 28 April and the third was deployed in forested site 201E (tortoise KV5) on 11 May. The remaining two transmitters were dislodged by tortoises within their burrows shortly after deployment and did not obtain useable data. All three successfully attached transmitters from the first wave inexplicably failed after roughly a month in the field. (These units have been returned to the manufacturer and we will receive replacement transmitters for use in spring 2020. We will consult with Eglin Natural Resources personnel about desired use.) Both transmitters deployed at the C62 sites failed by the beginning of June. The transmitter in 201E failed sometime shortly after 18 June (but was replaced three days later with a transmitter from the second wave).

The second wave of six transmitters arrived in June and units were deployed from late June to early July. One of these transmitters replaced the original failed unit on tortoise KV5 in forested site 201E on 21 June and remained operational until it was removed in mid-October. Two additional transmitters were deployed on tortoises in forested site Bull Creek (tortoises BC3 & BC7) on 24 June & 26 June, both of which remained deployed until early-mid October. The remaining three transmitters were deployed at test range C62. One transmitter was deployed at C62N (tortoise BD5) and another at C62S (tortoise ED1) on 18 June, and a third tortoise from C62S (tortoise C9) received a transmitter on 21 June. Tortoise C9's transmitter was dislodged but recovered on 13 August, and was attached to a different tortoise in forested site Garnier Creek (tortoise GD11) from 25 August until 3 October. However, this tag also failed soon after, recording its last location on 6 September. The remaining two transmitters attached to BD5 and ED1 remained operational until the end of the study period and were removed in mid-October.

Once data were collected, locations were filtered by Dilution of Precision (DOP) to minimize error uncertainty. All locations with DOP greater than 2 were removed from our dataset. Though somewhat conservative, this cutoff was established a priori to minimize the inclusion of inaccurate locations. Gopher Tortoises rarely move more than 30 m from the burrow during typical daily activity (basking/foraging, McRae et al 1981). High precision was therefore required to reduce location biases due to GPS error, which we felt necessitated a relatively strict (though still somewhat arbitrary) DOP cutoff (Bjørneraas et al. 2010). This filtering process was especially important as trial data suggested that transmitters could still communicate with satellites when not exposed to an open sky (e.g. inside a building or underground in a burrow) but would generate inaccurate location fixes with large DOP estimates. These erroneous locations could have been misinterpreted as long-distance movements as they were often projected more than 30 m from the actual transmitter location. However, we also recognized that minimizing the inclusion of imprecise locations came at the expense of potentially losing informative data points (e.g. temporary forays into unexpected habitat patches, Lewis et al. 2007, Frair et al. 2010).

Once data were filtered, we generated minimum convex polygon (MCP) home range estimates and calculated maximum distances traveled (i.e. the furthest straight-line distance a tortoise moved from its burrow or between burrows in a single movement event). We counted the number of burrows used, regardless of duration, for each tortoise over the course of its tracking period. We also generated Kernel Density Estimates (KDE) to visualize relative spatial use within a home range for each tortoise but did not quantify home ranges using KDE estimation. Perimeter points forming MCPs were visually inspected and removed if they met a secondary filtering criterion (fix duration greater than 30 seconds). This secondary filtering criterion was applied at the recommendation of Virginia Tech faculty with expertise in spatial ecology and telemetry data (Dr. Marcella Kelly, personal communication). No internally located positions within a home range were removed. We recognized the potential biases associated with most home range estimation techniques, including MCP estimation (e.g. Laver & Kelly 2008, though see Row & Blouin-Demers 2006 regarding the utility of MCP estimation for herpetofauna) but chose this method for comparisons with previous studies of Gopher Tortoise home ranges. All spatial analysis and data visualization was performed in ArcMap 10.4.

RESULTS AND DISCUSSION

TEST RANGES VS. FORESTED HABITATS. — Cluster analysis comparisons of herbaceous community structures among sites indicated most test ranges generally had species compositions and abundances that were more similar to those found on other test ranges than to those of forested sites (Figure 2). Among all sites, forested sites Bull Creek and Middle Creek were most similar. Among test ranges, C52N, C62S, and C64 were most similar to one another followed by B71 and B75, then B70E and C72. All other sites exhibited increasingly dissimilar herbaceous communities and did not form particularly tight groups, with the forested site Garnier Creek being the least similar to all others. The larger cluster containing most test ranges and the cluster containing forested sites 201E, Bull Creek, Middle Creek, Turtle Creek, and test range C74 were more similar to one another than to the groups containing Garnier Creek, Pine Log, and Rogue Creek, though the distances between smaller clusters within those groups tended to be relatively large.

NMDS (final stress value =0.08) indicated herbaceous communities in forested sites and on test ranges were somewhat distinct, with certain species demonstrating no affiliation for one habitat type over the other while others appeared to be better represented in either forested sites or test ranges (Figure 3). Our results suggested that herbaceous communities in forested sites were distinct from those found on test ranges ($F_{1,15}$=4.50, $p<0.01$). Visual assessment of the two-dimensional plot and 95% confidence intervals suggested forested site herbaceous communities were far more variable than those of test ranges, the latter of which generally concentrated in the lower left quadrant of the ordination space (<0.1 NMDS axis 1, <0.1 NMDS axis 2). Between habitat types, the primary disparities among forbs were expected and involved disturbance-prone species (e.g., poor Joe *Diodea teres*) that showed a greater association with test ranges, and a number of infrequently encountered species, most of which were more affiliated with forested sites. Differences in graminoid species composition between habitat types included two non-native erosion control species, carpet grass (*Axonopus fissifolius*) and bahiagrass (*Paspalum notatum*), which were exclusively found on test ranges, as well as a native species, slender bluestem (*Schizachyrium tenerum*), which was far more abundant on test ranges than in forested sites. Other bluestems (*Andropogon* spp.) and little bluestem (*Schizachyrium scoparium*), alternatively, were more affiliated with forested sites.

Test ranges, on average, had higher coverage of graminoids, bare ground, and disturbance-prone species and lower legume, shrub, and litter coverage compared to forested sites (Table 3). Overall, many test ranges appeared to have potentially greater forage availability for Gopher Tortoises (particularly grasses which make up the bulk of the diet) than forested sites, though it should be cautioned that greater availability is not necessarily indicative of better forage quality as individual grass and forb species (e.g., non-native or disturbance-related species) may vary in palatability and available nutrients.

While test ranges appeared to provide the sun-exposed conditions preferred by Gopher Tortoises and considerable foraging opportunities, we lacked evidence to suggest a relationship existed between major vegetative cover type estimates and Gopher Tortoise burrow densities within any size class among sites (Table 4). Current habitat characteristics alone did not explain observed differences in burrow densities among sites and it is likely that a number of factors, past and present, have shaped Gopher Tortoise populations on Eglin.

At the burrow-scale, we found some evidence that Gopher Tortoises demonstrated selection preferences for certain cover types, but that these preferences may have differed between habitat types. In forested sites, Gopher Tortoises appeared to excavate burrows in areas with significantly greater graminoid cover than what tended to be available (Table 5). The compositional analysis also indicated that graminoids were significantly preferred in forested sites over all other cover types except bare ground (Table 6). In contrast, Gopher Tortoises inhabiting test ranges appeared to choose burrow locations with significantly higher legume and shrub cover compared to what was available (Table 5), though compositional analysis did not suggest a strong preference among the top five ranked cover types in pairwise comparisons (Table 7). These apparent differences may be due to generally greater and more uniform availability of graminoids and non-leguminous forbs on test ranges that result from a complete lack of canopy cover, relaxing constraints on suitable burrow locations. Alternatively, this lack of canopy may have prompted tortoises to select burrow sites near shrubs to provide cover. Legumes are highly nutritious and tend to be favored by Gopher Tortoises when available. Due to lower estimated legume cover on test ranges than in forested sites, Gopher Tortoises may have selected locations with greater legume abundance.

Recent work on Archbold Biological Station has shown that Gopher Tortoise populations were more than four times denser on a mowed field than on either fire-suppressed or restored forested sandhills (Howell et al. 2020). The mowed field also supported larger females that had larger clutch sizes and higher survivorship than forested areas. Their demographic analyses suggest that Gopher Tortoise populations in these artificially maintained open habitats could provide important contributions to the persistence of the species. Another recent study on Conecuh National Forest in Alabama, showed that three populations of only 20-40 individuals were stable over time and population viability analyses showed they had a high probability of persistence (Folt et al. 2021). This work was based on survival estimates calculated from long-term studies and refutes preliminary work that suggested only populations of 250 individuals are likely to persist (Folt et al. 2021). The populations on Conecuh that were stable were those where thinning, fire, or soil conditions maintained extensive open areas. Our current study focused on habitat conditions rather than demographic studies of tortoises, but combined with the results from recent publications, they suggest that test ranges and other open areas on military installations may contain populations that are more likely to be stable or increasing than populations in forested sites (Howell et al. 2020, Folt et al. 2021). Allowing Gopher Tortoise populations to persist on these ranges, and reducing nest failure by managing maintenance activities (see section below on Management Strategies of Testing and Training Areas), could be important steps to prevent population declines that could lead to federal listing.

AGE-SIZE DISTRIBUTIONS AND RECRUITMENT. — We found a higher density of total tortoise burrows on test ranges compared to sites in forested habitats. This disparity was especially evident in the subadult burrow size class (130-230 mm). Furthermore, while we found evidence of the successful establishment of young individuals (i.e., juvenile burrows; < 130 mm) in both habitats, test range habitats had on average a greater density, which supports our previous year of data suggesting greater recruitment on test ranges compared to forested sandhill sites. Although it is only one example, we did observe that efforts to open the canopy at one low-quality forested stand were followed by a doubling in the number of active burrows and a tripling in the number of burrows in the sub-adult size category, suggesting that active habitat management of forested sites can benefit Gopher Tortoise populations (Chandler et al. 2020).

COMMENSAL USE OF FORESTED SITES AND TEST RANGES. — Similar to our findings from 2016-2017, we found that forested sites generally had higher values of all three indices of diversity (alpha = average species/plot, beta = describes relative variability in species composition among plots within a site and increases in value with increasing dissimilarity among plots, gamma = total species/site) for total vertebrate burrow commensal and potential Gopher Tortoise predators (Table 8; Figure 4). Since forested sites typically also have lower densities of tortoises, these data suggest the value of having burrows on the landscape, even at low densities in forested areas. Similar to 2016-2017, Gopher Frogs were the third most common commensal observed, with more Gopher Frog observations in test ranges than forested sites. This is most likely because their early survival is dependent on their ability to locate available refugia (Roznik and Johnson 2009), and ranges provide a higher density of tortoise burrows near breeding ponds than forested sites. We also documented other sensitive species using burrows, such as the Eastern Diamondback Rattlesnake and Florida Pine Snake. Although many species were observed using burrows in both forested sites and test ranges, if Gopher Tortoise became extirpated from forested sites on Eglin the broader wildlife community would suffer. The burrows on forested sites provided important refugia and sheltered a wider array of native species.

Our wildlife cameras also allowed us to make observations of Gopher Frogs that would not have otherwise been possible. We observed an adult Gopher Frog calling from a burrow on 14 August 2018, which is outside of their breeding season (Oct-May) and was over 2.5 km from a known breeding pond. Additionally, we observed two Gopher Frogs that were over 6 km and 7 km from known breeding ponds, which suggests that there may be ponds on the landscape that we have not detected, or frogs are migrating farther distances than previously documented. Future work may include conducting additional surveys across the landscape to identify these and additional potential Gopher Frog breeding sites.

MANAGEMENT STRATEGIES OF TESTING AND TRAINING AREAS. — We had seven total respondents representing eight installations and outlying properties (Table 9). One individual represented two installations and completed separate questionnaires for each. We considered these separate responses. For this report, we have focused primarily on responses to questions specific to testing/training areas and airfields (henceforth collectively referred to as test ranges). Unfortunately, preliminary feedback on our questionnaire indicated that most installation personnel were not comfortable providing information on Gopher Tortoise density estimates, so we were unable to analyze how management regimes affect Gopher Tortoises across installations. Even without asking for information on tortoise densities, we received some comments from survey recipients to the effect that they already provided information about Gopher Tortoise to the US Fish and Wildlife Service (presumably for the Candidate Conservation Agreement annual reports) and they did not want to provide information to a university on this topic. As a result, we had few responses to the survey.

Among respondents, all reported tortoises inhabiting human-altered habitats and seven of eight installations reported tortoises occupying test ranges. Management techniques used to suppress vegetation in these areas were somewhat variable (Table 10). All respondents reported that test ranges were maintained by mowing and seven of eight installations reported the use of herbicides as well. An additional five installations reported chainsawing/logging occurred on test ranges. Two installations reported using roller-drum chopping. Additionally, it was reported that test ranges on six installations were managed with prescribed fire to some extent and three reported that incidental fires (i.e., lightning-fires or fires ignited by training activities) were allowed to burn.

Four installations commented on the season of burn (open response), of which, two reported dormant season prescribed fires only. One reported growing season (March-October) fires and some supplemental dormant season burning for areas in need. One reported that potential tortoise habitats had received growing season (April-May) fires at least once since 2012 and dormant season fires in years prior.

Among the eight installations that responded, seven indicated that certain management practices were used on test ranges specifically to improve or maintain Gopher Tortoise habitat. Additionally, a number of other beneficial management activities used on tortoise-occupied test ranges (open response) were identified. Five respondents listed prescribed fire and one installation listed midstory removal, mechanical clearing, timber harvest, and “RCW/Gopher Tortoise” as management practices implemented for the benefit of Gopher Tortoises. However respondents did not provide any information to document whether these practices did in fact benefit Gopher Tortoises, nor did they describe them in detail.

Respondents indicated that test ranges were used for a wide variety of testing and training activities. Three reported tactical land vehicle use, two reported bivouacs, three reported live-fire/incendiary exercises, and one reported no training activities occurred. Additionally, five installations listed other activities/conditions (open response) which included military personnel and aircraft movement, runway clear zone, flight operations in cleared areas, minimal live-fire (blank cartridges), and airfield.

When asked to comment on variability in the frequency and timing of management practices used to maintain test ranges (open response), most respondents indicated that management strategies were highly variable over time and space. One installation reported that it did not have test ranges, though open areas occupied by tortoises were used periodically for land navigation exercises only. Another installation commented that management was variable and that most habitat was “overgrown/had not been managed properly for several years.” A third installation mentioned attempts to reduce midstory vegetation on 600 acres/year across the base, some of which included tortoise habitat, and a fourth indicated prescribed burning at 2-3 locations per year, weather permitting.

On Eglin, we documented mowing activities occurring on some ranges during nesting season, which in several cases resulted in burrow collapse, and would likely have crushed any eggs present in the burrow aprons, an area where egg-laying typically occurs. Even though practices that more obviously disturb the soil, such as roller-chopping, were not applied to the ranges at Eglin during our study, the heavy mowing equipment used left deep tracks and still resulted in soil disturbance that appeared to be substantial enough to destroy nests. Although mowing likely creates dense herbaceous vegetation attractive to Gopher Tortoises, repeated disturbance of nests over the years would prevent the recruitment of young individuals into the population. At Eglin, close cooperation between fire and wildlife ensures that red-cockaded woodpecker cavity trees are marked and the areas around them are raked before burning to prevent damage to trees important to nesting woodpeckers. This type of coordination could benefit Gopher Tortoise populations, if wildlife crews could flag Gopher Tortoise burrows before mowing operations, and mowing crews could be trained to avoid driving over burrow aprons. The larger, more easily seen burrows are the ones that are most likely to be used for nesting, so even cursory surveys, once or twice/year, to locate and mark burrows for this purpose would likely carry a significant benefit to these populations over time.

GPS TELEMETRY. — MCP home range estimates, number of burrows used, and maximum distances traveled varied considerably among tortoises tracked in this study (Table 10). MCP home range estimates ranged in size from 0.1 ha (tortoise BD2, test range C62S) to 8.3 ha (tortoise KV5, forested site 201E). Average MCP home range size for all tortoises (n=9) tracked in this study was 2.4 ± 0.8 ha (all averages presented as mean ± 1 SE, Table 2). Average MCP home range size for tortoises in forested sites (n=4 tortoises) was 3.7 ± 1.6 ha and 2.3 ± 0.6 ha for tortoises on test ranges (n=5 tortoises). The number of burrows used by all tortoises ranged from two to four burrows over the course of the study. The average number of burrows used by all tortoises in the study was 2.3 ± 0.2 burrows. All tortoises in forested sites used two burrows over the course of the study. Tortoises on test ranges used two to four burrows (average = 2.6 ± 0.4 burrows). Maximum straight-line distances traveled ranged from 37 m (tortoise BD2, test range C62S) to 615 m (tortoise GD11, forested site Garnier Creek). Average maximum distance traveled by all tortoises was 197.6 ± 63.0 m. Average maximum distance traveled by tortoises in forested sites was 304.3 ± 107.9 m and 112.2 ± 21.1 m by tortoises on test ranges. We did not document any movements by tortoises between forested and test range habitats, although one of the tortoises from a forested site (GD11) moved over 500 m to an open, mowed food plot area.

The transmitter model we used was initially chosen under the assumption that battery life would be short due to the amount of time tortoises spend in their burrows where location fixes would presumably be unattainable and frequent attempts would rapidly deplete batteries. However, we found that transmitters were able to acquire location fixes far more frequently than originally anticipated and a smaller model with a smaller battery (potentially allowing for a wider range of size classes in future studies) may have been suitable. Though batteries were more efficient than initially expected, data required thorough inspection and filtering due to the number of erroneous locations presumably acquired while tortoises were underground. Transmitters were equipped with temperature loggers and future studies may be able to use rapid temperature increases (or even light detectors), along with improved data filtering criteria, to better differentiate locations recorded above ground from those where the tortoise may have been close to the surface but still in its burrow. Further, transmitters appeared to obtain a location fix relatively quickly under an open sky and shorter time-out durations may be an additional way to improve battery life.

Forested Site 201E

Tortoise **KV5** (Figure 5) moved approximately 300 m south to an old burrow where she spent the 13th of June and returned to her original burrow the following day. This movement inflated her estimated home range size considering the majority of her activity occurred relatively close to her original burrow over the approximately 5 months she was tracked (the longest tracking period of any tortoise included in this study). Two separate mating attempts were documented via a camera trap on 25 May and 7 June (Figure 6).

Forested Site Bull Creek

Two tortoises in forested site Bull Creek (tortoises **BC3** & **BC7**, Figures 7 & 8) were originally trapped in burrows located less than 50 m from one another. Shell-drilling marks already present upon capture revealed these individuals had been translocated to the site in the early 1990s (Jackson Guard, Eglin AFB Natural Resource Division, unpublished data). Both individuals made excursions to a third burrow located approximately 90-113 m east from their original burrows. BC3 moved to this burrow on 15 July and remained there until 11 August, at which point she returned to her original burrow. BC7 relocated from her original burrow to the recently abandoned burrow the day after it was vacated by BC3 on 12 August, and remained there until the end of the study. A mating attempt between a male tortoise and BC3 was documented via camera trap on 8 July (Figure 6). All three burrows appeared to remain active throughout the study period and it was believed that BC3, BC7, and at least one adult male tortoise may have been rotating between them. There was considerable overlap in the MCP home range estimates for both BC3 and BC7 but neither individual appeared to visit or use the third burrow while occupied by the other female tortoise.

Forested Site Garnier Creek

Tortoise **GD11** (Figure 9) was tracked for only an approximately two-week period before the transmitter failed. His MCP home range estimate was inflated by a single point recorded as he moved from his original burrow to a new burrow located in an open dove food plot 559 m away (straight-line distance) the day after capture. No locations were recorded at the original burrow (it is believed he left the burrow prior to the transmitter recording its first location of the day) though the emigration path to the new burrow was partially documented. The first location was recorded approximately 123 m north of the original burrow at 1015 on 25 August. At 1045 another location was recorded approximately 488 m from the original burrow location and approximately 367 m northwest of the previous location (the transmitter was unable to acquire a location during the 1030 fix). By 1101, he appeared to have moved an additional approximately 78 m to the northwest and the next successful fix did not occur until three hours later around 1400 at the newly occupied burrow. Measuring the distances between the original burrow and each consecutive location indicated GD11 travelled a non-straight-line distance of approximately 615 m, most of which occurred over the course of an hour. This movement was the longest distance travelled by a tortoise over the course of the study. The area to which it moved had been planted in lespedeza as a wildlife food plot and was maintained by mowing.

Test Range C62N

Tortoise **SG9** (Figure 10) was only tracked for roughly a month prior to his transmitter failing and his tracking period did not coincide with data collected for the other tortoises except for BD2 and some overlap with KV5. SG9 relocated to a previously inactive burrow approximately 50 m from his original burrow on 11 May, where he remained until the transmitter stopped working on 3 June. Tortoise **BD5** (Figure 10) concentrated most of his activity near his burrow, but made periodic movements up to approximately 100 m south to another burrow throughout the tracking period, though never appeared to remain at the second burrow for extended lengths of time. The second burrow appeared active but it was unknown whether this individual was visiting a potential mate or using both burrows simultaneously.

Test Range C62S

Tortoise **BD2** (Figure 11) was tracked for nearly two months until her transmitter failed roughly 20 days after SG9's. Transmitter failure occurred shortly before she changed burrows (she was located at a new burrow approximately 40 m away with remnants of epoxy and her unique painted ID number still visible but the non-functioning transmitter no longer attached) and her new location was not included in her final home range estimate. Tortoise **C9** (Figure 11) relocated to a different burrow approximately 50 m from her original burrow on 24 June and then occupied a third burrow an additional approximately 138 m away on 12 August, where she remained until her transmitter fell two days later on 14 August. The transmitter was recovered on the burrow apron on 20 August and was eventually attached to GD11 in a forested site Garnier Creek (see above). Tortoise **ED1** (Figure 11) made multiple burrow changes throughout the study period. This individual left her original burrow on 24 June and entered a previously inactive burrow approximately 100 m to the east. On 8 July, she was found excavating a new burrow 113 m away from her previous burrow during weekly tracking; however, the disturbance apparently prompted her to abandon the new burrow as she returned to the previous burrow the same afternoon. On 26 July she excavated a new burrow approximately 30 m to the southeast. She occasionally moved back and forth between burrows, though primarily used the newly excavated burrow, for the remainder of the tracking period.

Average MCP home range sizes for tortoises on Eglin in this study generally exceeded estimates for tortoises in an open canopy longleaf pine plantation in southwest Georgia (average 0.47 ha, McRae et al. 1981), an open roadside and surrounding slash pine plantation in north Florida (average 0.5 ha, Diemer 1992), a longleaf pine/turkey oak sandhill in north Florida (range 0.1 -1.4 ha, Smith 1995), an oak/palmetto scrub in central Florida (Smith et al. 1997, average 1.7 ha), and a longleaf pine savanna in southwest Georgia (average 0.1 ha for females, average 1.1 ha for males, Eubanks et al. 2003)[MW1]. Castellón (2018) reported spring home ranges for female Gopher Tortoises in south Florida mesic flatwoods (average 0.56 ha) and xeric scrub (average 1.38 ha) tended to be smaller than what we found on Eglin. However, male home ranges in that study were comparable in the spring (average 2.56 ha in flatwoods, 2.32 ha in scrub) to our estimates but exceeded our estimates in the summer (average 4.08 ha in flatwoods, average 12.4 ha in scrub). Burrow use during active seasons (i.e., total number of burrows used from approximately April-October) appeared to be similar in our study to the average number of burrows used over similar time frames reported by McRae et al. (1981). The average number of burrows used by females reported by Diemer (1992) and Eubanks (2003) during the active season was similar to what we observed in this study, regardless of sex, but males in those studies generally used considerably more burrows/month on average. Burrow use by both sexes in flatwoods and scrub reported by Castellón (2018) greatly exceeded the number of burrows used by tortoises on Eglin in this study. Long-distance movements by tortoises reported by Diemer (1992) and Eubanks et al. (2003) were comparable to maximum distances traveled by tortoises in this study.

Most MCP home range estimates reported for Gopher Tortoises in previous studies were smaller than what we observed on Eglin, despite our shorter tracking period. It was unclear whether typical MCP home range sizes were underestimations or if Gopher Tortoises on Eglin potentially had atypically large home ranges compared to most other habitats and locations. However, GPS telemetry allowed us to detect many above-ground locations, most of which likely would not have been recorded using traditional VHF tracking, and our MCP home range estimates would likely have been considerably smaller (Cagnacci et al. 2010, Walter et al. 2015). For example, the 407 m straight-line movement by tortoise KV5 away from her burrow and return the following day could have easily gone undocumented with a weekly or bi-weekly tracking schedule typically used in standard VHF studies. Similarly, much of the daily activity and short-term burrow use that we observed by multiple tortoises likely would not have been observable using VHF (only a single observation of a tortoise was made above ground, while it was attempting to excavate a burrow, during weekly VHF tracking). Broad patterns in spatial use may therefore be detectable using traditional methods, but GPS telemetry may provide greater fine-scale insight into within-home range habitat use as well as an increased likelihood of documenting intermediate, less permanent movement patterns (Walter et al. 2015). GPS technology may be particularly useful in observing spatial patterns of Gopher Tortoises due to their limited aboveground activity and reclusive nature (Douglas & Layne 1978, McRae et al. 1981).

SUMMARY, BEST PRACTICES, AND RECOMMENDATIONS ON FUTURE WORK. —In order to keep tortoises in forested habitats and out of test ranges, it will be necessary to either create a barrier (i.e., fencing) that prevents movement into test ranges or maintain forest habitat such that it is more attractive to tortoises. Fencing ranges would be logistically challenging as well as expensive as tortoises can dig and fences not maintained would be ineffective. Managing forests through fire and mechanical thinning and, where Gopher Tortoise presence on test ranges is compatible with military activities, facilitating reproductive success on test ranges by avoiding soil disturbance around large burrows during the nesting season would likely be more effective long-term solutions. Achieving successful management of Gopher Tortoises will require coordination between teams responsible for the habitat (e.g., mechanical thinning, fire) as well as wildlife. Using the success of red-cockaded woodpeckers (RCW) as a model, constant communication was key between these two groups. For example, the team responsible for monitoring RCWs would mark (with paint) actively nesting trees as well as indicate these trees on a GIS shapefile (including if the tree became inactive) and this information was provided to the team responsible for fire. In this way, during prescribed burns, active nesting trees could be protected from large fires in a targeted manner. For Gopher Tortoises, continuous monitoring of burrows including their location and status (active, inactive, or abandoned) could be indicated both within the habitat (e.g., flagging) as well as in a GIS framework to allow these locations to be protected from being impacted, especially in the nesting season. These efforts can be bolstered by communication from habitat management teams to the wildlife teams by ensuring that burrow locations are up-to-date before performing soil disturbing activities that could damage or destroy nest. With improved coordination, future work should seek to understand how the type of management practices affects both Gopher Tortoise populations over time, which would require control over, or at least advance knowledge of, the timing and intensity of habitat management.

CONCLUSIONS. —Our second year results, coupled with the first year, demonstrate that both test range and forested habitats are able to support populations of Gopher Tortoises on Eglin Air Force Base. Addressing each of our five objectives, we specifically found:

1. Gopher Tortoises showed the ability to move long distances in both habitats and individuals use multiple burrows even over the course of 2-4 weeks.

    The lack of movement of tortoises between test range and forested habitats may be a result of the location of the tortoises we studied and the result of a preference for range habitats. We were unable to locate active tortoise populations in forested areas adjacent to ranges, so the tortoises instrumented in forested areas were located several kilometers from ranges. The tortoises from forested habitats were unlikely to move these distances on to ranges. We did have one tortoise on a forested site (GD11) move over 500 m to a more open habitat maintained as a dove food plot. None of the tortoises on ranges entered adjacent forests even though they were near enough to reach forested habitat without exceeding the range of natural movements. The fact that even fire-maintained forested stands on the edge of ranges did not contain Gopher Tortoise populations suggests that the ranges may be more attractive to tortoises.

2. Using management practices that protect nesting sites will likely benefit tortoise populations on ranges.

    Management practices on test ranges that minimize damage to both the burrow and apron, especially during the nesting season, would likely benefit the long-term survival of Gopher Tortoise populations. The nesting season likely varies among installations, but egg laying is typically mid-May through mid-June, with eggs hatching 80 to 100 days later by mid-September (Iverson 1980, Diemer 1986). Managers may extend this window (i.e., from April in the southern part of the range to mid-October in the northern part of the range) in order to ensure that early or late nesting tortoises are also protected.

    Management of Gopher Tortoise habitat vary widely across installation, including mechanical (mowing, chain sawing, logging, roller-drum chopping) as well as non-mechanical (herbicides, prescribed fire) management practices. Additionally, the frequency at which these practices are applied to their respective habitats varied, although we lack details beyond identifying this variation. While we were unable to analyze Gopher Tortoise density with management practices across installations, a potentially positive outcome of our survey indicates that installations are actively managing and improving habitat for Gopher Tortoises. However, it is important to assess whether practices that maintain an open canopy and dense herbaceous vegetation also repeatedly destroy nests and eggs. More trust and communication is important to be able to understand how these practices may influence Gopher Tortoise populations.

3. Although the forested habitats had a larger variation in plant species, and higher legume availability, the considerable overlap among these two habitats indicates that both habitats provide necessary vegetative characteristics for Gopher Tortoises on Eglin Air Force Base.

    Tortoises likely found ranges more attractive due to the open habitats and individuals were drawn from the more closed canopy of the forests. Recent publications suggest that open habitats promote growth and reproductive success of Gopher Tortoises. Furthermore, while we documented larger home range sizes compared to other studies, established tortoises on Eglin primarily remained in their original habitat type. Future research to assess demographics of tortoises in different habitat types would be beneficial. There are also opportunities to take advantage of the translocation programs on-going on Eglin to assess growth, survival, reproductive success as well as movement and ultimate habitat selection of recently translocated tortoises.

4. Test range habitats support a higher density of Gopher Tortoises on Eglin Air Force Base compared to forested areas.

    At the outset of the study we had expected we would be able to obtain records of management practices on the ranges, but unfortunately, this information was never made available in a format conducive to answering research questions. This would have required data on timing (i.e., dates), location (e.g., spatial extent) and method (e.g., mowing, prescribed fire) of every management practice performed on Gopher Tortoise habitat while also having access to information on tortoise populations (e.g., density). Just as most landowners don't keep records as to what date they mowed their lawns and might not be able to tell you what type of equipment was used for mowing in 2008; most range managers do not have this information readily available. However, long-term records with details of range management practices are essential to be able to understand how these practices have long-term effects on wildlife populations. The lack of documentation of activities from range managers prevented us from being able to evaluate which management practices result in the high populations of Gopher Tortoises (and a high proportion of young individuals) found on some ranges.

    An important result of our study is the observation that there is a great need for better coordination and information-sharing between those responsible for maintenance/management of ranges and those responsible for wildlife. (For example, successful recovery of red-cockaded woodpecker populations on Eglin was possible because of close coordination between teams responsible for fire and for wildlife). Unfortunately, this coordination does not exist with teams responsible for mowing ranges.

    If future research could occur in partnership with range managers, there would be a benefit to an adaptive management experiment applying different management regimes to assess how they influence Gopher Tortoise population structure and density. In order to approach this question, future studies would have to control the timing and the types of management practices applied to a given habitat and measure the temporal response in multiple Gopher Tortoise populations as well as the line-of-sight characteristics or other metrics of the utility of the range for military operations.

While Gopher Tortoise density, especially among the youngest age classes, was greater in test range sites compared to forested sites, we did not find evidence that plant species richness varied between test range and forested sites. This likely indicates that other factors, other than species composition of ground cover vegetation, have a greater influence on current tortoise population structure (e.g., canopy openness). Despite the differences in canopy coverage, tortoises are able to forage on similar foods within test range sites as they would in forested areas.

5. Gopher Tortoise burrows provide important microhabitat to a variety of vertebrate species in both forested and test range habitats but forested sites support more species and apparently more individuals (based on frequency of observations).

   The broader wildlife community benefits from the burrows created by Gopher Tortoises and future studies could explore this role further. Similar to objective #4, understanding how specific management regimes affect tortoise burrow use by commensal and other associated species would require an explicit experimental design. However, our data provide the necessary first steps into identifying the differences in commensal use between test range and forested habitats. Future studies can build upon this research by manipulating management practices in a controlled experimental design. For wildlife of special interest, such as Gopher Frogs, using telemetry to understand how far they travel from burrows to breeding sites would be helpful to assess the importance of burrow distribution on the landscape. In order to facilitate possible reintroduction of indigo snake, evaluating proximity to wetland habitats would also be of interest.

BENEFITS. —Benefits to the military from this research include the following.

1. We identified a variety of management techniques that are currently being used to maintain ranges for military operations, but also documented that there is often very limited communication between those responsible for maintenance and management of ranges and those responsible for managing wildlife resources. Improving communication among these groups within installations, and improving more cross-installation communication about the pros and cons of various practices, would likely result in more efficient and effective practices to facilitate military operations while protecting Gopher Tortoises.

2. We documented that although Gopher Tortoise population density and age structure vary greatly across ranges, some military ranges provide apparently high-quality habitat for Gopher Tortoise. In some ranges, the high levels of recruitment of young tortoises create a more favorable age/size structure than that in populations in forested

habitats. Installations may be able to contribute to keeping Gopher Tortoises from federal listing by maintaining these habitats, as long as soil disturbance is minimized around burrow aprons during nesting season. Especially in light of recent research showing higher reproduction in mowed landscapes compared to the forest (Howell et al. 2020), and the possible viability of populations under 50 individuals (Folt et al. 2021), installations should be aware of the value these populations may contribute.

3. Our inability to find tortoise populations in apparently well-maintained forested areas adjacent to test ranges suggests that the open canopy of test ranges may be highly attractive to Gopher Tortoises. If these ranges are not managed to support Gopher Tortoises, they could be serving as population sinks by attracting tortoises but causing high nesting mortality if nests are mowed or roller-chopped.

4. Gopher Tortoises are able to fulfill their role as ecosystem engineers in the test ranges, providing habitat for many species that use burrows, including Gopher Frogs (located in burrows distant from any previously known populations). However, there was higher diversity of burrow associates in the forested sites, suggesting that there is a strong benefit to maintaining Gopher Tortoise populations in longleaf pine sandhills. Ensuring these areas have an open canopy and dense herbaceous understory is essential to maintain Gopher Tortoise populations in the forested sites.

5. Our finding that Gopher Tortoises on Eglin Air Force Base make more long-distance movements and have larger home ranges than previously documented, suggests that the behavior of Gopher Tortoise in one of the largest remaining expanses of habitat may differ from the behavior of tortoises in smaller, isolated patches. This documents the important role that large installations may have in the protection of Gopher Tortoise populations.

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TABLES

Table 1. Time periods during which the trail cameras were programmed to record the activity of Gopher Tortoises and their burrow associates at burrows on Eglin Air Force Base, FL between 2017 and 2018. Times are based on the 24-hour clock (CST).

Camera Settings	Winter 2017-18	Spring 2018	Summer 2018
Time lapse 1	0600-1600	1000-2100	0600-1300
Time lapse 2	–	–	1800-2200

Table 2. *Gopher Tortoise Capture Data.* Tortoises (n=9) included in this study were captured from three forested sites and two test ranges on Eglin Air Force Base, Florida, in summer 2018. Deployment period refers to the date of capture and transmitter attachment to the end of GPS data collection (i.e. transmitter failure or placement of trap for recapture and transmitter removal). Sex was determined via plastron concavity. Carapace length (CL) was measured along the midline from the posterior edge of the carapace to the tip of the nuchal scute anteriorly. Tortoises were weighed using a digital scale or a fish scale (by placing the tortoise in a burlap bag and subtracting the weight of the bag).

Habitat	Site	Tortoise ID	Deployment Period	Sex	CL (mm)	Weight (kg)
Forested n=4	201E	KV5	12 May-18 Oct.	F	289	4.51
	Bull Creek	BC3	29 June-15 Oct.	F	310	4.58
	Bull Creek	BC7	30 June-2 Oct.	F	312	4.52
	Garnier Creek	GD11	25 Aug.-6 Sept.	M	272	3.50
Test Range n=5	C62N	BD5	19 June-3 Oct.	M	251	2.99
	C62N	SG9	28 April-3 June	M	238	2.75
	C62S	BD2	28 April-23 June	F	282	4.61
	C62S	C9	22 June-14 Aug.	F	272	7.21
	C62S	ED1	19 June-20 Oct.	F	253	2.81

Table 3. *Site-wide comparison of percent cover estimates for major vegetative cover types between forested sites and test ranges occupied by Gopher Tortoise on Eglin Air Force Base, FL.* Site-wide scale two-sample T-test results comparing major cover class estimates and average species richness (γ) between forested sites and test ranges on Eglin Air Force Base, FL. Results are provided as means ± SE. Significant differences between habitat types highlighted in bold (α=0.05). Cover classes are defined as follows: Bare = bare ground cover; Forb = non-leguminous forb cover; Graminoid= graminoid cover, i.e. grasses (Family Poaceae) & sedges (Family Cyperaceae); Legume = leguminous-forb cover (Family Fabaceae); Litter = non-living plant material cover, i.e. leaves & woody debris; Shrub = woody plant cover; & Disturbance = disturbance associated species cover (see methods for disturbance-prone species list used for these estimates).

Habitat	Bare	Forb	Gram	Legume	Litter	Shrub	Disturbance	γ
Forested (n=7)	18.1±3.1	20.9±5.6	23.6±5.7	**8.6±1.8***	**50.5±6.8****	25.8±4.2	2.7±1.5	54.4±4.5
Test Range (n=10)	**34.3±5.6***	28.4±2.9	**42.0±2.7***	4.0±0.7	21.0±2.8	16.0±1.9	**18.±2.2****	52.3±3.4

*p=0.05 **p<0.01

Table 4. *Density of Gopher Tortoise burrows on Eglin Air Force Base, FL, was not related to vegetative characteristics of the sites*. In addition to analyzing all burrows we conducted separate tests for individuals size classes, which also showed no differences in vegetative characteristics. Multiple regression ANOVA table & Coefficients for y= total burrow density (number of burrows/hectare, all size classes combined) predicted by percent cover estimates for major cover types. Predictor variables are defined as follows: Disturbance = disturbance associated species cover, Forage= combined herbaceous cover (forbs and graminoids); Habitat= categorical, forested or test range; Shrub= woody plant cover.

Response		DF	SS	MS	F	R^2	p
Total burrows /ha	Model	4	5.00	1.25	0.73	0.21	0.59
	Error	11	18.91	1.72			
	Total	15	23.92				

Predictor	Est.	SE	t	p
Intercept	1.37	2.16	0.64	0.54
Disturbance	0.02	0.06	0.26	0.80
Forage	0.01	0.02	0.67	0.52
Habitat	0.07	0.63	0.12	0.91
Shrub	-0.03	0.05	-0.74	0.47

Table 5. *Burrow scale comparison of percent cover estimates for major vegetative cover types between foraging, availability buffers within forested sites and test ranges.* Burrow scale paired T-test results comparing cover types between foraging/use (U) and availability (A) buffers within forested sites (n=70 burrows) and test ranges (n=120 burrows) on Eglin Air Force Base, FL. Results are presented as means ± SE. Significant differences are highlighted in bold (α=0.05). Cover classes are defined as follows: Bare = bare ground cover; Forb = non-leguminous forb cover; Graminoid= graminoid cover, i.e. grasses (Family Poaceae) & sedges (Family Cyperaceae); Legume = leguminous-forb cover (Family Fabaceae); Litter = non-living plant material cover, i.e. leaves & woody debris; Shrub = woody plant cover; & Disturbance = disturbance associated species cover (see methods for disturbance-prone species list used for these estimates).

Habitat	**U/A**	Bare	Forb	Graminoid	Legume	Litter	Shrub	Disturbance
Forested	U	18.9±1.1	22.4±1.9	**27.0±2.1***	9.3±0.8	48.1±1.9	25.0±2.0	3.3±0.7
(n=70)	A	17.4±1.2	20.2±1.7	20.8±1.7	8.2±0.6	**56.2±1.9***	24.4±1.6	3.2±0.7
Test Range	U	34.3±1.4	31.2±0.8	39.3±1.1	**4.8±0.3****	22.5±1.0	**15.1±1.0****	15.4±1.2
(n=120)	A	**38.0±1.4***	31.2±0.8	39.2±1.1	4.0±0.3	21.5±0.9	12.2±0.9	16.8±1.0

*p=0.05, **p= <0.01

Table 6. *Gopher Tortoise burrows in forested sites on Eglin Air Force Base were located in areas with higher percent cover of graminoids.* Compositional analysis results ranking cover types within all forested sites surveyed on Eglin Air Force Base, FL. Analysis was performed using percent cover estimates for major cover types within foraging/use buffers and availability buffers. Significant pairwise log-ratio differences (α=0.05) between cover types are highlighted in bold. Log-ratio differences were used to rank cover types from most preferred (1) to least preferred (8).

	λ	P			Habitat:	**Forested**			
	0.4157	0.002			n=70	burrows			
	Use↓	Avail→							
Rank	Cover Type	Bare	Fern	Forb	Graminoid	Legume	Litter	Shrub	Vine
2	Bare		**2.10***	0.15	-0.11	0.15	**0.33***	0.21	**0.47***
8	Fern	**-2.10***		**-2.22***	**-2.26***	**-2.07***	**-1.85***	**-1.98***	**-1.56**
3	Forb	-0.15	**2.22***		-0.26	<0.01	0.18	0.07	0.34
1	Graminoid	0.11	**2.26***	**0.26***		**0.26***	**0.44***	**0.32***	**0.60***
4	Legume	-0.15	**2.07***	- <0.01	**-0.26***		0.18	0.06	0.34
6	Litter	**-0.33***	**1.85***	-0.18	**-0.44***	-0.18		-0.12	0.15
5	Shrub	-0.21	**1.98***	-0.07	**-0.32***	-0.06	0.12		0.26
7	Vine	**-0.47***	**1.56***	-0.34	**-0.56***	-0.33	-0.15	-0.26	

Table 7. *Gopher Tortoise burrows on test range sites on Eglin Air Force Base were somewhat more likely to be located in areas with higher percent cover of legumes and shrubs.* Compositional analysis results ranking cover types within all test range sites surveyed on Eglin Air Force Base, FL. Analysis was performed using percent cover estimates for major cover types within foraging/use buffers and availability buffers. Significant pairwise log-ratio differences (α=0.05) between cover types are highlighted in bold. Log-ratio differences were used to rank cover types from most preferred (1) to least preferred (7).

	λ	P		Habitat:	**Test Range**			
	0.4151	0.002		n=120	burrows			
	Use↓	Avail→						
Rank	Cover Type	Bare	Forb	Graminoid	Legume	Litter	Shrub	Vine
6	Bare		**-0.13***	**-0.13***	**-0.28***	**-0.17***	-0.20	1.77
5	Forb	**0.13***		- <0.01	-0.14	-0.03	-0.08	**1.89***
4	Graminoid	**0.13***	<0.01		-0.14	-0.03	-0.07	**1.95***
1	Legume	**0.28***	0.14	0.14		0.11	0.06	**2.17***
3	Litter	**0.17***	0.04	0.03	-0.11		-0.04	**1.87***
2	Shrub	0.20	0.08	0.07	-0.05	0.04		**2.07***
7	Vine	**-1.77***	**-1.89***	**-1.95***	**-2.17***	**-1.87***	**-2.07***	

Table 8. *Vertebrates found in association with Gopher Tortoise burrows in both forested and test range habitats during year 1 and 2 on Eglin Air Force Base*. Species shaded in gray represent potential Gopher Tortoise predators.

Species	Year 1		Year 2	
	Forested	Range	Forested	Range
American Kestrel	1	0	2	0
American Robin	3	0	0	0
Armadillo	7	1	4	0
Bachman's Sparrow	2	0	1	0
Black Bear	1	0	0	0
Black Racer	6	11	3	2
Blue-gray Gnatcatcher	1	0	0	0
Bobcat	2	0	1	0
Box Turtle	1	0	0	0
Broad-headed Skink	3	0	1	0
Burrowing Owl	0	78	0	17
Carolina Wren	0	0	1	0
Chipping Sparrow	1	0	0	0
Chuck-will's-widow	1	0	0	0
Coachwhip	68	33	20	15
Coral Snake	1	0	0	0
Corn Snake	0	2	0	0
Cotton Rat	1	0	0	0
Cottontail	40	32	13	11
Coyote	5	12	2	0
Crow	1	15	0	0
Crowned Snake	5	0	0	0
Deer	12	4	3	4
Eastern Diamondback Rattlesnake	0	0	1	0
Eastern Kingbird	0	1	0	0
Eastern Meadowlark	0	0	0	5
Eastern Woodrat	0	1	0	0
Fence Lizard	8	0	5	0
Flying Squirrel	1	0	0	0
Fox Squirrel	3	0	2	0
Gopher Frog	16	58	14	17
Grasshopper Sparrow	0	1	0	0
Great-crested Flycatcher	1	0	0	0
Green Anole	22	2	5	0
Grey Catbird	0	0	1	1
Grey Fox	3	0	0	0
Grey Squirrel	3	0	1	0

Ground Skink	5	1	2	0
Hermit Thrush	3	0	0	0
Eastern Hognose	1	1	0	1
House Wren	0	1	0	0
Mole Skink	1	0	1	0
Mourning Dove	0	0	3	0
Mouse	47	125	10	19
Northern Flicker	0	0	0	1
Northern Mockingbird	0	1	0	0
Opossum	5	1	0	0
Palm Warbler	5	1	0	0
Eastern Phoebe	19	3	0	0
Pine snake	1	2	2	0
Pocket Gopher	1	0	0	0
Pygmy Rattlesnake	1	5	1	0
Northern Bobwhite Quail	5	0	3	1
Raccoon	5	0	5	0
Six-lined Racerunner	95	97	26	20
Savanah Sparrow	0	14	0	1
Scarlet Snake	1	1	0	1
Screech Owl	7	2	1	0
Song Sparrow	0	0	0	0
Southern Toad	38	18	12	3
Striped Skunk	12	3	0	3
Swamp Sparrow	0	0	0	0
Turkey	0	0	1	1
Two-lined Salamander	1	0	0	0
Vesper Sparrow	0	0	0	0
White-throated Sparrow	0	1	0	0
Wild Boar	3	1	2	0

Table 9. *Participating installations.* Branches and locations of Department of Defense installations that participated in our test range management questionnaire.

Installation	Branch	State
Fort Benning	Army	GA
Fort Stewart/Hunter Army Airfield	Army	GA
MacDill AFB	Air Force	FL
Marine Corps Logistics Base Albany	Marine Corps	GA
NAS Jacksonville/OLF Whitehouse/ Rodman Range	Navy	FL
NAS Pensacola/Bronson Field/Saufley Field	Navy	FL
Naval Submarine Base Kings Bay	Navy	GA
NAS Whiting Field	Navy	FL

Table 10. *Management practice summary*. Management practices used to maintain test ranges as reported by participating Department of Defense installations (n=8).

Management Practice	# of Installations	% Installations
Fire	6	75
Prescribed	6	75
Incidental	3	37.5
Herbicide	7	87.5
Mechanical	8	100
Chainsawing/Logging	5	62.5
Mowing/Bush-Hogging	8	100
Roller-Drum Chopping	2	25

Table 11. *Minimum Convex Polygon (MCP) Home Range, Movement, and Burrow Use Summary Statistics.* MCP home range size was calculated in ArcMap 10.4 and presented as total area in ha. Burrows used was the total number of burrows a tortoise occupied over the entirety of the tracking period, regardless of the amount of time spent in the burrow. Max distance traveled was the longest straight-line distance moved between burrows or between a burrow and an outlying location in a single movement. Averages for all tortoises in forested sites (n=4), all tortoises on test ranges (n=5), and for all tortoises included in the study (n=9) are presented as means ± 1 SE.

Habitat	Site	Tortoise ID	Deployment Period	Sex	MCP area (ha)	Burrows Used	Max Distance Traveled (m)
Forested n=4	201E	KV5	12 May-3 Oct.	F	8.3	2	407.0
	Bull Creek	BC3	29 June-2 Oct.	F	1.7	2	113.0
	Bull Creek	BC7	30 June-2 Oct.	F	1.9	2	138.0
	Garnier Creek	GD11	25 Aug.-6 Sept.	M	2.7	2	559.0
Test Range	C62N	BD5	19 June-3 Oct.	M	2.7	2	163.0
n=5	C62N	SG9	28 April-3 June	M	1.0	2	110.0
	C62S	BD2	28 April-23 May	F	0.1	2	37.0
	C62S	C9	22 June-14 Aug.	F	1.7	3	138.0
	C62S	ED1	19 June-20 Oct.	F	1.9	4	113.0

	MCP Area (ha)	**Burrows Used**	**Max Distance Traveled (m)**
Forested Average	**3.7±1.6**	**2.0±0.0**	**304.3.±107.9**
Test Range Average	**1.5±0.4**	**2.6±0.4**	**112.2±21.1**
Average All Tortoises	**2.4±0.8**	**2.3±0.2**	**197.6±63.0**

FIGURES

Figure 1. *Transmitter Attachment***.** Transmitters were attached to the anterior costal scutes with epoxy putty or gel, with antennas secured against the carapace.

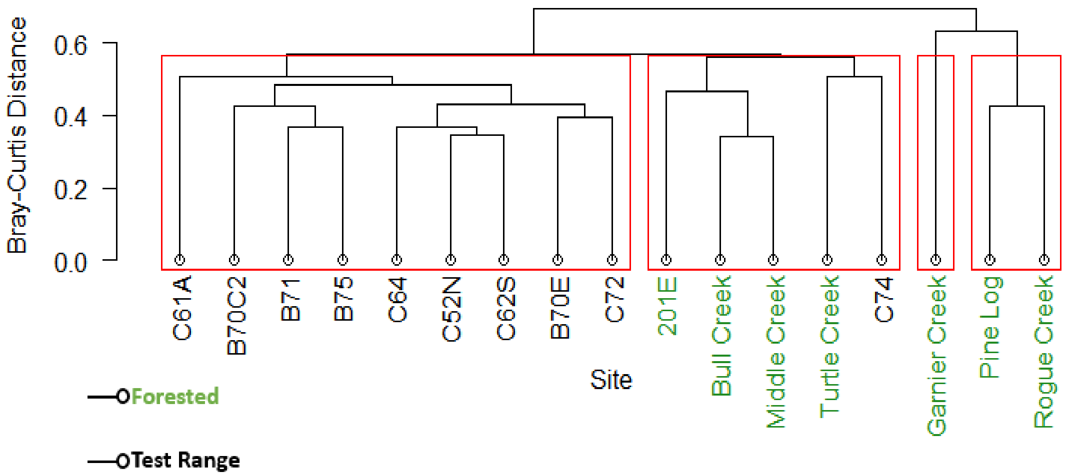

Figure 2. *Hierarchical Clustering of Sites Based on Estimated Herbaceous Community Structure comparing all Gopher Tortoise study sites on Eglin Air Force Base.* The dendrogram depicts relative similarities among sites based on presence and estimated percent cover for forb and graminoid species (excluding some rare species). Bray-Curtis dissimilarity indices among sites were used to generate the distance matrix. Distances (y axis) range from 0 (complete community overlap) to 1 (no shared species). Forested sites are highlighted in green, test ranges are highlighted in black. Test range sites shared more similarities with several of the forested sites than a few of the forested sites shared with each other.

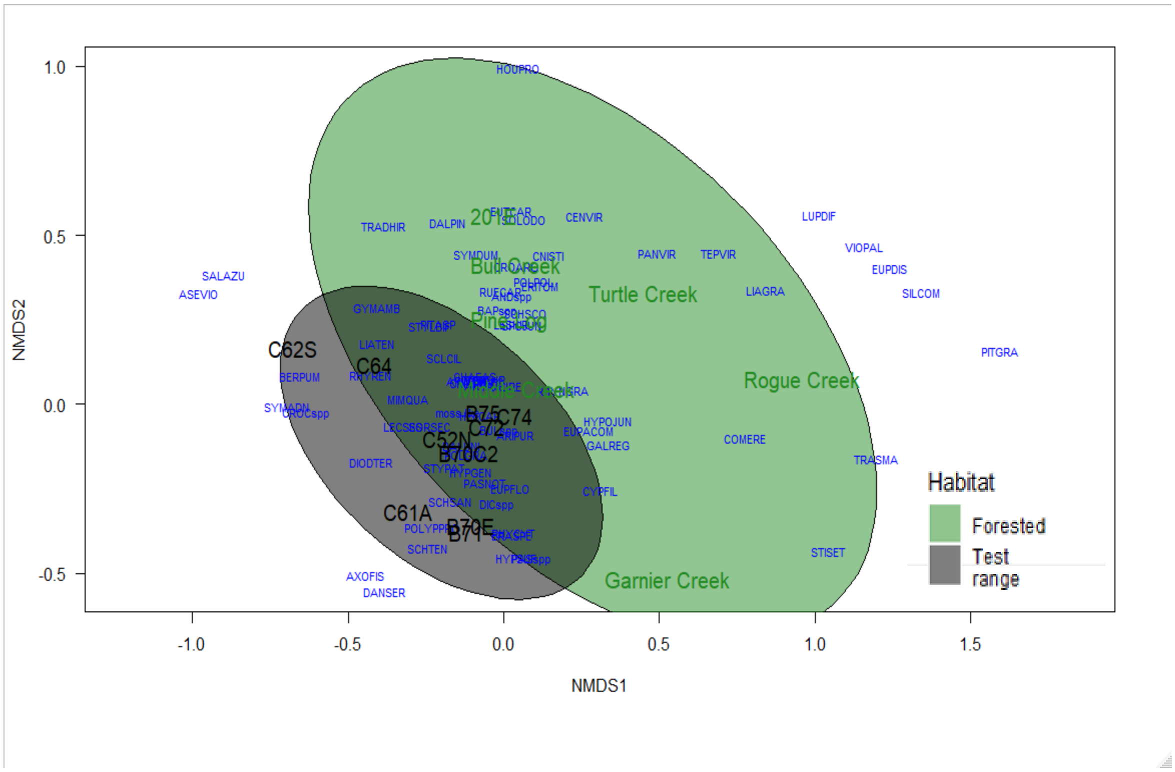

Figure 3. *Non-metric multidimensional scaling (NMDS) sites & herbaceous species on forested and test range sites occupied by Gopher Tortoise on Eglin Air Force Base.* Visual representation of overlap and dissimilarity in species composition and relative cover for herbaceous plants between test ranges (black labels) and forested sties (green labels) at the site-wide scale. Each code is a unique species identifier (blue labels). Ellipses represent 95% confidence intervals for each habitat type.

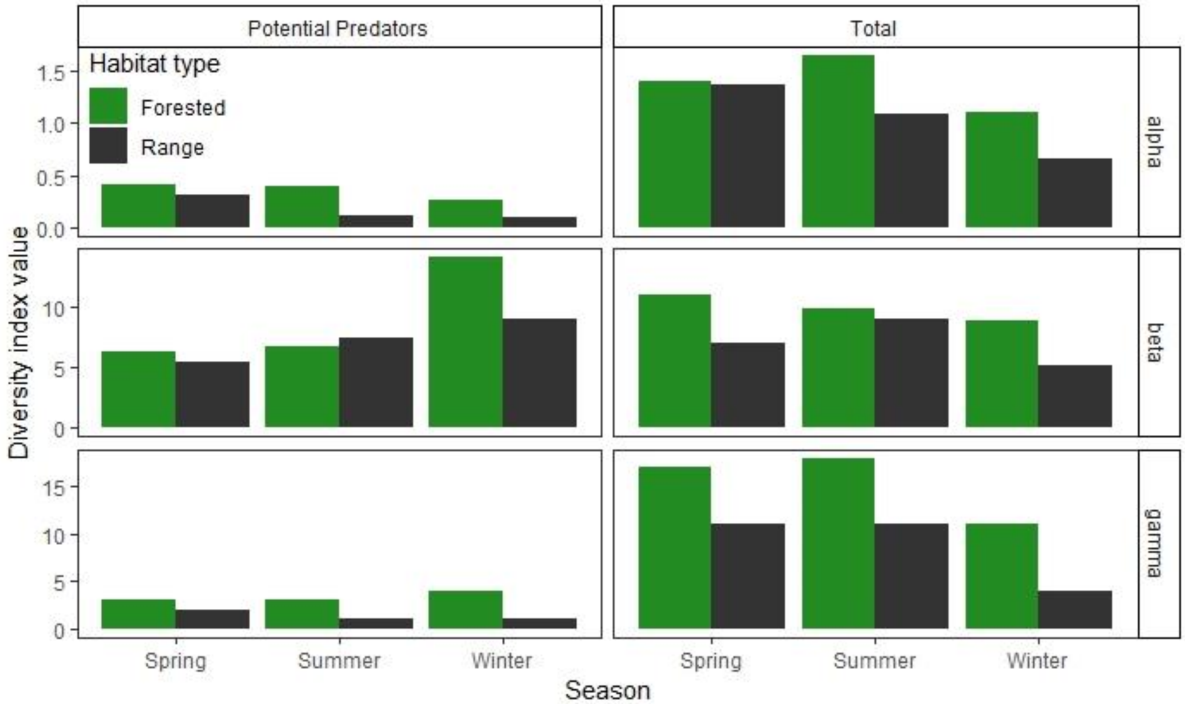

Figure 4. *Diversity indices for commensal species using Gopher Tortoise burrows among habitat types and seasons during year 2 on Eglin Air Force Base*. Diversity indices are shown for both forested (green) and black (test range). Species that are considered potential predators can be found in Table 8.

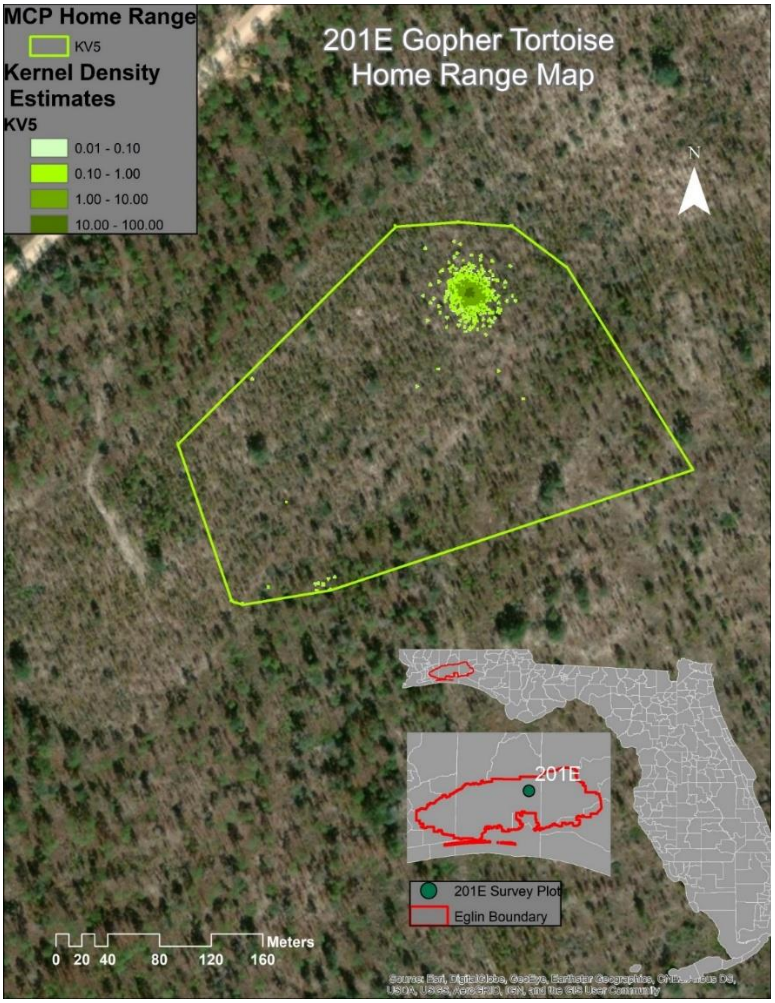

Figure 5. *MCP Home Range Estimate KV5 at site 201E.* MCP home range is represented by an open polygon. Kernel densities representing the number of locations recorded per m^2 are classified on an exponential scale to visualize spatial use and movement within each MCP.

Figure 6. *Mating Attempts.* Two different mating attempts between male tortoises and study tortoises KV5 at forested site 201E (left) and BC3 at forested site Bull Creek (right).

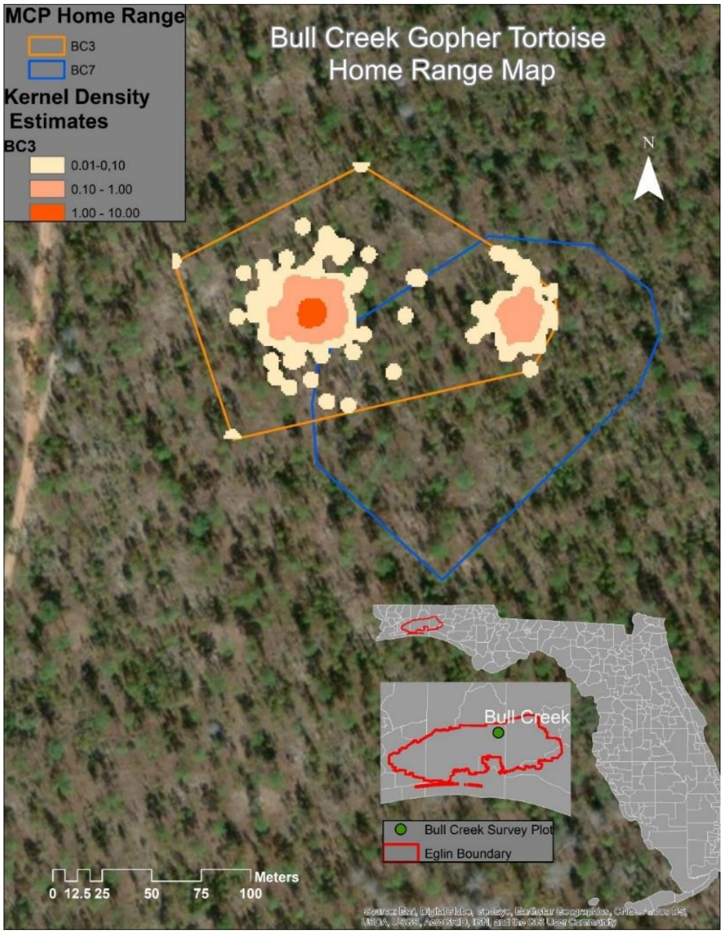

Figure 7. *MCP Home Range Estimates BC3 & BC7.* MCP home range is represented by an open polygon. Kernel densities representing the number of locations recorded per m^2 are classified on an exponential scale to visualize spatial use and movement within each MCP. Due to the large amount of home range overlap making it difficult to visualize on a single map, Home ranges for tortoises BC3 & BC7 are displayed separately.

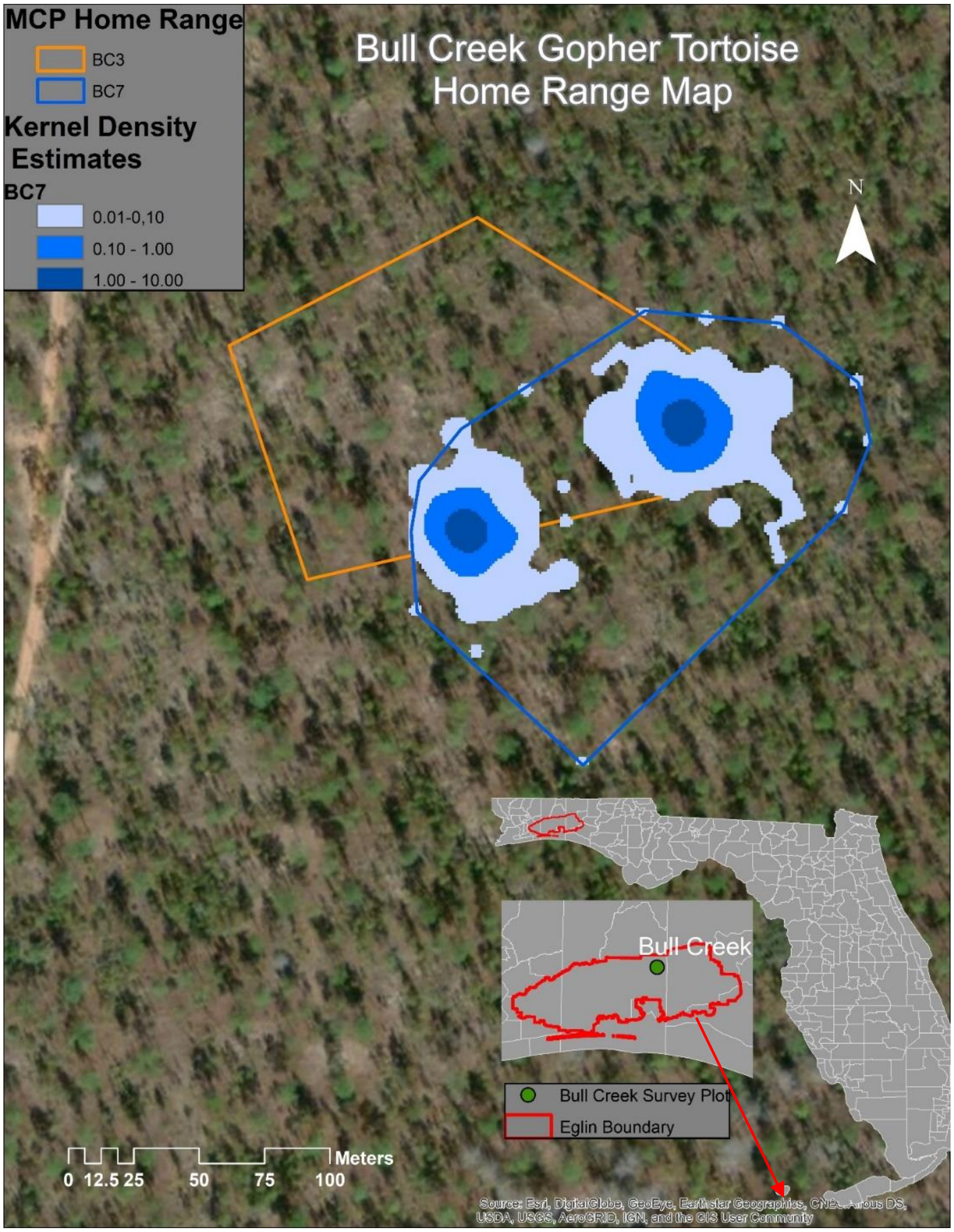

Figure 8. *MCP Home Range Estimates BC3 & BC7.* MCP home range is represented by an open polygon. Kernel densities representing the number of locations recorded per m^2 are classified on an exponential scale to visualize spatial use and movement within each MCP. Due to the large amount of home range overlap making it difficult to visualize on a single map, Home ranges for tortoises BC3 & BC7 are displayed separately.

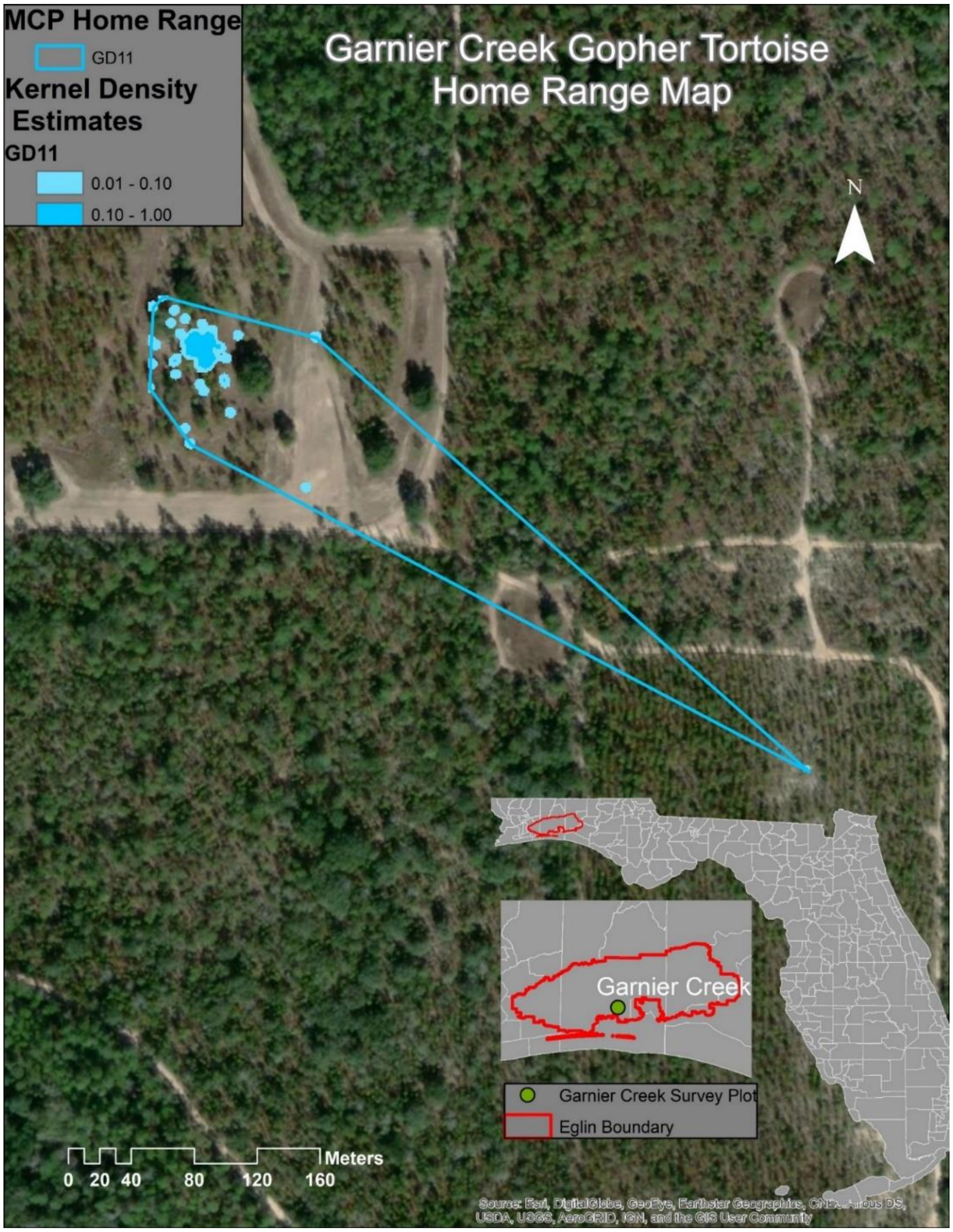

Figure 9. *MCP Home Range Estimate GD11*. MCP home range is represented by an open polygon. Kernel densities representing the number of locations recorded per m^2 are classified on an exponential scale to visualize spatial use and movement within each MCP.

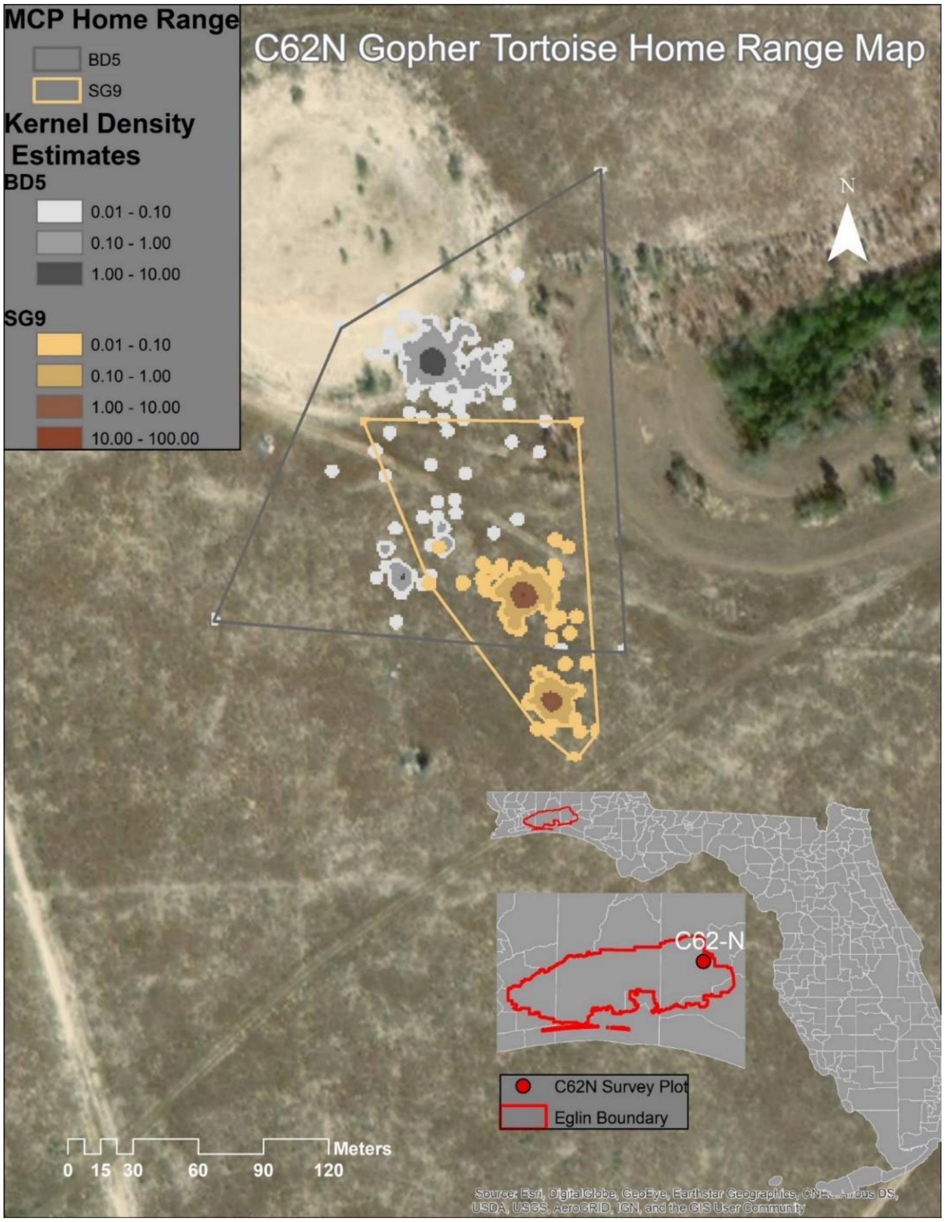

Figure 10. *MCP Home Range Estimates BD5 & SG9.* MCP home range is represented by an open polygon. Kernel densities representing the number of locations recorded per m^2 are classified on an exponential scale to visualize spatial use and movement within each MCP.

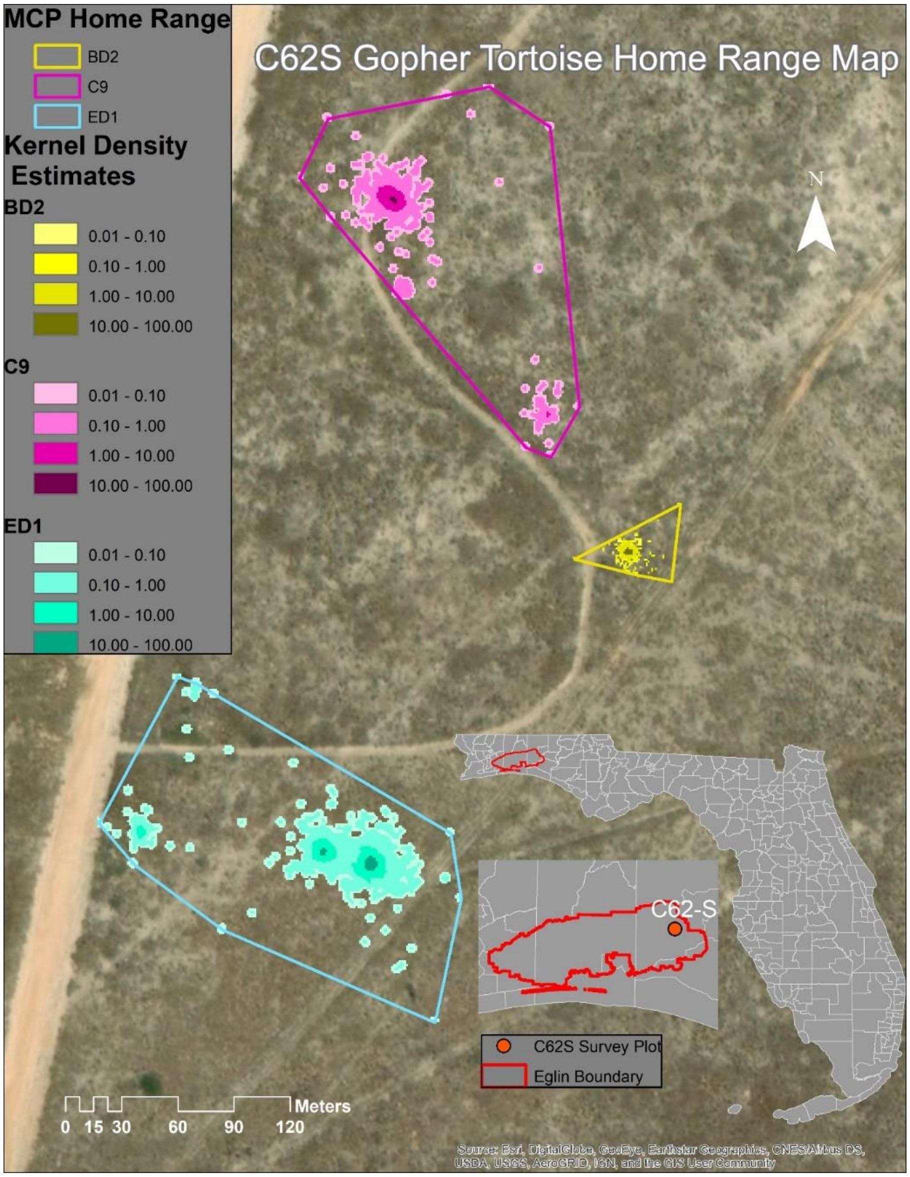

Figure 11. *MCP Home Range Estimates BD2, C9, & ED1.* MCP home range is represented by an open polygon. Kernel densities representing the number of locations recorded per m^2 are classified on an exponential scale to visualize spatial use and movement within each MCP.

Appendix A

Test range management questionnaire distributed to natural resource personnel at military installations where tortoises occur. Actual questionnaire was distributed electronically.

Introduction

All participating natural resource managers are strongly encouraged to return the survey regardless of how many questions may be applicable (**All questions are completely voluntary**, but any feedback will be helpful, even if you're only able to answer one or two questions).

On Eglin Air Force Base, many Gopher Tortoise populations currently reside on expansive military testing and training ranges that are maintained in an open state (i.e. vegetation kept short through some combination of mowing, roller-drum chopping, fire, chemical treatments etc.). The lack of trees and tall shrubs on test ranges creates appealing habitat to Gopher Tortoises and many of these sites appear to support diverse native herbaceous ground cover that tortoises eat. However, tortoise burrow densities, particularly in smaller size classes that suggest recruitment potential, vary significantly among test ranges. Different management practices, both past and present, may at least partially explain differences in burrow densities and vegetation characteristics we currently observe on Eglin.

Therefore, we feel that a broader comprehension of how these unique landscapes are managed on other tortoise-occupied installations could help mitigate future conflicts between military training objectives and Gopher Tortoise conservation goals. This questionnaire, in combination with field work currently being conducted on Eglin as part of DoD Legacy Project 16-818, will be useful in determining common management practices employed to maintain test ranges and other human altered habitats on DoD lands. Ideally, the results of this questionnaire will be used to inform DoD natural resource managers whether test ranges can harbor Gopher Tortoises long-term without impacting training objectives and, if so, what the optimal management strategies are to promote healthy tortoise populations while still maintaining desired conditions for military mission activity. Thank you for your participation.

<u>Name of Respondent:</u>

<u>Properties/Installations Managed:</u>

<u>Contact Info if Follow-up Desired:</u>

Phone: (   )   Email:

<u>Request for Results Summary upon Completion (please check):</u>

_Yes   _No

Gopher Tortoise Habitat Use/Distribution on Installation

1. On the military installation you manage, what habitat types do Gopher Tortoises occupy? (check all that apply)

- ☐ **forested sites** (sandhill, pine savanna, flatwoods, xeric hammock, planted pine, scrub etc.,)
- ☐ **ruderal/disturbed areas** (check all that apply)
  - ☐ **clearcuts**
  - ☐ **power line cuts**
  - ☐ **test ranges/airfields maintained for military training operations**
  - ☐ **road edge/fire break**
  - ☐ **pasture/old field**
- ☐ **other** (please list)

- ☐ **unknown**

Habitat Management Practices Specific to Military Training/Testing Areas

2. What management practices are used to control or remove tall woody vegetation from the military testing and training areas where the tortoises are present?

- ☐ **mechanical** (check all that apply)
  - ☐ mowing
  - ☐ roller-drum chopping
  - ☐ chainsawing
  - ☐ logging
- ☐ **herbicide**
- ☐ **fire** (check all that apply)
  - ☐ prescribed burning
  - ☐ incidental (live fire, incendiary devices, lightning)
- ☐ **none**
- ☐ **other** (please list)

- ☐ **N/A**

3. If prescribed fire is used to manage testing or training areas and/or incidental fires are allowed to burn, what seasons do these sites typically burn? How frequently?

4. Are any management practices used specifically to improve/maintain Gopher Tortoise habitat (or habitat for threatened species, e.g. red cockaded woodpeckers) in testing or training areas?

- ☐ **yes** (if so, please list)

- ☐ **no**
- ☐ **N/A**

5.. What general military training/testing activities occur in the habitats occupied by Gopher Tortoises? (check all that apply)

- ☐ **tactical land vehicle use**
- ☐ **bivouacs**
- ☐ **live fire/incendiary exercises**
- ☐ **other** (please list)

- ☐ **none**
- ☐ **N/A**

6. If possible, please briefly comment on the frequency and variability in the application of any management practices used to maintain test ranges managed primarily for military training operations (e.g. are management practices used to suppress tall, woody vegetation fairly uniform among test ranges or do they vary widely in frequency within or among ranges and depending on mission purpose?).

Habitat Management Practices Specific to Other Ruderal/Disturbed Areas

7. What management practices are used to control or remove tall woody vegetation within disturbed/ruderal areas such as clearcuts, old fields, pastures or powerline cuts?

- ☐ **mechanical** (check all that apply)
    - ☐ mowing
    - ☐ roller-drum chopping
    - ☐ chainsawing
    - ☐ logging
- ☐ **herbicide**
- ☐ **fire** (check all that apply)
    - ☐ prescribed burning
    - ☐ incidental (live fire, incendiary devices, lightning)
- ☐ **other** (please list)

- ☐ **none**
- ☐ **N/A**

8. If prescribed fire is used to manage disturbed/ruderal areas, please comment on month/season/frequency of burns.

9. Are any management practices used specifically to improve/maintain Gopher Tortoise habitat within disturbed/ruderal areas such as clearcuts, old field, pastures or powerline right of ways?

- ☐ **yes (if so, please list)**

- ☐ **no**
- ☐ **N/A**

10. If possible, please briefly comment on the frequency and variability in the application of any management practices used to maintain disturbed/ruderal areas such as clearcuts, old field, pastures or powerline right of ways (e.g. are the management practices used to suppress tall, woody vegetation fairly uniform for most ruderal/disturbed areas or do they vary widely over time and from one site to the next?)

Comments and Suggestions

11. Please use the space below for additional comments, suggestions and to clarify or elaborate on any responses.