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Bat Diversity and Activity: A Comparison Among Texas Army National Guard Sites

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Abstract

Five Texas Army National Guard training sites (Camp Maxey, Fort Wolters, Camp Swift, Camp Bowie, and Camp Mabry) were surveyed for bats using mist nets and Anabat units during spring, summer, and fall from October 2005 to November 2006. A total of seven species, *Lasiurus borealis*, *L. cinereus*, *L. seminolus*, *Myotis velifer*, *Nycticeius humeralis*, *Perimyotis subflavus*, and *Tadarida brasiliensis*, were documented across all five sites. Based on mist net captures, Camp Maxey had the highest species diversity (five species documented) whereas Camp Swift and Camp Mabry had the lowest (one species documented at each site). The capture of *L. seminolus* and *L. cinereus* represent county records for Lamar County (Camp Maxey) and the capture of *T. brasiliensis* was a county record for Parker County (Fort Wolters). Species occurrence was also recorded at each site using acoustic monitoring. Canonical correspondence analysis of acoustic data revealed no impact due to training on the bat communities.

Key words: Anabat, bat diversity, Chiroptera, National Guard, survey, Texas

Introduction

Five Texas Army National Guard training sites (Camp Maxey, Fort Wolters, Camp Swift, Camp Bowie, and Camp Mabry) were surveyed for bats using mist nets and Anabat (Titley Electronics, Australia) units during spring, summer, and fall from October 2005 to November 2006. The training sites are located in different vegetational areas of Texas. Camp Maxey (Lamar Co.) is in the Post Oak/Blackland Prairie region, Fort Wolters (Parker Co.) is in the Cross Timbers and Prairies, Camp Swift (Bastrop Co.) is located in the Blackland Prairie region, but nearby is a small area of relict pine forest (the "Lost Pines"), Camp Bowie (Brown Co.) is in the Rolling Plains, and Camp Mabry (Travis Co.) is in the Edwards Plateau. Because of the diverse plant communities and habitats at each of these properties, different species of bats are expected to use these sites for foraging and roosting activities.

Previous survey work using mist nets documented three bat species at Camp Maxey (Edwards and Johnson 2007), two at Fort Wolters (Thies 2004b), and three at Camp Bowie (Dowler et al. 2004). No bats were captured by Thies (2004a) at Camp Swift or at Camp Mabry (McDonough et al. 2005). According to Schmidly (2004), there are as many as 9-10 species expected to occur at each of the sites. In this study, we employed traditional mist-netting techniques as well as acoustic monitoring to assess bat diversity at each site.

The five sites differ in overall size, amount of improved grounds, amount of water present, and biotic communities. Additionally, the sites differ in frequency and intensity of National Guard training activities that may affect bat foraging activity. To better understand the relationship between observed bat assemblages and environmental variables, a canonical correspondence analysis (CCA) was performed. A CCA is a multivariate statistical tool used in community ecology to examine relationships between environmental variables and species data (ter Braak and Smilauer 1998). This technique is used most often when ample environmental data are available. Previous mammal studies that have used this technique include the relationships of: bat assemblages and vegetation in Paraguay (López-Gonzalez 2004); mammal abundance relative to vegetation, soil, and slope (Brant and Dowler 2001); and moth communities versus vegetation and geography (Ober 2006).

The objective of this project was to determine the bat species richness and abundance at each training site and identify relationships between the relative abundance of species and the environmental variables associated with each of the sites.

Methods

Sampling methods.—We employed mist nets, harp traps, and acoustic monitoring to survey the bat community at all five Texas Army National Guard training sites. Bats were captured in mist nets or harp traps placed in flyways (trails, paths, creeks, dirt roads) and over water sources as recommended by Kunz (1988). Water sources (small lakes) that were too large to use capture devices were sampled acoustically. Sites were selected to represent the major habitat types present on the area. Sampling sites were also selected to minimize interference of our sampling with National Guard activities. Localities of all sampling sites were recorded with a handheld global positioning system (GPS) using Universal Transverse Mercator (UTM) North American Datum of 1983 (NAD 83) coordinates. Searches for potential roost sites were also conducted to completely assess bat diversity at a site.

Bats that were captured were identified, sexed, aged, and measured. Some voucher specimens (Appendix I) were collected from each site, but all other bats were released at the site. Specimens (skin, skull, and tissues) were prepared and deposited in the Angelo State Natural History Collection. Relative abundance of bat species was assessed using capture data. Abundance based on captures was estimated for each site by the number of individuals captured per net hour (one "net hour" is equal to one net open for one hour).

The Anabat Detection System, which consisted of a bat detector and CF (compact flash) storage ZCAIM (Zero-Crossings Analysis Interface Module), was used to acoustically record bat echolocation calls at selected sampling sites. The Anabat system was placed at an approximate 45° angle from the ground facing over a water source or flyway. Two Anabat systems were used in a night; one unit placed over the site where bats were captured and another unit placed at another location distant from the net. Call files were recorded to the compact flash card contained within the CF storage ZCAIM. Call files were downloaded from the CF card using the CFCread ZCAIM interface software (Corben 2006, http://users.lmi.net/corben/anabat.htm#Technical_Notes). Call files were labeled with date and locality information and analyzed to species using the AnalookW software (Corben 2006, http://users.lmi.net/corben/anabat.htm#Technical_Notes). Call files were screened visually to remove files of non-bat calls, so that only suitable bat calls remained. Call files were compared to libraries of known bat reference calls and assigned to species. When a single species could not be deciphered from the call, these calls were assigned to species-group categories. This was possible only when clear calls were recorded and only with certain species. Fragmented and unclear calls were assigned as "unknown." Each group, whether single species or species group, was considered a different phonic group for the calculation of species activity. Relative activity based on acoustic data was calculated based on the number of bat "passes" per unit time. These data could not be used to estimate relative abundance of species because individual bats might be detected multiple times.

Each training center was surveyed 4-6 times over the approximate course of a year (October 2005-November 2006) to determine seasonal occurrence of bat species. Camp Maxey was the only site sampled in the winter because of its high diversity and likelihood of obtaining information on winter activity which is lacking in many bat species (Boyles et al. 2006). Each visit lasted two nights and sampling was conducted from sunset to sunrise.

Canonical Correspondence Analysis.—A total of 25 environmental variables (Appendix II) and nine phonic groups were included in the CCA of the five National Guard training sites using CANOCO V4.0 (ter Braak and Smilauer 1998). CCA can help identify relationships between the observed bat assemblages and environmental variables that might influence bat activity such as amount of water, insect diversity, proportion of improved grounds, and intensity of training activities.

Training impact was measured as the number of man-days of training activities at each site from September 2005 to September 2006. The acoustic data (number of passes for each phonic group) for each training site was divided by the number of survey nights to eliminate uneven sampling and then log-transformed to account for the high values that could potentially influence the ordination. For example, some sites had inflated call activity that might be due to multiple passes by a few bats. Training impact could not be estimated for Camp Mabry because this site serves as the headquarters and the primary activity is indoor office/classroom work and is not outdoor training activity. Because Camp Mabry had no training impact or training acres estimated, we ran 2 separate CCA analyses – one that included Camp Mabry and one without – to evaluate the effect.

RESULTS

Survey Results for Camp Maxey.—Camp Maxey is a 2,600-ha site in Lamar County of northeastern Texas located just south of Pat Mayse Lake. Habitat on Camp Maxey falls in the Northern Post Oak Savannah between the Northern Blackland Prairie and Red River Bottomlands ecoregions of Texas. Plant communities present include Post Oak-Black Hickory woodlands, Shortleaf Pine forests and savanna, Little Bluestem-Indiangrass grasslands, and Water Oak-Willow Oak riparian forests (Farquhar et al. 1996; Wolfe et al. 1996; Hunter 2005).

This site had the highest bat species diversity. A total of nine sites were sampled within training areas II, IV, V, VI, and VII of the Camp Maxey training center (Fig. 1). Five sites were sampled with mist-netting and acoustic monitoring and four sites were sampled only by acoustic monitoring. Mist nets were monitored for a total of 667 net hours and resulted in 83 captures of five species: *Lasiurus borealis* (eastern red bat) (n=45), *Nycticeius humeralis* (evening bat) (n=32), *Perimyotis subflavus* (eastern pipistrelle) (n=4), *Lasiurus cinereus* (hoary bat) (n=1), and *Lasiurus seminolus* (Seminole bat) (n=1). The predominant species were *L. borealis* and *N. humeralis*. The capture of *L. seminolus* and *L. cinereus* were the first documented individuals in Lamar County. In addition, the capture of *L. seminolus* represented the most northern record in Texas. *Nycticeius humeralis* was the most abundant species during the spring sampling period and *L. borealis* was most abundant during the summer (Fig. 2).

Capture activity at Camp Maxey dropped off in June (n=8) as opposed to the preceding month (May, n=22) and the following two months (July, n=28; August n=24). Only two bats were captured in October (*L. borealis* and *N. humeralis*). Higher capture rates in May and July can be attributed to a single pond (15 S 262282 E 3742719 N) in training area IV that was surveyed during those months and not in June rather than other environmental factors such as lunar illumination. This particular pond when surveyed produced

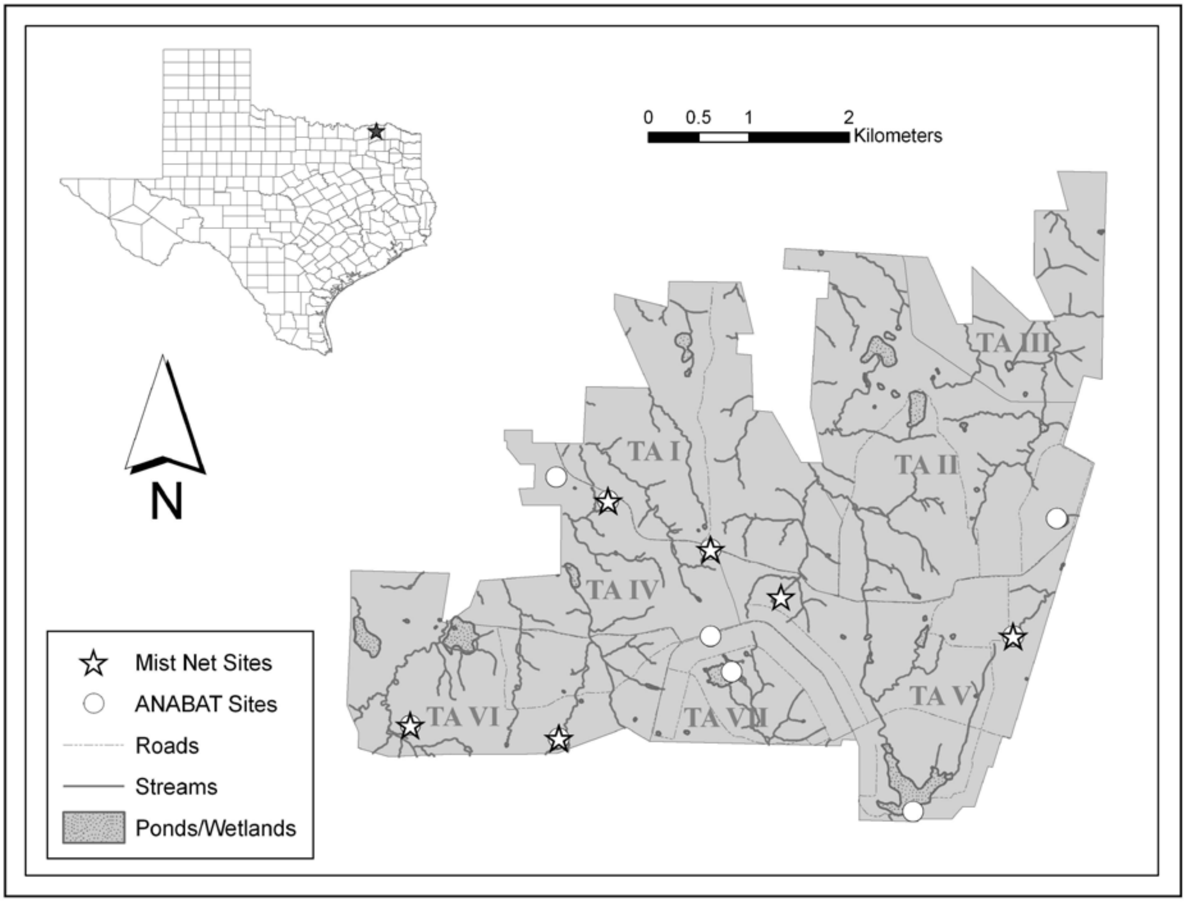


Figure 1. Location of sampling sites at Camp Maxey (Lamar County). Stars represent sites sampled by mist net; circles represent sites that were sampled acoustically. TA=training area.

higher captures and exhibited the majority of the overall captures (n=58, 70%). Interestingly, all species found in Camp Maxey were captured at this pond.

A total of 5,951 call files were recorded and designated into nine classes: LABO (*L. borealis*), LABOPISU (*L. borealis*/*P. subflavus*), LACI (*L. cinereus*), LAsp (*Lasiurus* sp.), NYHU (*N. humeralis*), NYHULABO (*N. humeralis*/*L. borealis*), NYHUPISU (*N. humeralis*/*P. subflavus*), PISU (*P. subflavus*), and UNKNOWN (Fig. 3). LABO calls constituted the majority of calls with NYHULABO calls being the second most recorded. Although *N. humeralis* represented 39% (n=32) of the captures, very few identifiable NYHU calls were recorded (n=375, 6%). This can be the result of a large number of *N. humeralis* calls being indistinguishable from *L. borealis* calls resulting in 1,372 calls (23%) being classified as NYHULABO. A large number of calls were recorded for *P. subflavus* (n=760), thus indicating that *P. subflavus* may be more numerous within the training center area compared to the few captures (n=4) that were made. Few calls were recognized for *L. cinereus* (n=42) and no calls were recognized for *L. seminolus*. A number of *L. cinereus* and *L. seminolus* calls could be contained within the call classification LAsp (n=390). With the presence of three species of *Lasiurus*, call identification can become difficult with much overlap among species. The case can be more so for *L. borealis* and *L. seminolus*, which have similar body sizes; total length = 108 mm and forearm = 40 mm for *L. borealis* and total length = 103 mm and forearm = 39 mm for *L. seminolus* (Schmidly 2004). Congeneric bat species that are similar in size tend to have a high degree of call similarities (Bogdanowicz et al. 1999). *Lasiurus cinereus* generally has a call repertoire that is lower in frequency than *L. borealis* and *L. seminolus*, but during times when *L. cinereus* produces higher frequency calls, confusion can occur with the two former species.

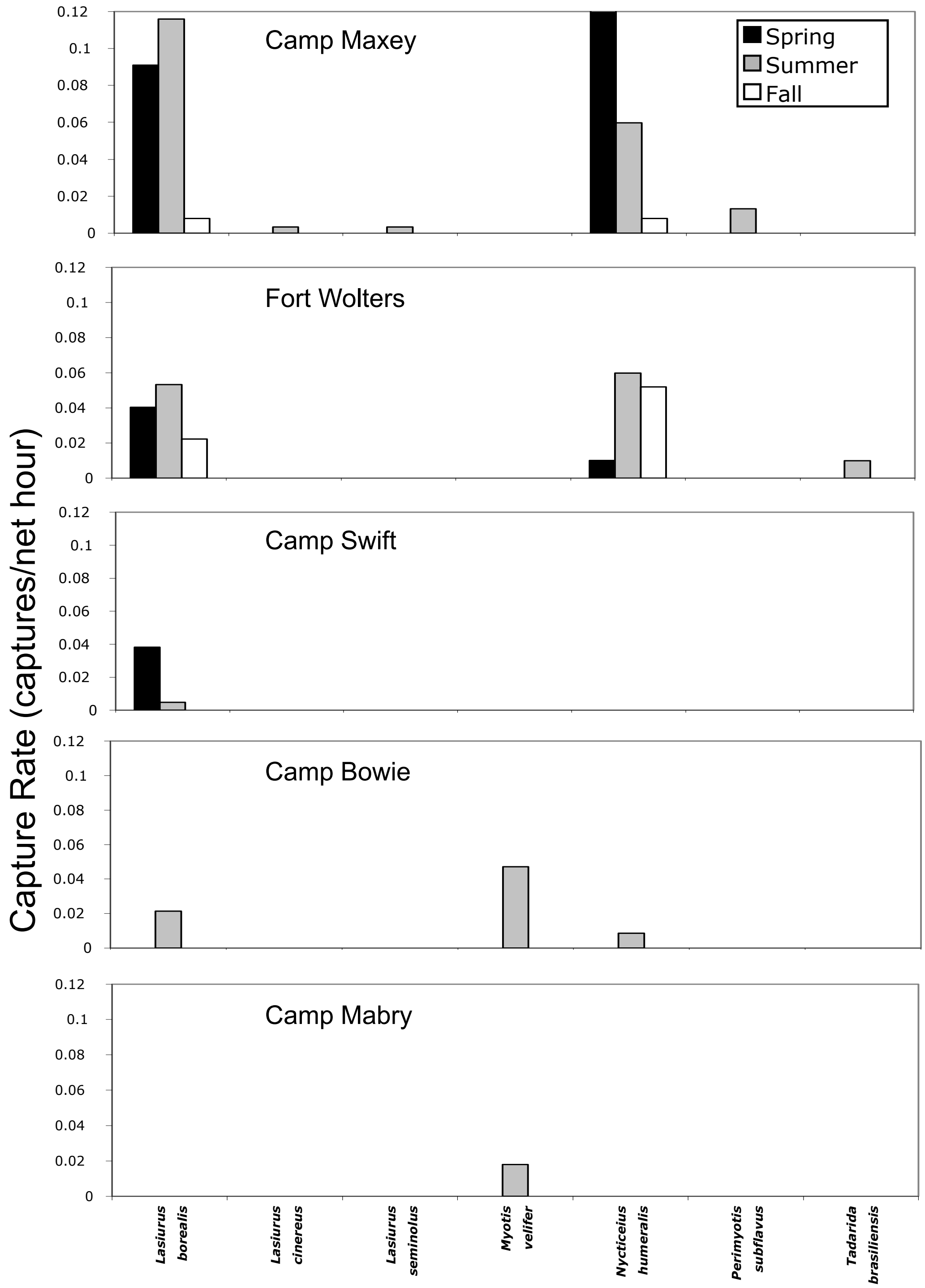


Figure 2. Capture rates of bats at Texas Army National Guard training sites in spring, summer, and fall (2005-2006).

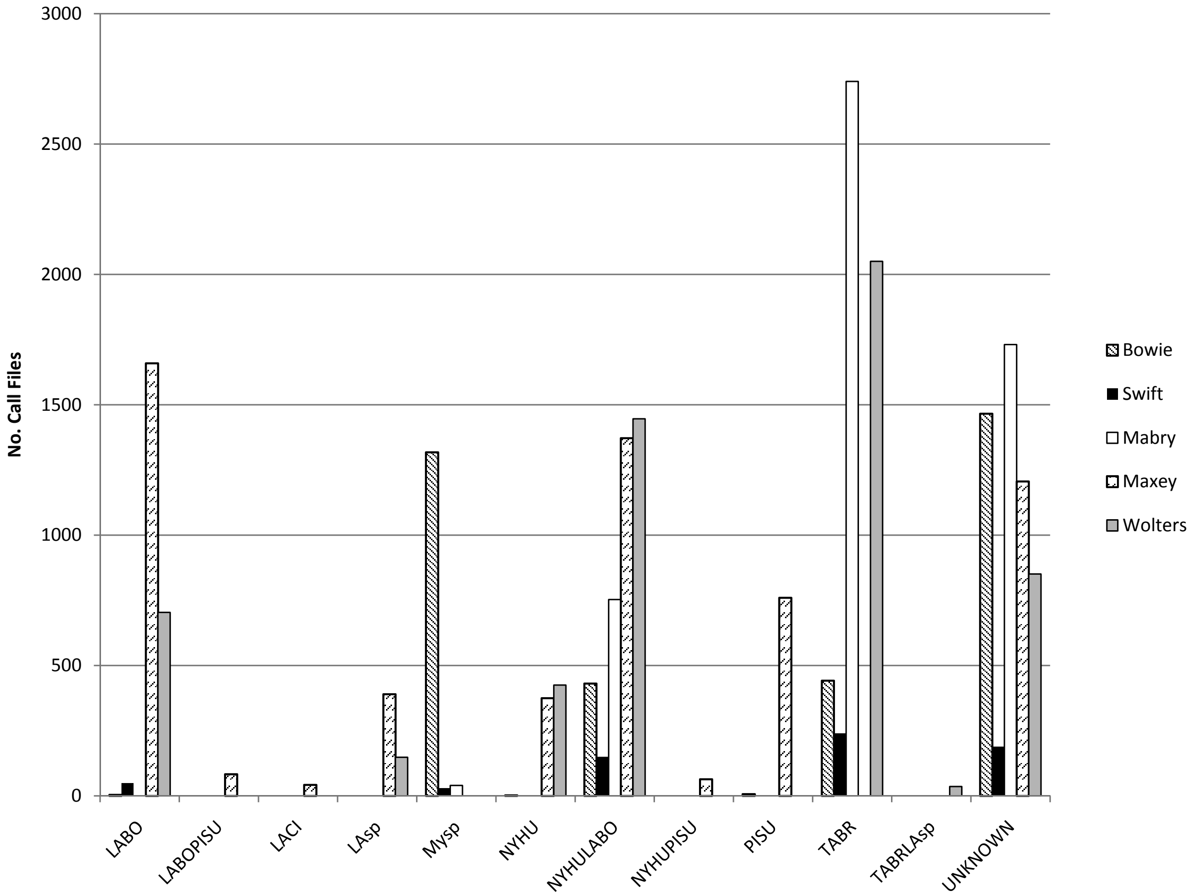


Figure 3. Phonic groups identified using Anabat for bats at Texas Army National Guard training sites. LABO=*Lasiurus borealis*, LACI=*Lasiurus cinereus*, LAsp=*Lasiurus* species, MYsp=*Myotis* species, NYHU=*Nycticeius humeralis*, PISU=*Perimyotis subflavus*, and TABR=*Tadarida brasiliensis*.

Call activity showed an increase from spring to the summer months, yet call activity peaked in June (Fig. 4). While more calls were recorded in June (n=1990) than in July (n=1478), more captures were made in July (n=28) versus June (n=8). The higher number of captures in July are likely because sampling at a pond (15 S 262282 E 3742719 N) in training area IV during this month resulted in the most captures of all sites surveyed at Camp Maxey. Bats may be more easily caught at this pond versus other sites. Also, the bat activity (based upon acoustic monitoring) at the sites surveyed in June may have been higher, yet these sites did not facilitate the capture of bats. There was a single call recorded in December (NYHULABO).

Survey Results for Fort Wolters.—Fort Wolters is a 1,614-ha site located in Parker and Palo Pinto counties in north-central Texas near Lake Mineral Wells State Park at the transition between the Oak Woods and Prairies and Blackland Prairies natural regions of Texas in an ecoregion called the Western Cross Timbers. Plant communities present include Post Oak-Blackjack Oak Woodland, Ashe Juniper-Oak Woodland, Little Bluestem-Indiangrass Grassland and Sugar Hackberry-Elm Riparian Woodlands (Farquhar et al. 1996; Wolfe et al. 1996; Hunter 2005).

A total of seven sites were sampled within training areas Ia, II, IIIa, IIIb, IV, and VI of the Fort Wolters

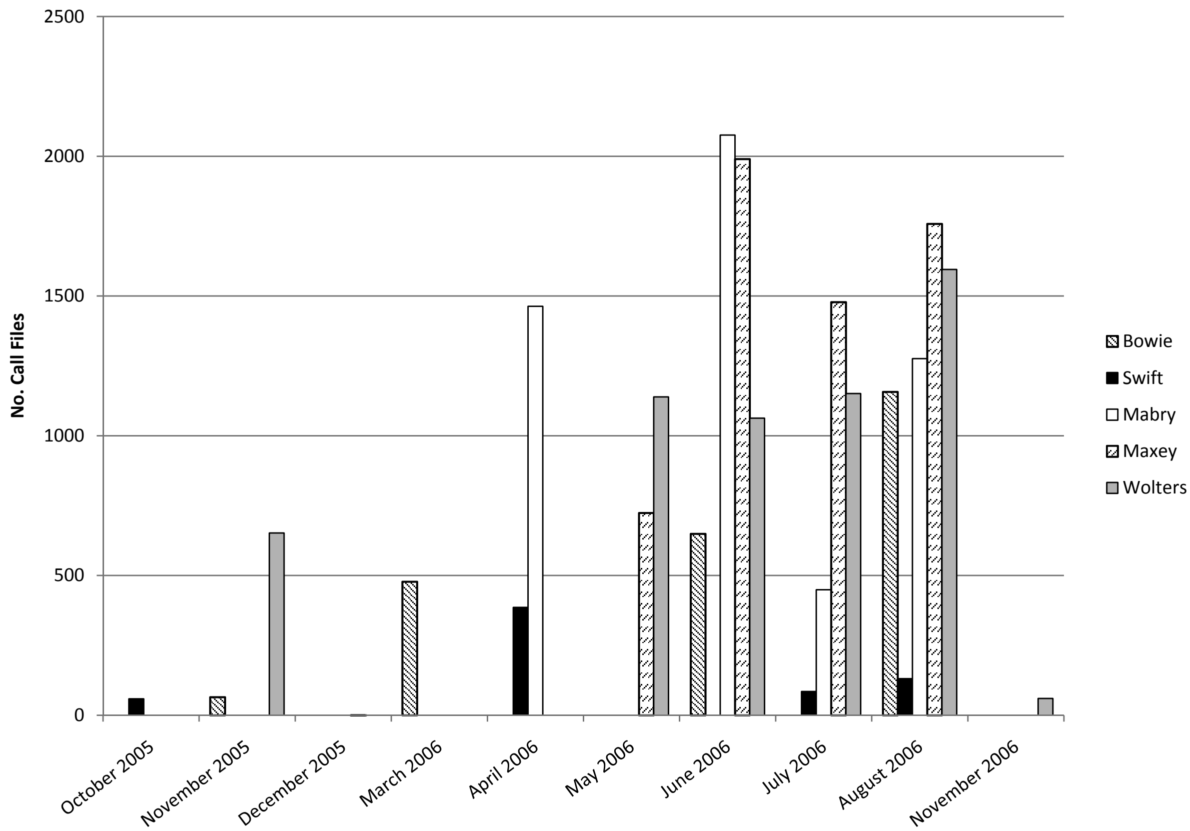


Figure 4. Monthly distribution of call files recorded at Texas Army National Guard training sites in 2005-2006.

training center (Fig. 5). Five sites were sampled with mist-netting and acoustic monitoring and two sites were sampled only by acoustic monitoring. Mist nets were monitored for a total of 534 net hours and resulted in 52 captures of three species: *Lasiurus borealis* (n=23), *Nycticeius humeralis* (n=26), and *Tadarida brasiliensis* (Brazilian free-tailed bat) (n=3).

The rate of captures varied throughout the year with captures peaking in mid-summer (10 captures in November 2005, 5 captures in May 2006, 14 captures in June 2006, 22 captures in July 2006, 1 capture in August 2006, and 0 captures in November 2006). This fluctuation in activity is likely due to the particular ponds surveyed during that time. For instance, a pond (14 S 589651 E 3637414 N) in training area IIIa which produced the most captures overall (n=27, 52%) was surveyed in November 2005, June 2006, and July 2006, but not in May 2006 or August 2006. This specific pond appears to facilitate the captures of bats over other ponds, thus demonstrating higher capture rates during those months when it was surveyed. Overall, *L. borealis* and *N. humeralis* were captured in approximately equal frequency. However, more *N. humeralis* were captured in the summer and fall while more *L. borealis* were captured in the spring (Fig. 2).

A total of 5,660 call files were recorded among seven sites within the Fort Wolters training center designated into seven classes: LABO (*L. borealis*), LAsp (*Lasiurus* sp.), NYHU (*N. humeralis*), NYHULABO (*N. humeralis*/*L. borealis*), TABR (*T. brasiliensis*), TABRLAsp (*T. brasiliensis*/*Lasiurus* sp.) and UNKNOWN (Fig. 3). Although very few *T. brasiliensis* (n=3) were caught, they constituted the most calls recorded. *Tadarida brasiliensis,* being a less maneuverable but fast flying bat, requires large, open pools of water in order to drink (Norberg and Rayner 1987). Thus, a pond located within training area Ia (14 S 587901 E 3635242 N) presented an adequate source in which to

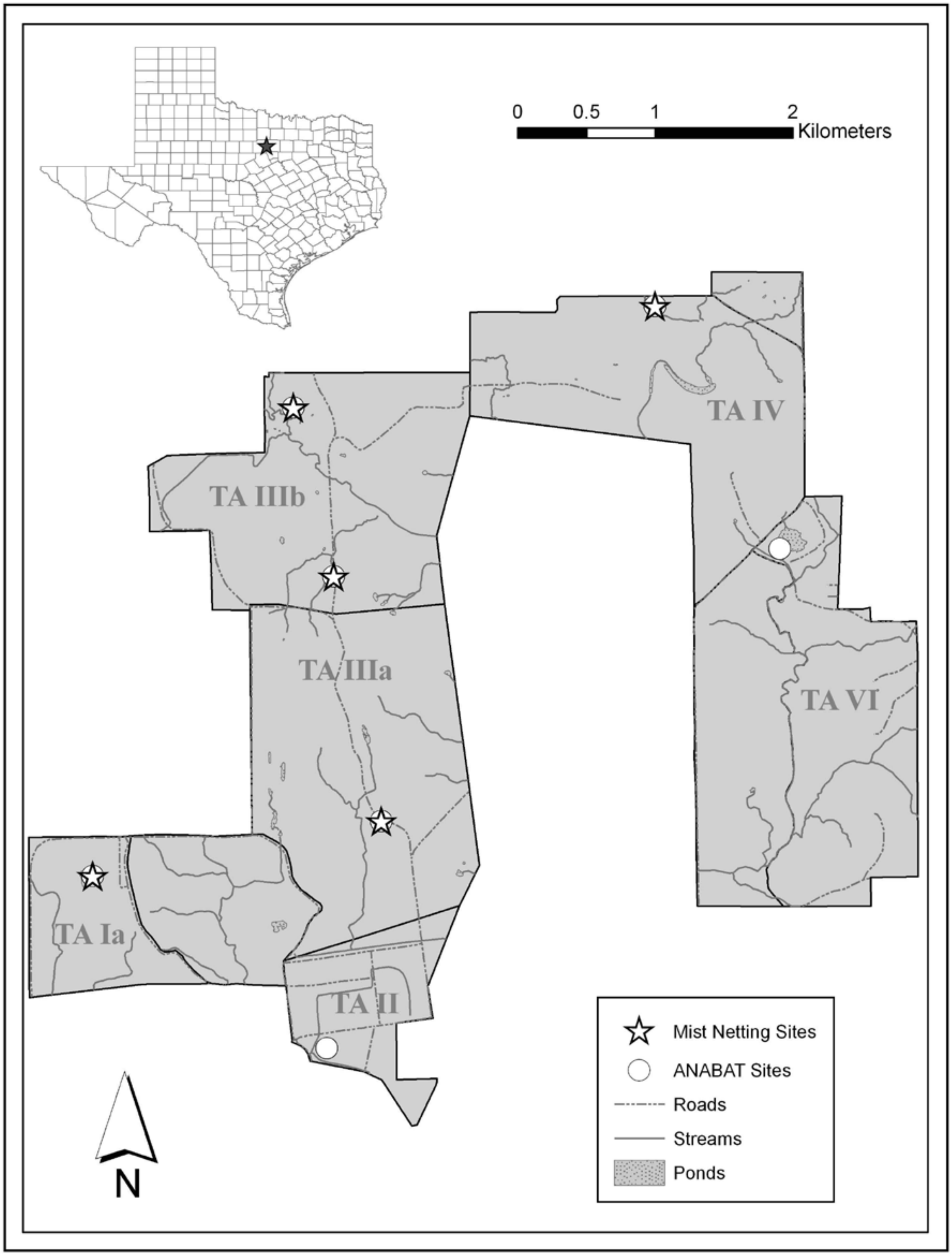


Figure 5. Location of sampling sites at Fort Wolters (Parker County). Stars represent sites sampled by mist net; circles represent sites that were sampled acoustically. TA=training area.

catch the three individuals of *T. brasiliensis* that represent a first record for Parker County. Few calls were classified as *T. brasiliensis*/*Lasiurus* sp. (n=36), which is indicative of the presence of *L. cinereus* because *T. brasiliensis* and *L. cinereus* calls often can be confused. Also, a number of calls were identified as *Lasiurus* sp. (n=148) leading to the possibility of other *Lasiurus* species being present in addition to *L. borealis*. No calls were found to strongly resemble *L. cinereus* calls and a capture of *L. cinereus* was not made. *Lasiurus borealis* and *N. humeralis* exhibited similar activity by captures (n=23 and n=26, respectively), yet call activity varied (n=704 and n=425, respectively). Some of the discrepancy observed might be accounted for by the large number of calls that were classified as either *N. humeralis* or *L. borealis* (NYHULABO, n=1446). The lack of *Myotis* calls at this site was unexpected and may possibly be a result of placement of Anabat units in more open areas.

Call activity increased from fall 2005 (November) to spring and summer months of 2006 with peak activity in August 2006 (Fig. 4). During the summer months, overall call activity in June (n=1,063) and July (n=1,151) was approximately equal. However, considerably more captures were made in July (n=28) versus June (n=8). The higher number of captures in July primarily are attributable to captures at a pond in training area Ia (14 S 587901 E 3635242 N), which was the site with the most captures of any surveyed. One interesting result is the comparison of activity between November 2005 and November 2006 in which surveys were conducted around the same time of the month (11-12 November 2005 and 10-11 November 2006). Higher capture and call activity was found in November 2005 (n=10 and n=652, respectively) in contrast to November 2006 (n=0 and n=60, respectively) (Fig. 4). These vast differences in activity levels can be attributed to a notable disparity in temperature for the two survey periods. When looking at archived temperature data (Miami Herald 2007) the two nights surveyed during November 2005 (20.11°C and 18.06°C, respectively) showed an average of 11 degrees higher than the two nights surveyed during November 2006 (9.83°C and 6.06°C, respectively).

Survey Results for Camp Swift.—Camp Swift is a 4,718-ha site located in Bastrop County in central Texas and is located within the Southern Post Oak Savannah between the Northern Blackland Prairie and Bastrop Lost Pines ecoregions of Texas. Plant communities present include Oak-Eastern Red Cedar Forest, Little Bluestem-Indiangrass Grassland, Green Ash–American Elm Riparian Forest, and Loblolly Pine Forest (Wolfe et al. 1996; Fischer and Senseman 2003; Williams 2003).

A total of nine sites were sampled at the Camp Swift training center (Fig. 6). Four sites were sampled with both mist nets and Anabat, four sites were sampled with Anabat only, and one site was sampled with mist nets alone. Mist nets were monitored for a total of 431 net hours and resulted in five captures of a single species, *Lasiurus borealis* (Fig. 2). Four individuals were captured in April (two males, two pregnant females) and one in July (juvenile). This site had the lowest netting success of all of the training sites. Most captures occurred at Long Skinny Pond.

Camp Swift had the lowest call activity of all five sites. A total of 661 call files were recorded with most of the call activity in April (Fig. 3). The dominant call activity in April (59% of calls) was *T. brasiliensis*, but none were captured in nets. The highest call activity in summer was the NYHULABO phonic group (Fig. 4). Although it is possible that *N. humeralis* and *P. subflavus* are present at Camp Swift, no captures were made and no undisputed call files were scored.

Survey Results for Camp Bowie.—Camp Bowie is a 3,542-ha site located in Brown County in west-central Texas at the transition between the Western Cross Timbers and Limestone Plains ecoregions. Plant communities present include: Plateau Live Oak-Midgrass Woodland, Post Oak-Blackjack Oak Woodlands, Texas Oak Woodlands, American Elm-Cedar Elm Woodlands, Pecan-Sugarberry Woodlands, Ashe Juniper-Oak Woodlands, Ashe Juniper Woodlands, Mesquite Woodlands and Forests, and Sideoats Grama–Little Bluestem Grasslands (Wolfe et al. 1996; Fischer and Senseman 2003).

A total of five different sites were sampled at Camp Bowie training center (Fig. 7) with mist-netting and acoustic monitoring. Mist nets were monitored for a total of 428 net hours and resulted in 18 captures of three species. *Myotis velifer* (cave myotis) was captured most often (n=11), followed by five *L. borealis*

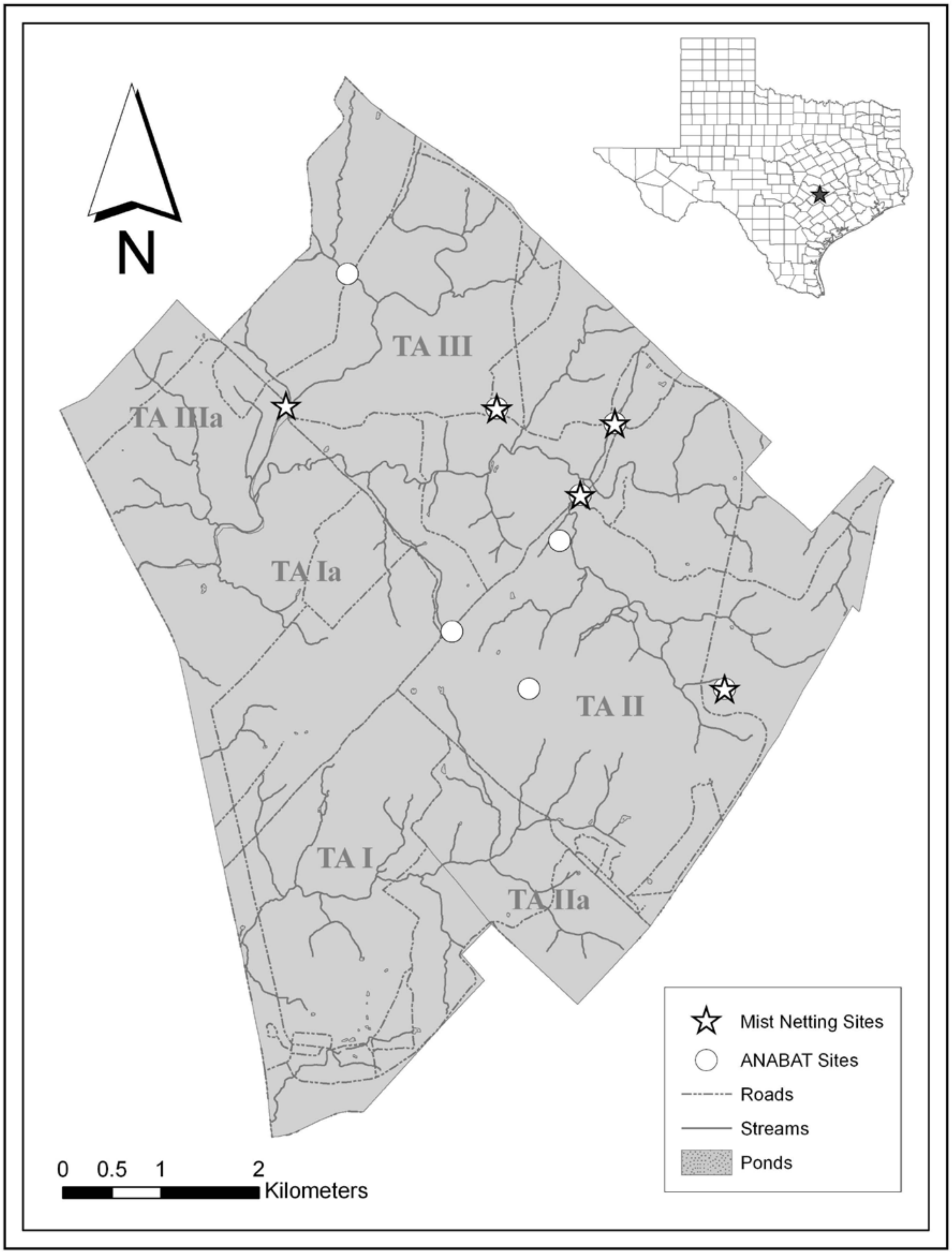


Figure 6. Location of sampling sites at Camp Swift (Bastrop County). Stars represent sites sampled by mist net; circles represent sites that were sampled acoustically. TA=training area.

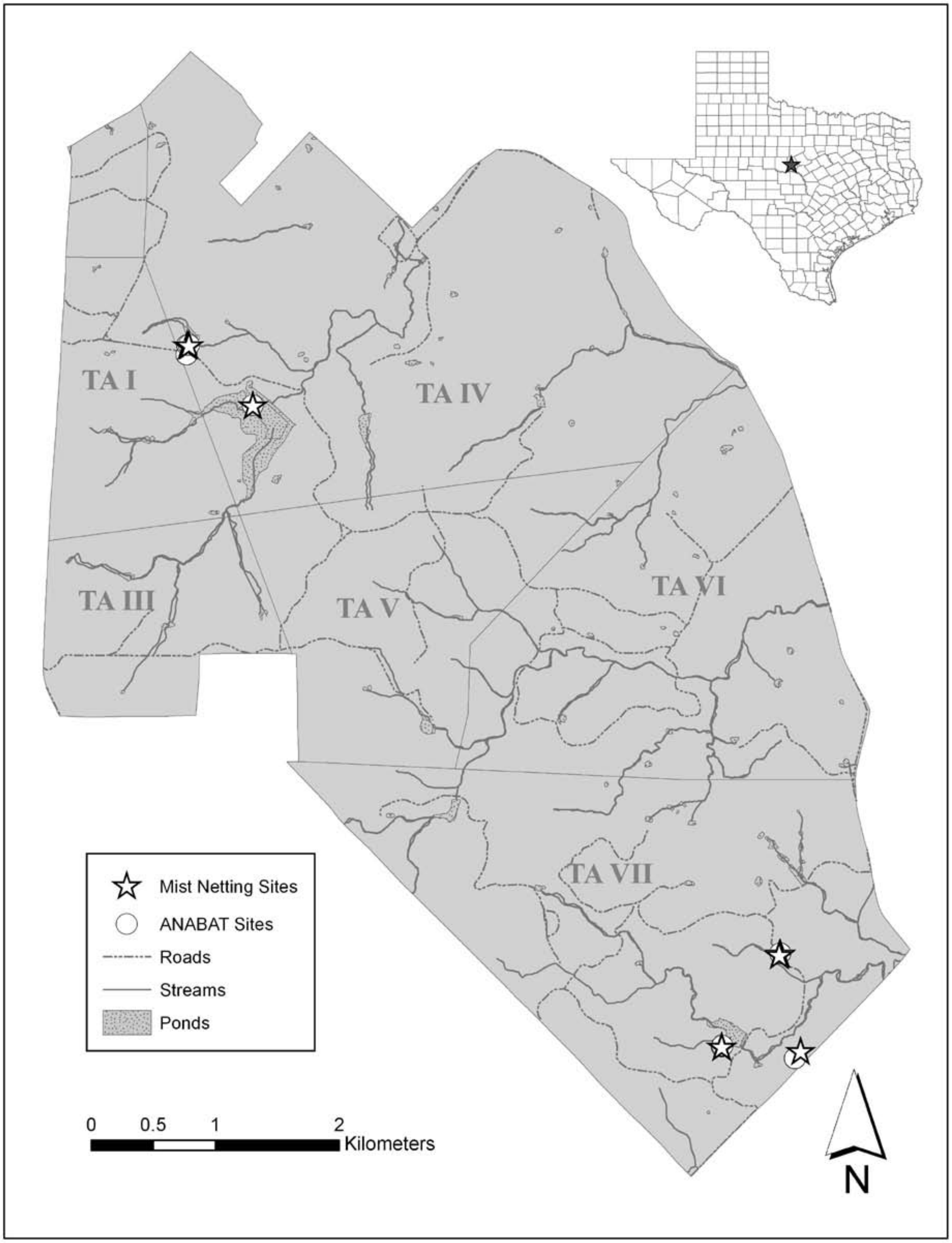


Figure 7. Location of sampling sites at Camp Bowie (Brown County). Stars represent sites sampled by mist net; circles represent sites that were sampled acoustically. TA=training area.

and two *N. humeralis* (Fig. 2). All captures were made in the summer months. A total of five sampling nights resulted in no bat captures.

A total of 3,658 call files were recorded at Camp Bowie. The dominant activity (33% of calls) was identified as *Myotis* species (Fig. 3). *T. brasiliensis* and NYHULABO phonic groups were each approximately 10% of all calls recorded. There were no *T. brasiliensis* captured in mist nets. The highest call activity at Camp Bowie was in August and the lowest in November (Fig. 4).

Survey Results for Camp Mabry.—Camp Mabry is an urban, 152-ha facility in central Austin, Travis County, that serves as headquarters for the Texas Military Forces and as a Texas Army National Guard Training Site. Camp Mabry is located on the Balcones Escarpment on the transition from Northern Blackland Prairie to Balcones Canyonlands ecoregions. The plant associations are classified as Live Oak Savannah, Ashe Juniper-Oak Woodlands, Ash-Elm Woodlands, Hackberry-Elm Woodlands, Willow-Hackberry Elm Woodlands, Non-native plants on fill soil, and disturbed Bermuda Grasslands (Farquhar et al. 1996; Wolfe et al. 1996).

A total of 17 sites were sampled at Camp Mabry (Fig. 8). One site was sampled with both mist-netting and acoustic monitoring, six sites were sampled with mist nets alone, and 10 sites only were sampled acoustically. Many of the sites were within 1/10 of a mile of each other. Mist nets were monitored for a total of 453 net hours and resulted in six captures of a single species, *Myotis velifer* (Fig. 2) in summer. There were eight sampling nights that resulted in no bat captures.

A total of 5,264 call files were recorded at Camp Mabry. Activity of *T. brasiliensis* was highest at this site comprising 52% of all recorded calls (Fig. 3). This was not surprising considering the proximity to the large urban colony of this species found under Congress Avenue bridge and that Anabat sampling was primarily conducted over large open water. No *T. brasiliensis* were captured, probably as a result of the net placement and the reluctance of this species to forage or drink from confined water sources. NYHULABO activity was the next highest. Few *Myotis* calls were recorded even though this was the genus captured most often in nets. This result might be explained by the tendency to place Anabat units to record in open areas. The site where most of the *Myotis* were captured was in a wooded, riparian area where insect activity is high. High frequency insect noise can interfere with Anabat recordings, so it is possible that *Myotis* call files were excluded or classified as "unknown" because of interference. Most call activity at Camp Mabry was in June (Fig. 4).

DISCUSSION

Comparison of bat diversity across five Texas Army National Guard training sites.—Netting effort was similar across all training sites (Fig. 9). Most netting effort occurred at Camp Maxey because of winter sampling efforts (no captures). Camp Maxey also had the highest species diversity with five species recorded and the most activity based on acoustic monitoring (total of 5,951 call files). Despite similar netting effort, the lowest bat species diversity was found at Camp Mabry and Camp Swift, with only one species captured at each site. Camp Swift had very low activity as determined by the total number of call files recorded (total of 661 call files). The three other sites had call activity at least five times that found at Camp Swift (3,658 call files at Camp Bowie, 5,264 at Camp Mabry, and 5,660 at Fort Wolters).

Previous mammal surveys at Texas Army Natioanl Guard training sites also have documented few species of bats (Dowler et al. 2004; Thies 2004a, 2004b; McDonough et al. 2005; Edwards and Johnson 2007). This study combined mist-netting efforts with acoustic monitoring at all sites. The results of this survey added *Lasiurus cinereus*, *L. seminolus*, and *Perimyotis subflavus* to the list for Camp Maxey, with both the hoary bat and Seminole bat being county records. Edwards and Johnson (2007) reported both *L. borealis* and *Nycticeius humeralis*, which were the most common species we encountered (both in nets and with acoustic monitoring). One record of the Mexican free-tailed bat (*Tadarida brasiliensis*) was reported from a capture in May by Edwards and Johnson (2007). It is surprising that neither of our survey methods were able to

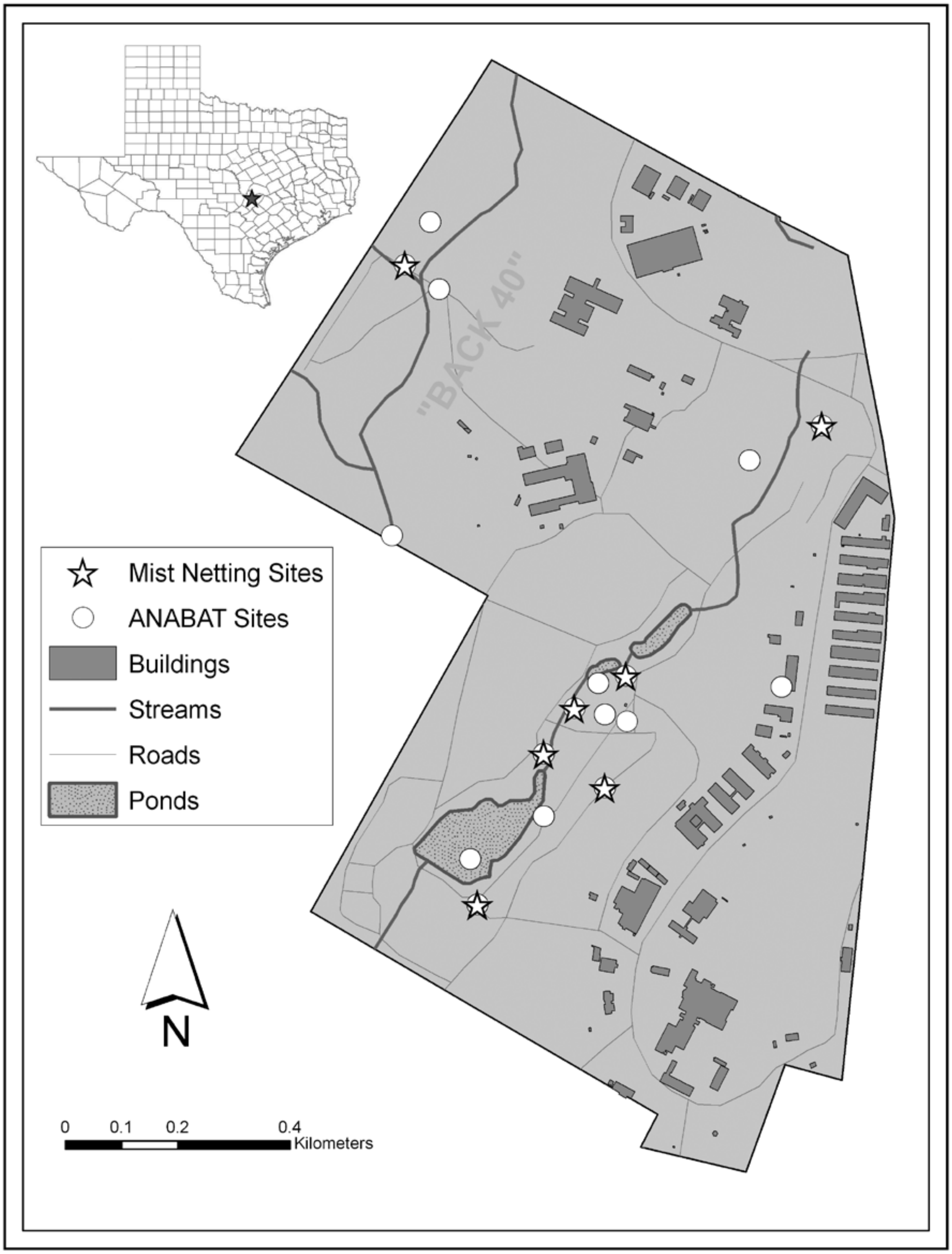


Figure 8. Location of sampling sites at Camp Mabry (Travis County). Stars represent sites sampled by mist net; circles represent sites that were sampled acoustically.

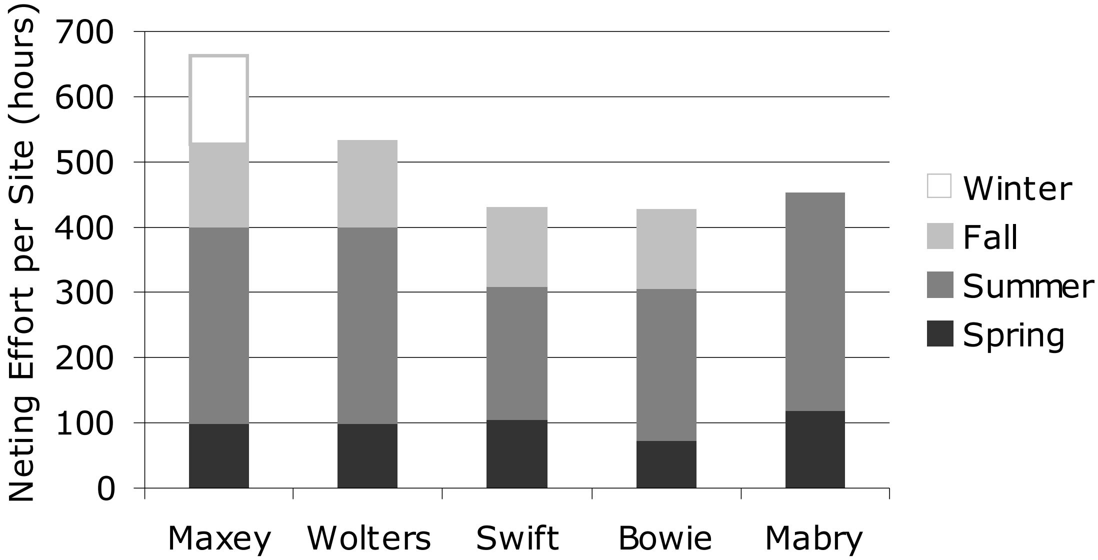


Figure 9. Netting effort (in net hours) at Texas Army National Guard training sites in 2005-2006.

document this species during the study. Perhaps this species only uses Camp Maxey for occasional feeding forays, but routinely roosts and has maternity colonies elsewhere. Other species expected at Camp Maxey but not encountered include the silver-haired bat, *Lasionycteris noctivagans*, the northern yellow bat, *Lasiurus intermedius*, and the big brown bat, *Eptesicus fuscus* (Schmidly 2004). All of these are relatively uncommon species in northeastern Texas. *Lasiurus intermedius* is known from a single recent record in Lamar County (Schmidly 2004). The prior distribution for this species reported in *The Bats of Texas* (Schmidly 1991) does not include northeastern Texas in the distribution of this species. *Lasionycteris noctivagans* is a migratory species that passes through eastern Texas, but does not breed here. The nearest record for *Eptesicus fuscus* is three counties away. It is clear from our work that these species likely are not an important part of the bat fauna at Camp Maxey.

Previous studies of mammals at Fort Wolters (Thies 2004b) resulted in only four bats of two species, *Lasiurus borealis* (n=3) and *Nycticeius humeralis* (n=1). Additional focus on netting in our study increased the number of captures to 52 of three species adding *Tadarida brasiliensis* to the list of species. Acoustic monitoring did not add additional species; however, it revealed that the previously undocumented *T. brasiliensis* is likely the most common species at Fort Wolters. Two migratory species whose ranges include this area, *Lasiurus cinereus* and *Lasionycteris noctivagans*, might be revealed with emphasis on monitoring the site during spring and fall. *Perimyotis subflavus* is within the range also, but is usually far less common than those species documented.

A previous survey at Camp Swift (Thies 2004a) had resulted in no bat captures and only one identifiable echolocation call (*Lasiurus borealis*). We had five captures of that species and added *Tadarida brasiliensis* on the basis of a few calls. Despite increasing the known species at this site to two, the low frequency of bat activity at Camp Swift remains confusing. Perhaps this result is an artifact of environmental factors on the nights that were surveyed. Call files for the NYHULABO phonic group may indicate the presence of *Nycticeius humeralis*, but no calls were able to confirm the presence of this species. Future surveys may reveal the factors for the low activity of bats at this site.

At Camp Bowie the use of acoustical surveying and mist-netting added documentation of *Tadarida brasiliensis*, *Perimyotis subflavus*, and *Myotis velifer* to the two species (*Lasiurus borealis* and *Nycticeius* *humeralis*) previously collected and one species for which we had acoustical evidence (*L. cinereus*) reported for this site (Dowler et al. 2004). The only other species expected here is *Lasionycteris noctivagans*, though it should be in Brown County only during migration. It is interesting that the highest number of calls documented was for *Myotis velifer*, a species previously unreported from this site (Dowler et al. 2004). Likely it is not a new occurrence to the site, but perhaps previous surveys failed to document *M. velifer* due to limited sampling using acoustic methods. Because very few locations were examined in this survey, we recommend future surveys include acoustic monitoring of additional sites.

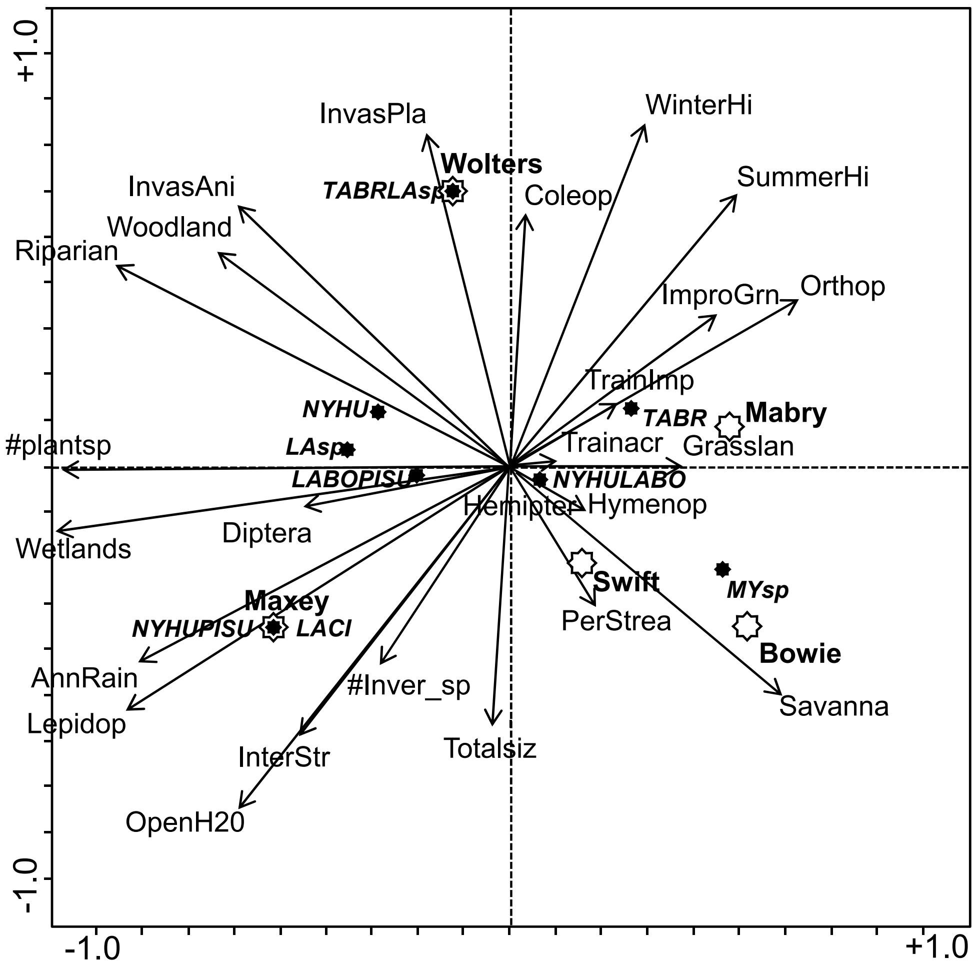
A previous baseline survey of mammals at Camp Mabry was unable to document any bat species although bats were observed flying (McDonough et al. 2005). We documented *Myotis velifer* in this study by capture data and *Tadarida brasiliensis* with acoustic data. In fact, the majority of calls recorded at Camp Mabry were *Tadarida*. *Myotis velifer* is known to roost in caves, rock crevices, bridges and buildings (Schmidly 2004). It will be important to monitor the *M. velifer* population and we recommend using radiotracking to identify possible roost sites at Camp Mabry. Several calls were identified as NYHULABO and both species likely occur there. Additional survey work in the fall and at additional sites in the "Back 40" should improve our estimate of the bat diversity at this site.

Relationship between environmental factors and bat activity.—A canonical correspondence analysis (CCA) was used to evaluate the relationship between environmental variables, (including training activities) and phonic groups at each of the sites. In our analysis, the first two canonical axes accounted for 88.5% of the total variation, indicating that the environmental variables included are good predictors of the locations of the phonic groups. The CCA was interpreted using an ordination diagram (Figs. 10 and 11). The ordination displays phonic groups as closed circles, the sites as open circles, and the environmental variables were represented by arrows. The phonic groups and the site locations in the ordination can be explained by the direction and length of the vectors for the environmental variables (ter Braak 1986). The length of a vector is indicative of the overall importance of the environmental variable to the ordination; therefore, longer vectors represent more important environmental variables than shorter vectors (ter Braak 1986). The position for the site and phonic group points in relation to the vectors can be used to interpret habitat associations. For instance, sites and phonic groups near the arrow at the end of a vector indicate a strong association to that particular environmental variable.

Within the CCA ordination diagram, there is a left to right gradient of moisture across the horizontal axis with areas of high moisture on the left side and drier areas on the right (Fig. 10). Vegetation is similarly represented with moist habitats (woodland and riparian) on the left and dry, warmer habitats on the right (grassland and savannah). Overall, Camp Maxey is the site most associated with available water, whereas Camp Mabry and Camp Bowie are sites that are most associated with drier habitats.

The phonic groups that are found toward the center of both axes (NYHU, LAsp, LABOPISU, and NYHULABO) are generalists that are not closely related to any of the environmental variables associated with the sites. As a result of certain phonic groups only occurring at a single site, LACI and NYHUPISU are found in the center of Camp Maxey's point and TABRLAsp is found at the center of Fort Wolters point (Fig. 10). Camp Maxey is also the site with the highest overall bat diversity based on captures and call activity. TABR is most closely associated with Camp Mabry, a site that has the most improved grounds (57% buildings and infrastructure). This result is not surprising because *Tadarida brasiliensis* commonly uses manmade structures in urban settings (bridges, buildings) and is found in large numbers in the Hill Country of Texas (Schmidly 2004). *Myotis* were most associated with Camp Bowie and Camp Swift and are closely associated with savannah habitat.

All of the environmental variables (except training impact and training acres) are important to the ordination as demonstrated by the long vectors. The vectors for training impact and acres are pulled in the direction of Camp Mabry, a site which has no training acres or impact. Training impact at other sites ranged from a low of 22,444 man-hours at Camp Bowie to 96,067 man-hours at Camp Swift (Appendix II). When Camp Mabry is removed from the analysis, the vectors related to training are directed even farther away



TrainImp: training impact
Totalsiz: total size
Trainacr: training acres
ImproGrn: improved grounds
Wetlands: wetlands
Open H20: open water
PerStea: perennial streams
InterStr: intermittent streams
AnnRain: annual rainfall
WinterHi: winter high temperature
SummerHi: summer high temperature
#plantsp: number plant species
#Inver_sp: number invertebrate species
Lepidop: Lepidoptera
Orthop: Orthoptera
Coleop: Coleoptera
Diptera: Diptera
Hemipter: Hemiptera
Hymenop: Hymenoptera
InvasPla: invasive plants
InvasAni: invasive animals
Woodland: woodlands
Grasslan: grasslands
Savanna: savannah
Riparian: riparian

Figure 10. Canonical correspondence analysis of 25 environmental variables and acoustic monitoring data (frequency of phonic groups) at all five Texas Army National Guard training sites.

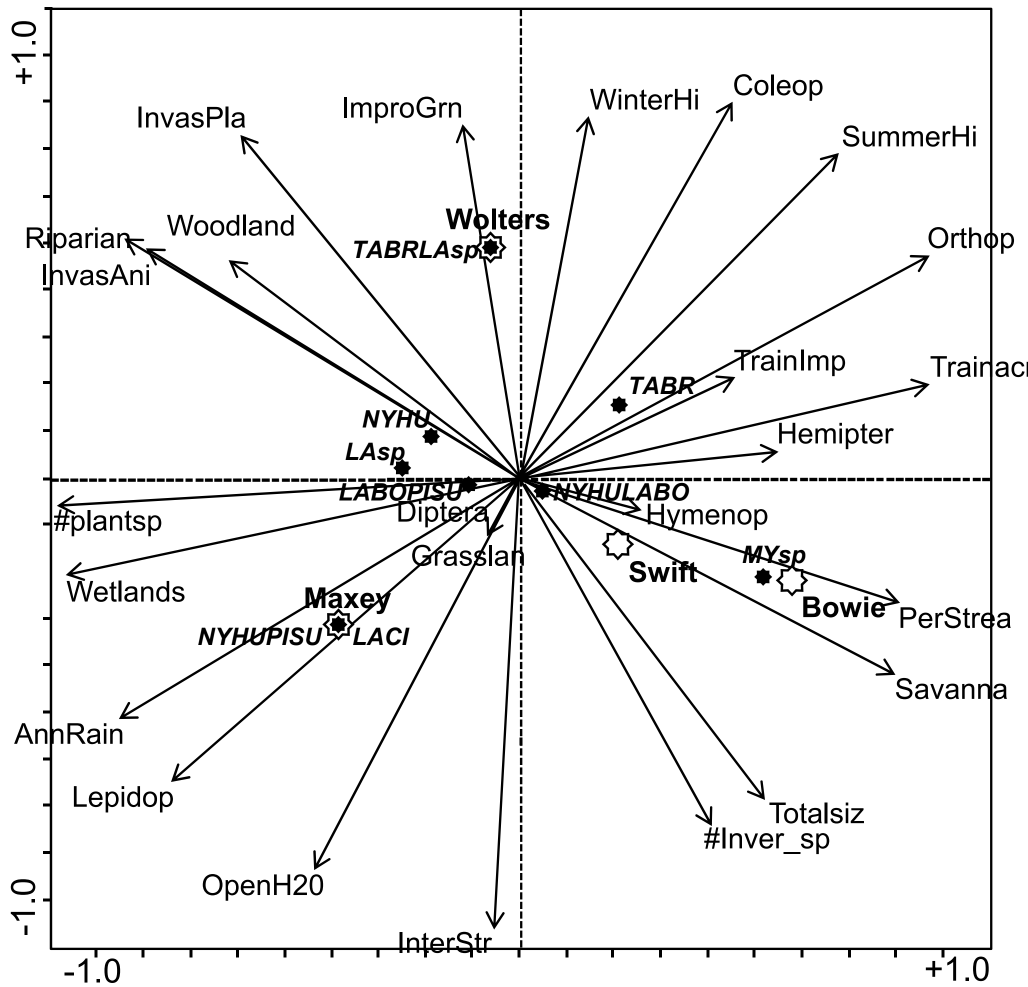


Figure 11. Canonical correspondence analysis of 25 environmental variables and acoustic monitoring data (frequency of phonic groups) at four Texas Army National Guard training sites (Camp Mabry was removed). Refer to legend in Figure 10.

from all sites, confirming that these variables are poor predictors of distribution and phonic groups (Fig. 11). In addition, when training impact and training acres are removed from the analysis, the pattern is identical to Figure 10, which is further evidence for the lack of influence by these two variables. Because there was little change in the direction of the training impact vectors, the other 23 environmental variables are better predictors of the relative abundance of bat activity at each of the sites. In conclusion, the level of training impact, as estimated in this study, does not seem to have a negative effect on the bat community at any of the National Guard training sites.

Management Recommendations and Future Work.—Based on our survey of bat activity and diversity using mist nets and acoustic monitoring, we recommend that each of the five National Guard training sites promote or maintain wetland habitats as foraging areas for bat communities. Open sources of water are critical to bat populations, allowing access to drinking water as well as providing areas for insect foraging in some species. Maintaining woodland habitat is also important for species that roost in tree foliage (*L. borealis* and *L. cinereus*, among others). We also recommend leaving dead snags in place to serve as possible cavity roosts for bats, as well as other wildlife. Further, we recommend placing bat boxes (Tuttle and Hensley 1993) to serve as alternative roost sites for species that prefer crevices and are known to inhabit bat houses (*Myotis velifer*, *Tadarida brasiliensis*, and *Nycticeius humeralis*). Although no natural roost sites were discovered in our survey, we observed *Tadarida* in buildings at Camp Swift and if exclusions are performed, it would be important to provide alternative roost sites (such as bat boxes).

Several results of this survey deserve further investigation. First, more frequent and more widespread sampling at each site may reveal additional species. This is especially true for Camp Swift, where bat diversity and activity were exceptionally low relative to other sites. Intensive sampling in the summer would increase our understanding of the bat fauna at Camp Swift. Additionally, more complete survey efforts during fall and spring at all sites would increase the likelihood of documenting migratory bat use at National Guard training facilities in Texas. Furthermore, future work should include systematic re-sampling of the sites used in this study in order to monitor long-term trends in these bat communities. Lastly, to determine if training acres/impact actually has an effect on the distribution of phonic groups at each of the training sites, sampling should be replicated to span a greater number of training impact days over the course of several years.

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APPENDIX I

Voucher specimens of bats collected during survey of Texas Army National Guard Training Sites, 2005-2006. All specimens have been deposited in the Angelo State Natural History Collections (ASNHC).

Locality			UTM coordinates			Species	Date	ASNHC #
Texas	Brown Co.	Camp Bowie	14R	0509239	3495511	*Lasiurus borealis*	02/Jun/06	13245
			14R	0509721	3496250	*Lasiurus borealis*	22/Jul/06	13243
			14R	0509892	3495475	*Lasiurus borealis*	23/Jul/06	13244
			14R	0509721	3496250	*Myotis velifer*	22/Jul/06	13252
			14R	0509892	3495475	*Myotis velifer*	23/Jul/06	13254
			14R	0504965	3501163	*Myotis velifer*	26/Aug/07	13253
			14R	0509239	3495511	*Nycticeius humeralis*	02/Jun/06	13259
Texas	Travis Co.	Camp Mabry	14R	0618940	3354471	*Myotis velifer*	08/Jun/06	13255
			14R	0618940	3354471	*Myotis velifer*	08/Jun/06	13256
			14R	0619049	3354411	*Myotis velifer*	28/Jul/06	13257
			14R	0619049	3354411	*Myotis velifer*	28/Jul/06	13258
Texas	Lamar Co.	Camp Maxey	15S	0262282	3742719	*Lasiurus borealis*	23/May/06	13247
			15S	0260770	3740838	*Lasiurus borealis*	24/May/06	13246
			15S	0262282	3742719	*Lasiurus borealis*	12/Jul/06	13248
			15S	0262282	3742719	*Lasiurus cinereus*	18/Aug/06	13251
			15S	0262282	3742719	*Lasiurus seminolus*	18/Aug/06	13267
			15S	0259285	3740967	*Nycticeius humeralis*	29/Oct/05	13260
			15S	0262282	3742719	*Nycticeius humeralis*	23/May/06	13261
			15S	0262282	3742719	*Nycticeius humeralis*	23/May/06	13262
			15S	0265299	3741854	*Perimyotis subflavus*	10/Jun/06	13264
			15S	0262282	3742719	*Perimyotis subflavus*	12/Jul/06	13265

Appendix I (cont.)

Locality			UTM coordinates			Species	Date	ASNHC #
Texas	Bastrop Co.	Camp Swift	14R	0665734	3350887	*Lasiurus borealis*	29/Apr/06	13240
			14R	0665734	3350887	*Lasiurus borealis*	29/Apr/06	13241
			14R	0665383	3350153	*Lasiurus borealis*	15/Jul/06	13242
Texas	Parker Co.	Fort Wolters	14S	0589651	3637414	*Lasiurus borealis*	12/Nov/05	13250
			14S	0589996	3635639	*Lasiurus borealis*	26/May/06	13249
			14S	0589651	3637414	*Nycticeius humeralis*	12/Nov/05	13263
			14S	0587901	3635242	*Tadarida brasiliensis*	15/Jul/06	13266

APPENDIX II

Environmental variables used in the CCA analysis. Data were extracted from the Integrated Natural Resources Management Plan for each site (D. L. Johnson et al. 2007a,b,c,d and pers. comm.). Training impact and training range for Mabry was not possible to compute because this site is not used for training activities, but instead serves as the headquarters.

Variable	Swift	Bowie	Maxey	Wolters	Mabry
Training impact (man days)	96067	22444	43209	27620	--
Physical features					
Size of site (total ha)	4718	3542	2600	1614	152
Training range (ha)	91	77	36	61	--
Improved grounds (ha bldgs)	36	14	18	32	87
Unimproved grounds (ha)	4591	3452	2545	1521	65
Wetlands (ha)	3	1	20	10	0
Open water (ha)	6	20	37	4	2
Perennial streams (km)	23	18	9	10	1.25
Intermittent streams (km)	73	60	68	37	0.86
Weather					
Average annual rainfall (cm)	97	69	119	81	86
Average winter high temp (°C)	17	13	12	16	16
Average summer high temp (°C)	34	36	34	36	34
Plant and insect diversity					
Number of plant species	600	400	710	600	428
Number of invertebrate species	812	720	680	600	357
Lepidoptera species	31	34	109	31	2
Orthoptera species	60	66	4	53	23
Coleoptera species	200	237	202	248	184
Diptera species	27	78	71	68	4
Hemiptera species	3	58	28	36	5
Hymenoptera species	416	106	89	110	94
Non-native plant species	35	16	31	42	45
Non-native animal species	9	4	9	10	9
Habitat					
Forest/Woodlands (%)	75	7	49	62	27
Grassland (%)	15	38	36	33	59
Savannah (%)	0	47	5	0	5
Riparian (%)	4	0	5	6	0

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