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Grassland Bird Productivity on Military Airfields in the Mid-Atlantic and Northeast Regions - Interim Report.

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EXECUTIVE SUMMARY

Grasslands associated with airfields in the northeastern United States (both military and civilian) often support large numbers of regionally rare grassland birds. As grassland habitat area in the region continues to decline, the role that that large airfields play in maintaining populations of these species is likely to increase. Despite this, relatively little is known regarding reproductive success in these habitats, and whether they act as population sources or sinks. This is a particular concern because vegetation management on airfields often involves regular mowing during the summer breeding season, a practice presumed to be harmful to nesting success. To obtain a general picture of grassland bird reproductive success on regional airfields, and to examine possible factors that may be affecting it (including mowing), we conducted a nest monitoring study in 2009 on three military airfields in the Mid-Atlantic and Northeast: Westover Air Reserve Base (Massachusetts), Lakehurst Naval Air Engineering Station (New Jersey), and Patuxent River Naval Air Station (Maryland).

Nests of two target species (grasshopper sparrow (*Ammodramus savannarum*) and eastern meadowlark (*Sturnella magna*) and of other grassland-obligate species were located and monitored at regular intervals until success (fledging) or failure. We measured vegetation characteristics around each nest, and through direct observation and cooperation with mowing crews were able to determine: 1) if a nest was located in a regularly mowed area, 2) if a nest was directly mowed over while active, and 3) the condition of each nest immediately following a mow. We calculated daily nest survival rates (DSR), and examined the effects of various predictor variables using logistic modeling in program MARK. We also modeled the mean number of fledglings produced per nest using Generalized Linear Models (GLM).

During the first year of this two-year study, we located and monitored 42 grasshopper sparrow nests, 48 eastern meadowlark nests, and 41 nests of other species across all three sites. Daily survival rates for grasshopper sparrow ranged from 0.96 at Lakehurst to 0.99 at Westover, while rates for eastern meadowlark ranged from 0.92 at Patuxent River to 0.98 at Lakehurst. DSR modeling did not reveal any strong predictors for either target species when analyzed using data from all sites combined. When sites were analyzed separately, percent grass cover around the nest, distance to active runway, and date of season all emerged as potential factors influencing nest DSR. However, these results should be viewed as tentative because they are based on relatively low sample sizes from each site. Mowing variables did not emerge as good predictors of nest survival, and DSR was not significantly lower for nests that were mowed over vs. those that were not (i.e., direct mowing effects), or for nests in mowed areas vs. those in unmowed areas (i.e., indirect mowing effects). Nevertheless, we did observe some direct mortality due to mowing (4 of 19 mowed nests), and some potential secondary mortality due to scavenging or abandonment (3 additional nests). We anticipate that data from our second field season in 2010 will allow us to draw stronger conclusions regarding the effects of mowing and other factors on grassland bird nest survival on DoD airfields.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Background and Objectives

The Department of Defense (DoD) is the steward of approximately 30 million acres of land in the United States, many of which contain threatened and endangered species as well as critical habitats. Programs that seek to protect and enhance natural resources on DoD lands acknowledge the importance of military lands to the conservation of species and habitats of concern (e.g., DoD Partners In Flight). It has been suggested that airfields in general, if properly managed, may be important for producing stable breeding populations of grassland birds (Askins 1993). This guild has experienced steep and geographically widespread population declines (Askins 1993, 1996, Rich et al. 2004, Brennan and Kuvlesky 2005). Military airfields have been specifically identified as important components in the conservation of rare grassland birds (Osborne and Peterson 1984).

Current Air Force policy includes provisions for the protection and conservation of state-listed species, so long as such actions do not interfere with the military mission (AFI 32-7064-2004). At the same time, aviation safety procedures dictate that grassland management methods on USAF airfields comply with Bird/Wildlife Aircraft Strike Hazard regulations (BASH, AFI 91-212-2004). Naval air stations also often adopt BASH recommended management strategies (K. Rambo, *personal comm.*), although Navy management standards are currently under review and should be finalized in 2010. BASH management generally adheres to a strict mowing regime, with vegetation directly adjacent to runways consistently managed to 7-14 inches (AFI 91-212-2004). Habitat management and restoration activities at military airfields focus on using mowing and other mechanical methods to enhance habitat for grassland-dependent species and to comply with BASH regulations. Prescribed burning also offers a cost-effective management alternative when trained personnel are available on-site, and this technique has been implemented on several bases including Lakehurst Naval Air and Engineering Station (LNAES) and Westover Air Reserve Base (WARB).

Several grassland bird species of regional and national concern breed on military airfields in the Mid-Atlantic and Northeast regions. These include upland sandpiper (UPSA, *Bartramia longicauda*), grasshopper sparrow (GRSP, *Ammodramus savannarum*), Henslow's sparrow (HESP, *A. henslowii*), eastern meadowlark (EAME, *Sturnella magna*), and field sparrow (FISP, *Spizella pusilla*), all of which are regarded as grassland obligates (UPSA, GRSP, HESP, EAME) or associates (FISP) during the breeding season. For instance, WARB hosts the largest breeding population of UPSA and GRSP in Massachusetts, and LNAES hosts the largest breeding population of UPSA, and second largest population of GRSP, in New Jersey (J. Joyce, *personal comm.*). Patuxent River Naval Air Station (PRNAS) also supports breeding populations of GRSP and EAME. To date, monitoring data from these sites indicate that the local densities of target grassland species are stable or increasing, although it is difficult to assess whether these patterns are driven by fine-scale habitat selection, site fidelity, or other species-specific behavioral responses. Grassland habitat is also increasingly rare in the heavily-developed Northeast and Mid-Atlantic regions, so that lack of alternative breeding habitat may be affecting site use (Melvin 1994, Askins 1996, Vickery and Dunwiddie 1997, Norment 2002).

It is widely accepted within the ecological community that avian abundance measures alone are not adequate for measuring habitat quality and, in particular, species response to anthropogenic habitat manipulation (Van Horne 1983). Several factors can make evaluating the effects of habitat changes on bird population status problematic, such as the potential influences of site fidelity and social interactions. An individual may return to a prior breeding site or to its natal site regardless of that habitat's characteristics or quality. Territorial behavior exhibited by dominant individuals may relegate subordinate individuals to suboptimal habitats, a process known as despotic distribution (Fretwell and Lucas 1969). Lack of alternative habitat also often forces individuals to use sites that are suboptimal (e.g., Perlut et al. 2006).

In addition, some sites may function as ecological traps, where habitat cues are decoupled from (i.e., do not represent) actual habitat quality. Such cases may arise when altered, enhanced or created habitats are selected by individuals based on environmental cues. These cues, however, misrepresent the functional habitat quality of the sites, which ultimately act as ecological sinks. In such instances, lower quality habitats could exhibit greater bird densities than high quality habitats. For instance, Kershner and Bollinger (1996) found that EAME were attracted to Illinois airfields, although mandated mowing practices were responsible for 44% of nest failures. On the other hand, Jones (2000) found no differences in GRSP breeding densities or reproductive success between WARB and an island population located 160 km east. Evidence also suggests that human-induced disturbance can directly reduce fitness in breeding bird colonies through displacement or increased nest predation (review in Carney and Sydeman 1999), but comparatively little is understood about the potential effects of disturbance to individually-nesting grassland birds. The few studies that have addressed the issue of disturbance and grassland birds have produced unclear and sometimes conflicting results. For instance, Forman et al. (2004) reported that grassland bird nesting activity was affected by road traffic, but only above defined threshold traffic levels. Alternatively, military activity did not affect nest site selection or nesting success in EAME or GRSP on Fort Riley, KS (Hubbard et al. 2006).

In response to uncertainties about the suitability of military grassland habitats for priority bird species, emphasis is now being placed on monitoring local demographic parameters (e.g., nest survival, fledging success, fecundity) as targets for management rather than on abundance parameters alone (Martin 1992, Conway and Martin 1999). The goal of the first year of this ongoing project was to expand our current avian monitoring program on LNAES, WARB, and PRNAS (i.e., avian density monitoring, Peters and Allen 2009a) to include demographic parameters for breeding grassland birds (i.e., reproductive success). Target species were GRSP and EAME, both of which breed on all three sites. GRSP is listed as "threatened" in MA and NJ, "at risk" in MD, and of regional concern in need of "immediate management" (PIF BCR 30). EAME is considered a species of "special concern" in NJ, and "of management concern" in the Northeast (USFWS Region 5). EAME also serves as a good model for ground-nesting grassland birds as it is a relatively abundant species that has shown sharp and consistent population declines throughout much of its breeding range (Rich et al. 2004, Askins et al. 2007). The current study was designed to provide a clearer picture of the bird-habitat dynamics on LNAES, WARB and PRNAS. Our specific objectives in Year 1 were to: (1) obtain nesting success measures for the target species, (2) relate nesting success to habitat characteristics, and (3) relate nesting success to restoration/enhancement and BASH management history. Particular emphasis was placed on determining how nests placed in intensively mowed areas (i.e., BASH management areas) compared to those placed outside of mowed areas, and how nests that were directly mowed over while active fared as compared to undisturbed (i.e., unmowed) nests. Results presented within this report should be treated as preliminary. Additional data will be collected in spring 2010 to enhance sample size and strengthen inferences about the relationships among management, habitat structure and grassland bird productivity.

STUDY SITES

Lakehurst Naval Air Engineering Station

The LNAES in Lakehurst, New Jersey, consists of 7,400 acres and is located within the Pinelands National Reserve (PNR). The mission of LNAES Environmental Department includes land management, forestry, threatened and endangered species management, and habitat improvement. Approximately 1,700 acres of the site is considered grassland habitat, 1,200-1,300 acres of which are actively managed (J. Joyce, *personal comm*.). Species of concern on the site include upland sandpiper (state endangered), and grasshopper sparrow (state threatened), both regarded as grassland obligates during the breeding season. The LNAES supports the largest known breeding population of upland sandpipers in New Jersey (10-12 pairs), and the second-largest known population of grasshopper sparrows in the state (after Atlantic City International Airport) (J. Joyce, *personal comm*.). Habitat improvement measures for grassland birds have been implemented over the last 13 years and have included controlled burns, mowing, and mechanical shrub-removal methods. Burn schedules currently run on a four-year basis, and affect 145-185 acres of the site per year. The grasslands are not mowed during the breeding season (April – August), but late-winter mowing affects 750 – 1,000 acres per year.

Westover Air Reserve Base

Westover Air Reserve Base in Chicopee, Massachusetts contains approximately 2,511 acres of land in an area of the Connecticut River Valley characterized by gently sloping terrain of moderately fertile, sandy, well-drained loams. The base maintains the largest contiguous grasslands in the Connecticut River watershed (>1,200 ac). The grasslands contain over 100 species of plants but large areas are dominated by alien vegetation. Westover's grasslands provide breeding habitat to New England's largest populations of three rare species: upland sandpiper, grasshopper sparrow, and Phyllira tiger moth (*Grammia phyllira*). The sandpiper and moth are listed by Massachusetts as endangered and the sparrow is state-listed as threatened. The 1987 populations of 25 upland sandpipers and 55 singing male grasshopper sparrows increased to 150 and 182 of the birds, respectively, by 2003 (Melvin 1994). The U.S. Fish and Wildlife Service identified Westover as a Special Focus Area with "high" priority within the Silvio O. Conte National Fish and Wildlife Refuge. Mowing frequency for 523 acres of vegetation within 300 feet of runways and taxiways is determined by the time it takes vegetation to approach an average height of 14 inches (i.e., approximately once per month, A. Milroy, *personal comm.*). The remaining 690 ac are mowed after 1 August each year to avoid the rare bird nesting season. Prescribed fire was introduced in 2002 (60 ac) with subsequent burns in 2004 (122 ac) and 2006 (250 ac). Westover is building toward a four-year return interval for burning the grasslands. The base has begun integrated pest management of invasive plant species.

Patuxent River Naval Air Station

The PRNAS is located in St. Mary's County, Maryland, and consists of approximately 6,300 acres along the western shore of Chesapeake Bay near its confluence with the Patuxent River. Another ~1,000 acres of Navy land occurs at a nearby outlying field known as Webster Field Annex. The mission of the PRNAS Environmental Department includes land management, forestry, threatened and endangered species management, and habitat improvement. Several hundred acres of the site are considered grassland habitat, with most of that subjected to regular mowing or some other form of active management (K. Rambo, *personal comm.*). Species of concern on the site include upland sandpiper and buff-breasted sandpiper *(Tryngites subruficollis)* during migration, and breeding populations of grasshopper sparrow, eastern meadowlark (*Sturnella magna*), and northern bobwhite *(Colinus virginianus)* -- the latter three regarded as grassland obligates during the breeding season. Upland sandpiper is considered a species that is endangered in Maryland and a "species of high concern" continentally (Brown et al. 2001). Buff-breasted sandpiper and grasshopper sparrow are considered species "at risk" in Maryland and globally (the former) or continentally (the latter; Brown et al. 2001, Rich et al. 2004). Concentrations of individual upland sandpipers typically reach into the 40s and 50s during the non-breeding season and numbers of buff-breasted sandpipers often are in the 30s. These are some of the highest population densities reported within the mid-Atlantic region (K. Rambo, *personal comm.*). Habitat improvement measures for grassland birds have been implemented over the last 5-10 years and have included establishment of native warm-season grasses, regulated mowing heights and frequency, controlled burns, and various shrub-removal methods (mechanical, manual, and chemical).

METHODS

Nest searching and monitoring

Nest-searching blocks at each installation were selected prior to the field season based on scheduled mowing regimes (PRNAS, WARB) or spatial separation (LNAES). Blocks provided relatively equal representation of areas on WARB that were (1) intensively mowed to 7-14 in during the breeding season, and (2) were not mowed during the breeding season. All blocks on PRNAS, except for one, represented areas that were mowed to 7-14 inches, while no blocks on LNAES were mowed. Blocks on LNAES were located in three distinct areas: (1) around an active runway (Westfield Runways),

(2) a less active runway (Test Runway), or (3) an air drop area not associated with any runways (Jump Circle). Maps depicting search blocks established at each site are available in Appendix A. Each block was searched once every one to two weeks.

Various methods of locating nests were implemented throughout the season (16 April - 15 July) including systematic area searches, behavioral observations, 'sticking' and rope-dragging. Specific methods were similar to those used by Nesbit and Robinson in the Illinois Natural History Survey (http://virtualbirder.com/vbirder/onLoc/onLocDirs/ILSUM/pa/Wilmington2.html). Systematic searches consisted of observers walking a defined grid within a study plot in order to flush adults off nests. Specific adult breeding behaviors recorded included singing, calling, counter-calling, carrying nesting material or food, and defensive (i.e., agonistic) actions. "Sticking", or flushing adults off the nest with a 1-meter stick, was the primary method of enhancing sample size at LNAES, while rope-dragging (two observers dragging an approximately 20 m weighted rope) as well as sticking were used to increase nest sample-size at PRNAS and WARB. An attempt was made to employ equal search effort across blocks.

Mowing activities at PRNAS and WARB were tracked through communication with on-site management crews, and observers visited known active nests in targeted areas immediately prior to and after mowing. Nests were ultimately categorized as "not in mowing plan area", "in mowing plan area but not directly mowed over", or "directly mowed over". Nests that were directly mowed over were easily recognizable due to mower tracks, grass clippings and reduced vegetation height at and around the nest.

Once located, nests were monitored every 2-3 days through completion or termination. Based on conditions observed at and around nests, nest failures were categorized as depredated, abandoned, destroyed by mower, or unknown. Successful nests were defined as those that fledged at least one GRSP or EAME chick. Overall probability of nest success were based on a 20 day nesting cycle (including incubation) for GRSP (Vickery 1996), and a 24 day nesting cycle for EAME (Lanyon 1995). Similar methods were used to define success of other grassland breeding passerines monitored during the study.

The date of nest initiation (i.e., start of incubation) was estimated in most cases by back-dating from the known or estimated hatch date or fledge date. Incubation and nestling periods were assumed to be 12 and 8 days for GRSP, and 14 and 10 days for EAME, respectively (Lanyon 1995, Vickery 1996). The date of hatching or fledging (when not directly observed) was estimated as the mid-point between the two checks surrounding the event. Nests at which eggs were present for significantly longer than the expected incubation period were classified as abandoned. In these cases, the date of termination was assumed to have occurred mid-way between the last date at which parental activity was observed, and the subsequent check date.

At LNAES, grasshopper sparrow and eastern meadowlark nestlings were marked when they were 4-6 or 8-9 days old, respectively, to examine future recruitment into the population. They were fitted with a USFWS aluminum leg band and batch-marked with a single green color band to uniquely identify the site and year in which they were banded. Data collected during banding are discussed in a separate report (Allen et al. 2009).

Vegetation Surveys

Vegetation around each nest was quantified within a 1 m^2 quadrat centered on the nest. Percent horizontal coverage (including overlap) of four cover types was visually estimated within the quadrat: grass, forb, bare ground, and shrub. Vegetation height at the time of nest discovery was measured as the maximum height at which vegetation touched a vertical pole, averaged over five sub-sample locations (the center and four corners of the quadrat). This measure was performed again on the last day a nest was visited. The extent of vegetation "clumpiness" in the general area around the nest (e.g., as formed by warm season grasses) was categorized as: 1) grass mostly even and homogeneous, 2) grass somewhat clumpy, and 3) grass mostly in clumps.

Statistical Analyses

We modeled daily nest survival rate (DSR) of grasshopper sparrow, eastern meadowlark and 'other' grassland obligate species using the logistic nest survival model within the program MARK (v. 5.1; White and Burnham 1999, Dinsmore et al. 2002). 'Other' species consisted of savannah sparrow (n=27), bobolink (n=1), and horned lark (n=2) on WARB, and field sparrow (n=11) on LNAES. A set of 9 candidate models evaluated included data from all three study sites. Each model included a 'site' class variable to account for location as well as vegetation characteristics, mowing history, or day of season (i.e., estimated date of start of incubation). Because of sample size limitations, a maximum of one parameter (plus 'site' and intercept) was included per model. Two management models were included in the initial model set; a 'Mowed Area' model, and a 'Nest Mowed' model. The 'Mowed Area' candidate modeled nest success based on whether or not a nest was located within a mowing plan area. The 'Nest Mowed' candidate modeled the success of nests that were directly mowed over vs. those that were not. A null (intercept only) model was also run, and separate null models were used to generate daily survival rate (DSR) estimates and confidence intervals for groups of nests. The best performing model(s) were selected based on Akaike's Information Criterion adjusted for low sample sizes (AIC_c; Burnham and Anderson 2002). Models within ≤ 2 ΔAIC points were considered equally supported. A similar set of models was also examined for each base separately. This was done to address the possibility that different factors may be affecting DSR at the different sites; however, it also necessarily resulted in lower than optimal sample sizes of nests for some species (e.g., 20 nests, Hensler and Nichols 1981).

In addition to DSR, we estimated the number of young successfully fledged for the two target species. We used General Linear Models (GLM, SAS v. 9.2, SAS Institute Inc. 2004), with number of young successfully produced as the dependent variable and either a habitat parameter (i.e., distance to nearest runway, % horizontal grass cover, mean vegetation height) or management parameter (i.e., "Mowed Area" or "Nest Mowed" included as independent class variable [1=yes, 0=no]). All models also included a "Site" term and "Date" estimate (i.e., Julian day start of incubation), to account for expected geographic and temporal differences in clutch size.

FINDINGS

Nest Site Characteristics

A total of 42 grasshopper sparrow and 49 eastern meadowlark nests were located and monitored in 2009, with the greatest number of nests of each species found at PRNAS (Tables 1-2). Maps of all monitored nests, by site and nest fate, can be viewed in Appendix A. Mean height of vegetation around nests at completion or termination of the nesting cycle, for both species combined, was greatest at WARB (Tables 1-2). For grasshopper sparrow, this difference in vegetation height was significant overall among sites ($F_{2,41} = 4.39$, P=0.02), but this was driven by a difference between WARB and LNAES (P = 0.007), as differences among other site pairs were not significant (Figure 1). Differences in vegetation height around eastern meadowlark nests at the three bases were not significant ($F_{2,48}$ = 1.99, P = 0.15). Vegetation height also did not differ between the two target species ($F_{2,90}$=0.18, P=0.67). Horizontal ground cover around nests of both species tended to be more heavily dominated by grass and forb cover at PRNAS and WARB, whereas more bare ground was present at LNAES (Figure 2).

Nest Initiation Dates

Patterns of nest initiation dates at the three sites are illustrated in Figures 3-5. Nest initiations for grasshopper sparrow followed a similar unimodal pattern at LNAES and WARB, but appeared to exhibit a bimodal pattern at PRNAS, suggesting two broods per season (Figure 3). Eastern meadowlark nest initiations were unimodal, with the possible exception of WARB (Figure 4). The nesting season for meadowlarks apparently started earlier at PRNAS (late April), compared with at WARB and LNAES (early to mid May, Figure 4). Initiation dates for savannah sparrow and field sparrow are presented in Figure 5.

Nest Survival Rates

Combined-site nest survival models

Daily survival rate across all bases was modeled separately for grasshopper sparrow (n=42), eastern meadowlark (n=49), and 'other' species (n=41, see Methods). Grasshopper sparrow DSR was best predicted by distance to runway or percent horizontal grass cover, although these models performed only marginally better than the null model (Table 3). Nests that were located farther from active runways tended to fare better than those located adjacent to runways, a finding driven by patterns of success recorded at LNAES and WARB (Table 4, Figure 6). Nests that were placed within areas dominated by grass cover were also more successful than those in areas with less grass (Table 4, Figure 7).

Eastern meadowlark DSR was best predicted by percent grass cover and day of season (i.e., 1 = the first day of the breeding season, 2 = the second day, etc., Table 3). In contrast to findings for grasshopper sparrow, meadowlark nests tended to fare better in areas with less grass cover (Table 4, Figure 8). Nests active earlier in the season also were more successful than those active later in the season (Table 4, Figure 9), a pattern which was most pronounced at WARB and PRNAS. Nest survival for other passerines breeding at LNAES and WARB also varied by day of season (Table 3), with earlier nests generally more successful than later nests (Table 4, Figure 10).

Overall probability of nesting success for grasshopper sparrow was 52% at LNAES (95% CI = 24-75%), 49% at PRNAS (CI = 20-72%), and 79% at WARB (CI = 19-97%). Eastern meadowlark success was somewhat lower than grasshopper sparrow at LNAES (13%, CI = 4-26%) and WARB (23%, CI = 5-48%), but similar at PRNAS (62%, CI = 15-89%). Daily survival rate (DSR) values for nests at each site are broken down by management history in Tables 5 and 6.

<u>Individual-site nest survival models</u>

Although sample sizes from each site were relatively small, data were stratified and DSR models were run for each location separately (see Methods). At PRNAS, grasshopper sparrow nests that were surrounded by grass cover, initiated early, and not directly mowed over were most successful (Tables 7-8). However, the mowing effect should be considered spurious based on its associated variance (and corresponding CI), likely caused by low sample size. Grasshopper sparrow nests at LNAES and WARB were more successful when located farther from runways (Tables 7-8).

Eastern meadowlark nest survival at PRNAS was best predicted by day of season, with earlier nests faring better (Tables 9-10), whereas nests at LNAES and WARB were most successful in areas with less grass cover. Nests at LNAES also had greater DSR in less 'clumpy', more homogenous habitats (Tables 9-10), although this finding is inconclusive based on parameter variance (Table 10). Models including 'clumpiness' and mean vegetation height at completion also performed relatively well for WARB, although confidence intervals for these parameters did not exclude zero, or 'no effect' (Table 10). Individual site models for the other grassland associates included in analysis indicated that field sparrows at LNAES were more successful in areas dominated by grass cover (Tables 11-12). All models run for WARB, including the null model, performed equally well (Table 11), indicating that none of the parameters observed were especially useful for predicting nesting success. This is further substantiated by the fact that all parameter estimate 95% CIs overlapped zero (Table 12).

<u>Mowing effects</u>

At PRNAS, 27 of 28 eastern meadowlark nests and 19 of 20 grasshopper sparrow nests were located in areas that were regularly mowed. Of these, mowers passed over 14 active meadowlark nests and five active grasshopper sparrow nests. Four meadowlark nests (29% of those mowed) were directly destroyed by the mower (e.g., crushed by tires, killed by blades), while no grasshopper sparrow nests were directly destroyed. Two additional meadowlark nests failed soon after mowing, suggesting indirect effects (e.g., scavenging, abandonment). At WARB, 7 of 14 meadowlark nests and 3 of 7 grasshopper sparrow nests were located in mowed areas. Only one active nest of a target species (grasshopper sparrow) was mowed over at WARB, and it did not directly cause failure, although the nestlings were apparently abandoned soon afterwards.

Daily survival rates were not consistently (or significantly) lower for mowed vs. unmowed nests or for nests in mowed vs. unmowed areas at either PRNAS or WARB (Tables 5 and 6). Similarly, management (i.e., mowing related) models performed relatively poorly at predicting nest survival in both the combined-site and individual-site analyses (Tables 3, 7, 9, and 11).

Mean Productivity

General linear models were used to examine the relationships among mean number fledged per nest and several habitat and management parameters. Of the set of 7 candidate models, two models including distance to runway and percent grass cover best predicted mean number of grasshopper sparrows fledged, whereas the model including grass cover best predicted number of eastern meadowlarks fledged (Tables 13-14). Grasshopper sparrow nests were predicted to fledge more young when placed in areas with more grass cover (Table 14, Figure 11). The distance to runway model predicted that grasshopper sparrow nests placed further from active runways also produced more young (Table 14), but visual inspection of predicted values indicated that this finding may have been affected by a site-distance interaction (Figure 12), which could not be examined more closely due to sample-size limitations. Eastern meadowlark nests tended towards higher productivity when less grass cover was present (Table 14, Figure 13).

DISCUSSION

The first year of this study has generated useful qualitative and quantitative information regarding grassland bird nesting microhabitat and overall productivity on LNAES, PRNAS, and WARB. Although limited sample sizes obtained for each site has thus far precluded us from making strong inferences about site-specific limiting factors, a general picture is beginning to emerge regarding the implications of management actions on grassland bird breeding success on regional DoD airfields.

The top-ranking combined-sites models of daily nest survival rates (DSR) pointed to several potential factors affecting grasshopper sparrow and eastern meadowlark DSR, including distance to runway and percent grass cover. However, these models did not perform substantially better than the null model (e.g., pseudo $R^2 \leq 0.08$, confidence intervals overlapping zero) indicating poor predictive power. When the models were run separately for each site, performance was somewhat better. The best-performing individual-site models for grasshopper sparrow suggested that nests with greater amounts of grass cover (PRNAS) or those farther from active runways (LNAES and WARB) had greater survival. For eastern meadowlark, best-performing models suggested that nests active later in the season (PRNAS), or those with less grass cover (LNAES and WARB) fared better. While several of these models represented relatively good improvements over the null model (e.g., pseudo $R^2 \leq 0.42$, parameter confidence intervals not overlapping zero), it should be noted that the individual-site analyses were limited by smaller sample sizes, increasing the potential for spurious results. The addition of more nests in the 2010 field season will provide opportunities for further exploring these trends, several of which have plausible biological explanations.

The positive relationship found between grasshopper sparrow DSR and distance to runway at both LNAES and WARB (Table 7) could be due to disturbance associated with aircraft activity. Disturbance from human activities is well-known to reduce fitness in several avian guilds (reviews in Hockin *et al*. 1992, Carney and Sydeman 1999), through increased rates of predation (Giese 1996), nest abandonment (Anderson and Keith 1980) or lowered nest attendance by adults (Verhulst et al. 2001). Grassland birds have also been documented to avoid breeding in areas near heavy road traffic (Forman et al. 2004). Interestingly, in some cases this lowered habitat use may offset density-dependent reductions in breeding success, as has been demonstrated with ground-nesting woodlarks (*Lullula arborea*, Mallord et al. 2007). Clearly, more intensive data investigating the processes behind habitat selection and productivity on our airfields will be necessary to clarify potential runway effects. The dynamics will be particularly difficult to tease apart at LNAES, where most nests that are distant from runways are located in one area (i.e., Jump Circle), and at WARB, where the mowing plan dictates that areas directly adjacent to runways are mowed during the breeding season and those distant from runways are left unmowed. We feel that the best way to address these potential confounding factors and associated uncertainties is to implement an experimental approach. By initiating an experimental, rather than observational study, it would be possible to manipulate the variable of interest (i.e., grass height management), while controlling for other potentially confounding factors through sample design (e.g., randomization of treatment, paired-plot design). Such an approach would lead to stronger inferences about the true effects of runways and airfield mowing practices on avian habitat selection and breeding success.

Although mowing was a source of nest failure in our study, it did not emerge as a significant predictor of nest survival rates for either target species. It is important to note that sample sizes for directly mowed nests were extremely low, lowering the precision of DSR estimates, and making comparisons difficult. Only five grasshopper sparrow nests were mowed over during the course of the study, and the only data for mowed eastern meadowlark nests came from PRNAS (n = 14). Pooling data from both ‘mowed’ bases, we found that 19 of 56 target species nests located in mowed areas were passed over by a mower (34%), of which four (21%) were directly destroyed, and an additional three (16%) may have failed due to secondary causes (e.g., scavenging, abandonment).

Sample sizes for determining indirect effects of mowing (i.e., nests within areas that were mowed vs. unmowed areas) were generally higher, but only approached adequate levels for comparison at one site (i.e., eastern meadowlark at WARB: seven nests in mowed areas, seven in unmowed areas). For this group, we found meadowlark nests in mowed areas had poorer nest survival than those in unmowed (15 vs. 35% overall success, 0.92

vs. 0.96 DSR), though the 95% confidence intervals widely overlapped (Table 6). While this finding is inconclusive without additional data, it is relevant to note that in a separate study, these data were combined with those from other grassland obligate breeders on the site, including upland sandpiper, and the effect size was considerably larger (Peters and Allen 2009b).

Mowing-induced mortality rates at our sites (both direct and indirect) were lower than expected based on the results of several previous studies (Bollinger et al. 1990, Kershner and Bollinger 1996, Perlut et al. 2006). In a study of bobolinks in New York, hay cutting (not including raking and baling) caused direct mortality of 51% of eggs and nestlings, plus an additional 24% through nest abandonment (Bollinger et al. 1990). On Illinois airports, Kershner and Bollinger (1996) found mowing to be the cause of 44% of all grassland bird nest mortality. Haying in late May / early June in Vermont (including raking and baling) resulted in the direct mortality of 78% of savannah sparrow and bobolink nests, while nearly all remaining nests were scavenged by predators (Perlut et al. 2006).

Several factors may have resulted in the comparatively lower mowing mortality rates in our study, including mowing height, mowing intensity, and timing. Fields at airports studied by Kershner and Bollinger (1996) had a fairly low average mowing height of 11 cm and a minimum of 5 cm, while all fields at WARB and most at PRNAS were cut at a height of 18 cm (7 inches, D. Milroy, *personal comm.*). This height difference, though not large, could have reduced the probability of direct damage to eggs or nestlings. Studies involving hay cutting (Bollinger et al. 1990, Perlut et al. 2006) may have experienced higher mortality rates due to the larger and potentially more invasive machinery, especially in the case of Perlut et al. (2006) whose mortality rates also included additional passes by raking and baling machines. Timing could have also played a role, as mowing began unusually late on WARB in 2009 (early June; MCA, *personal obs.*), which may have allowed more pairs to complete the nesting cycle before being mowed.

Another potential factor is that our main measure of nest survival (DSR) doesn't take into account partial nest failures (i.e., one fledgling = successful nest, Dinsmore et al. 2002), and therefore ignores any individual egg or nestling mortality potentially caused by mowing. Productivity modeling (i.e., number of fledglings produced) such as we presented in Tables 13 and 14, is a first step towards addressing this. Results from these analyses showed similar trends as those from the DSR analyses: a positive effect of distance to runway for grasshopper sparrow productivity, and a negative effect of grass cover for eastern meadowlark. With greater sample sizes in 2010 we will also be able to examine productivity for the subset of 'successful' nests (i.e., mowed successful vs. unmowed successful), thus excluding the effects of predation and other causes of nest failure already captured by the DSR modeling. Another technique to consider would be comparing the mortality rates of individual eggs and nestlings (rather than of the nests as a whole) as was done by Bollinger et al. (1990).

We anticipate that the increased sample sizes obtained during the 2010 breeding season will enhance our ability to detect potential effects of mowing, either direct or indirect, on grassland bird breeding success. It seems likely that nests that are directly mowed over are at greater risk of failure, based on observations we made in 2009 of nests that were crushed or partially destroyed by mowers, and on results from similar studies (e.g., Kershner and Bollinger 1996). Also, because mowed areas generally have less concealing vegetation than unmowed areas, nests in these areas would be expected to be vulnerable to indirect effects including predation/scavenging (Bollinger et al. 1990, Perlut et al. 2006) and exposure to the elements (With and Webb 1993). A mowing-induced reduction in food resources could also reduce nest survival due to lowered provisioning rates (Zalilk and Strong 2008) and increase exposure as parents remain off the nest for longer periods of time in pursuit of food.

Despite these expectations, nest survival rates at our three study sites in 2009 were relatively high for both target species when compared with the literature. For grasshopper sparrow, pooled DSR estimates ranged from 0.96 at LNAES to 0.99 at WARB, compared to a range of 0.91-0.96 from three other studies (only studies with > 20 nests included; Perkins et al. 2003, Galligan et al. 2006, Giocomo et al. 2008). For eastern meadowlark, estimates ranged from 0.92 at PRNAS to 0.98 at LNAES, and from 0.93-0.95 in published reports (Galligan et al. 2006, Perkins and Vickery 2007, Giocomo et al. 2008). Given the nest survival rates we observed in 2009, we have no immediate reason to believe that our three study sites are acting as "ecological traps" (Robertson and Hutton 2006), or population sinks in which birds are attracted to nest, but do not reproduce successfully. Furthermore, there is evidence that grasshopper sparrow, at least, can produce two broods at our sites (e.g., Figure 8 [PRNAS], Jones 2000 [WARB]), which would allow a higher annual productivity for pairs that do escape the mower. However, source-sink population dynamics depend not only on annual productivity, but also on factors more difficult to measure, such as juvenile and adult survival (Perlut et al. 2008). For example, poor fledgling survival due to mowing-related habitat alteration would have a negative effect on population health, similar to poor nest survival, but would be logistically difficult to assess in the current study.

Because airfields are thought to be of great importance to regional populations of declining grassland birds, and are likely to become more so in the future (Askins et al. 2007), it is imperative that good data on populations and demography at these sites are available. Given the conflicting results of the first year of our study with those from other airports (e.g., Kershner and Bollinger 1996), much uncertainty remains concerning the effects of airfield management and operations on grassland bird productivity. More data from these and other sites with varying management and operational activities will be valuable in elucidating the role that DoD and other airfields will play in the future population viability of grassland birds.

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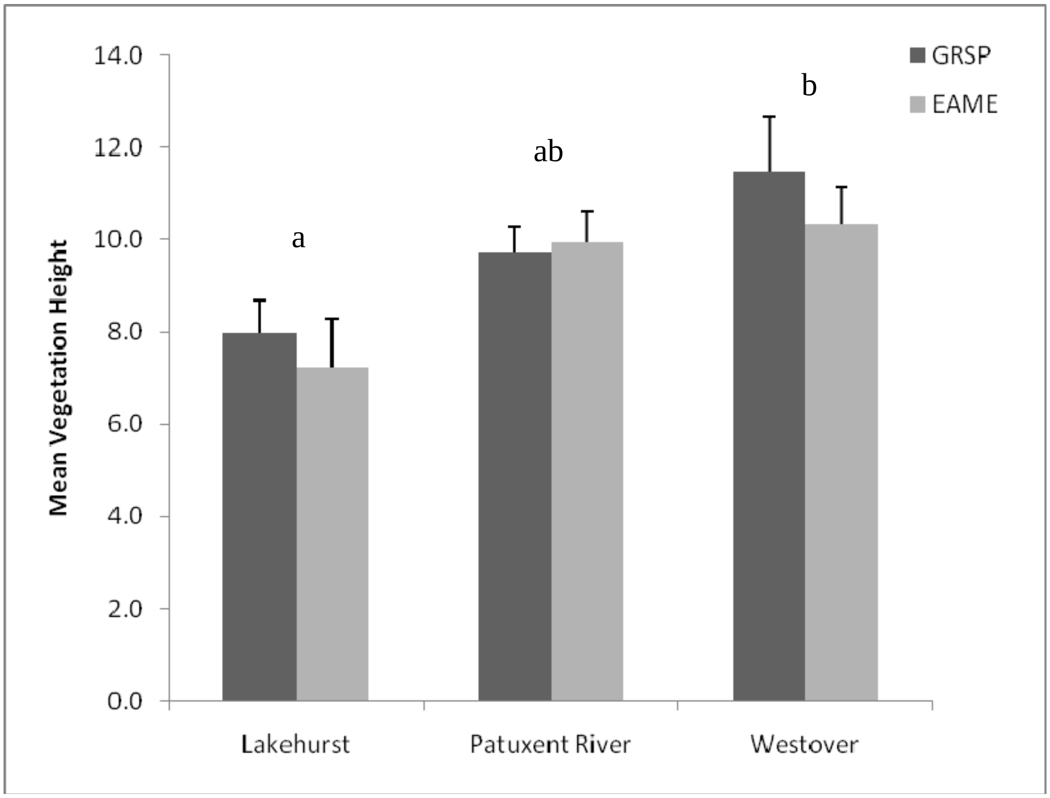


Figure 1. Mean (SE) vegetation height (in) around nests immediately after completion or failure. Vegetation around grasshopper sparrow nests at Lakehurst was significantly shorter than vegetation at Westover.

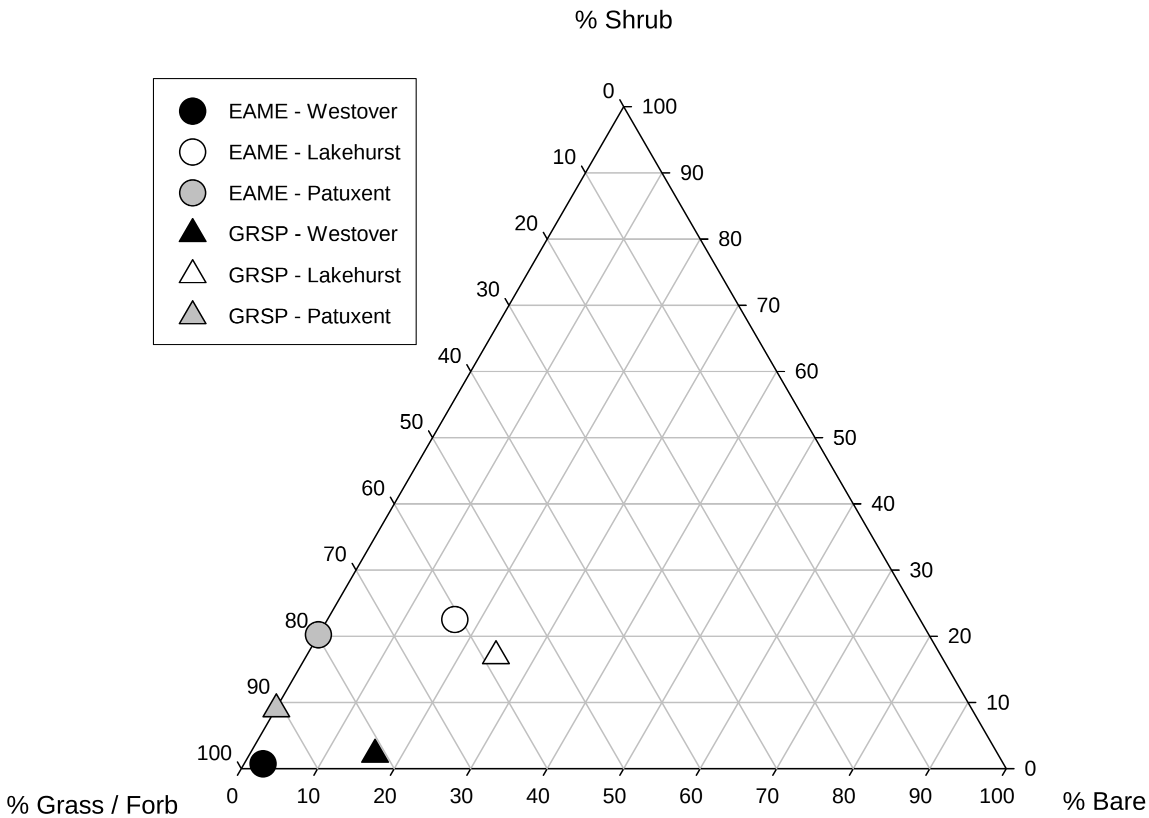


Figure 2. Horizontal cover profile of vegetation around nests. Nests of both target species tended to be in areas with more bare ground and shrub cover at LNAES than at other sites.

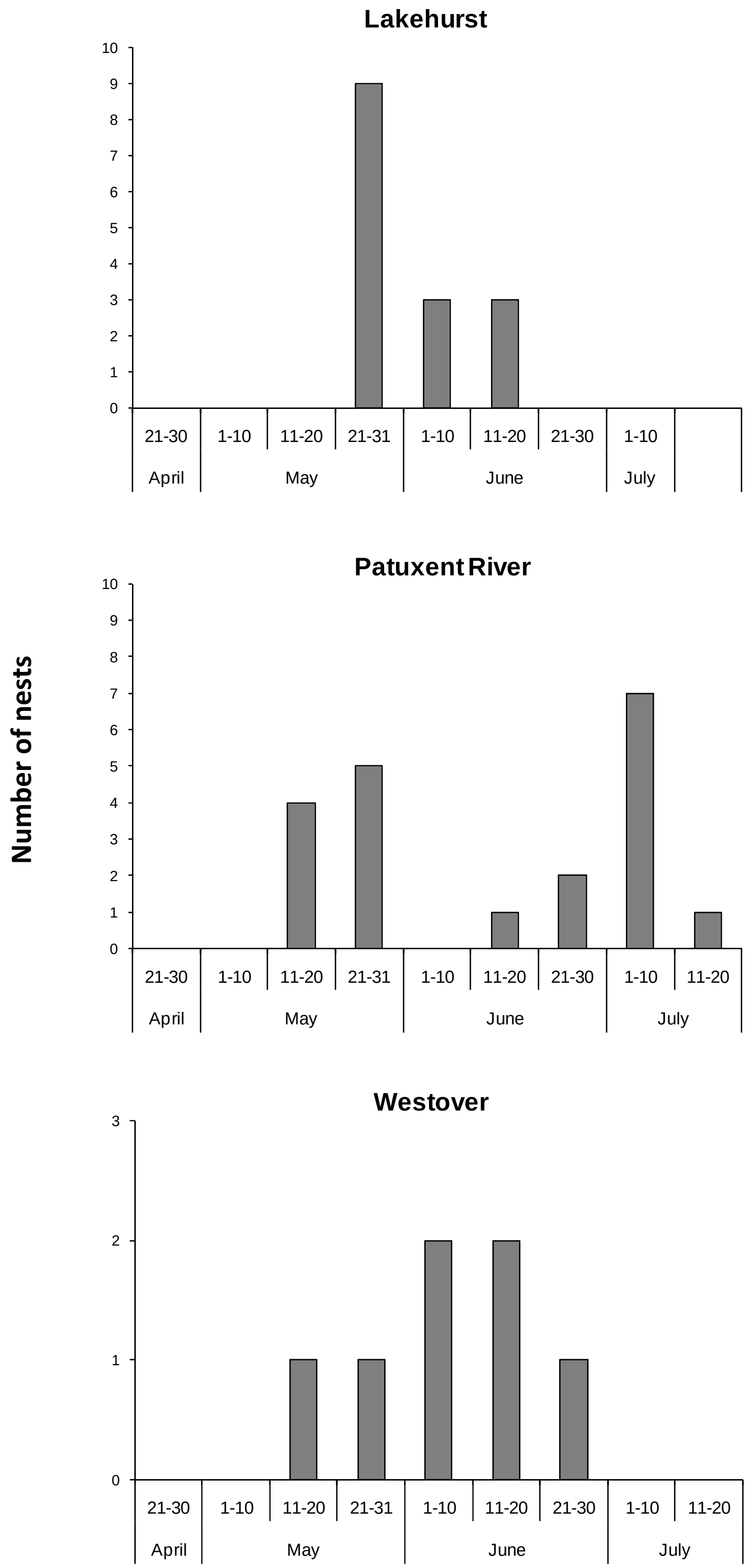


Figure 3. Estimated initiation dates (start of incubation) for grasshopper sparrow nests monitored at LNAES, PRNAS, and WARB, 2009.

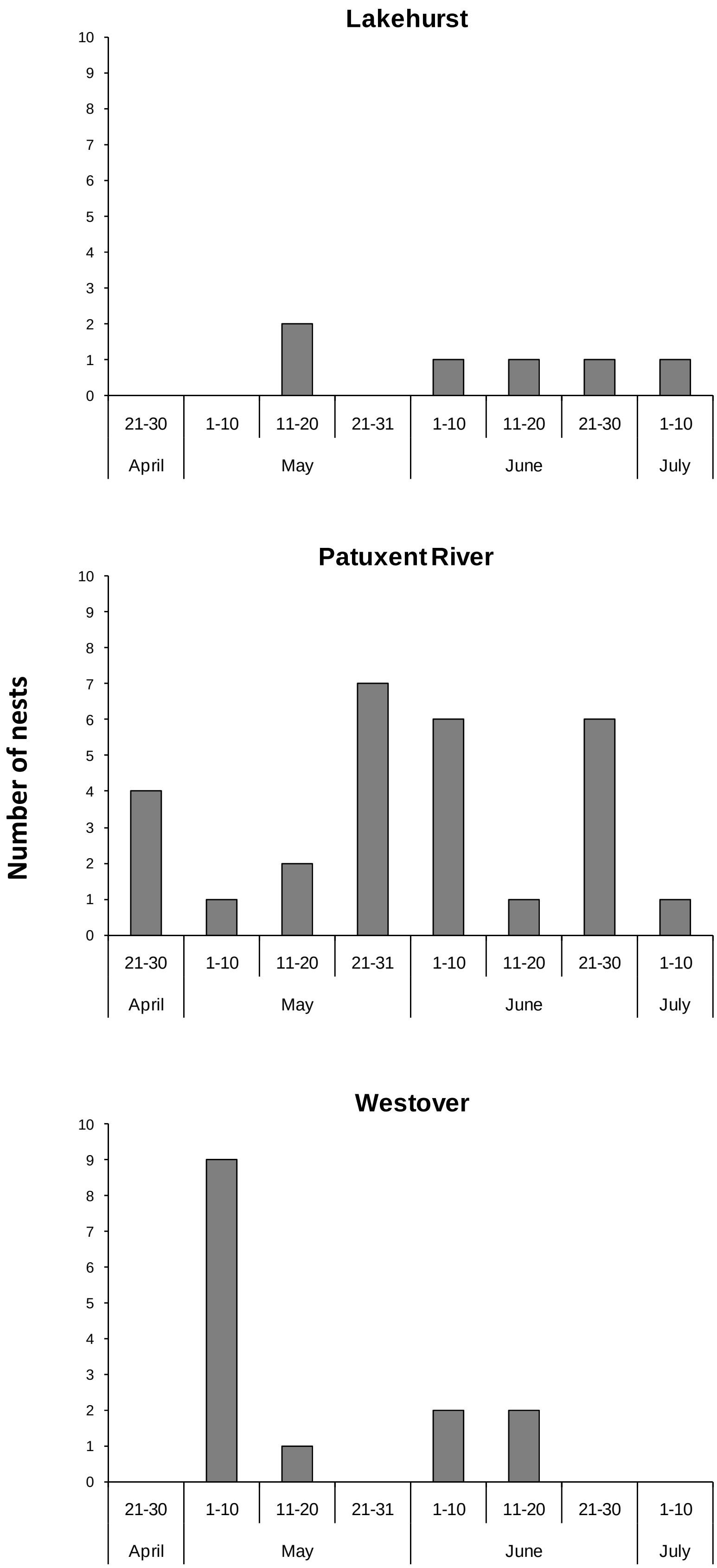
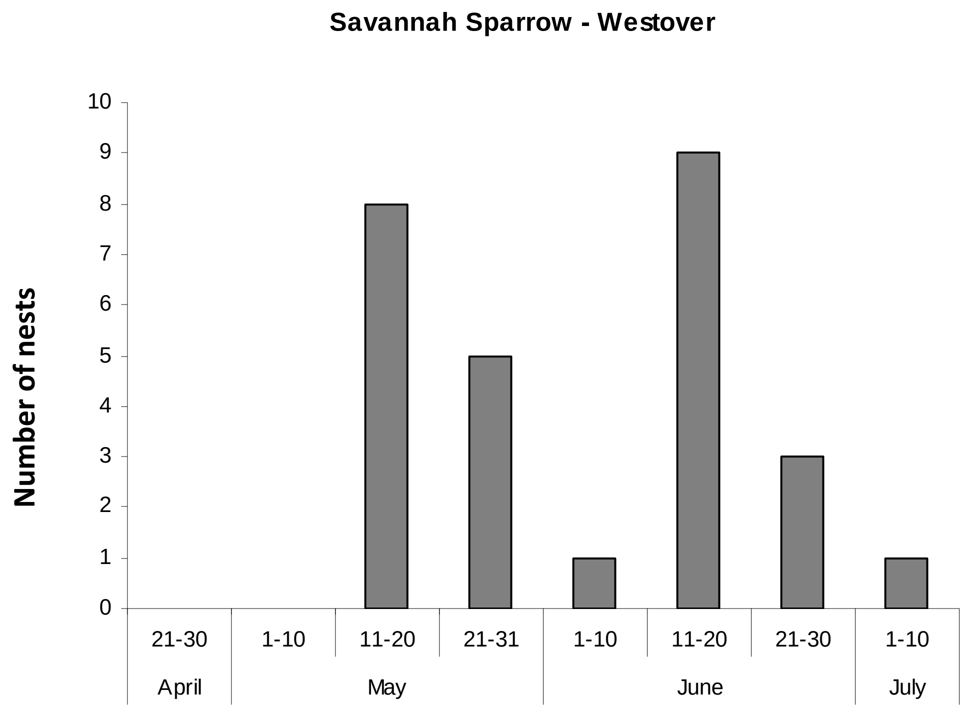


Figure 4. Estimated initiation dates (start of incubation) for eastern meadowlark nests monitored at LNAES, PRNAS, and WARB, 2009.



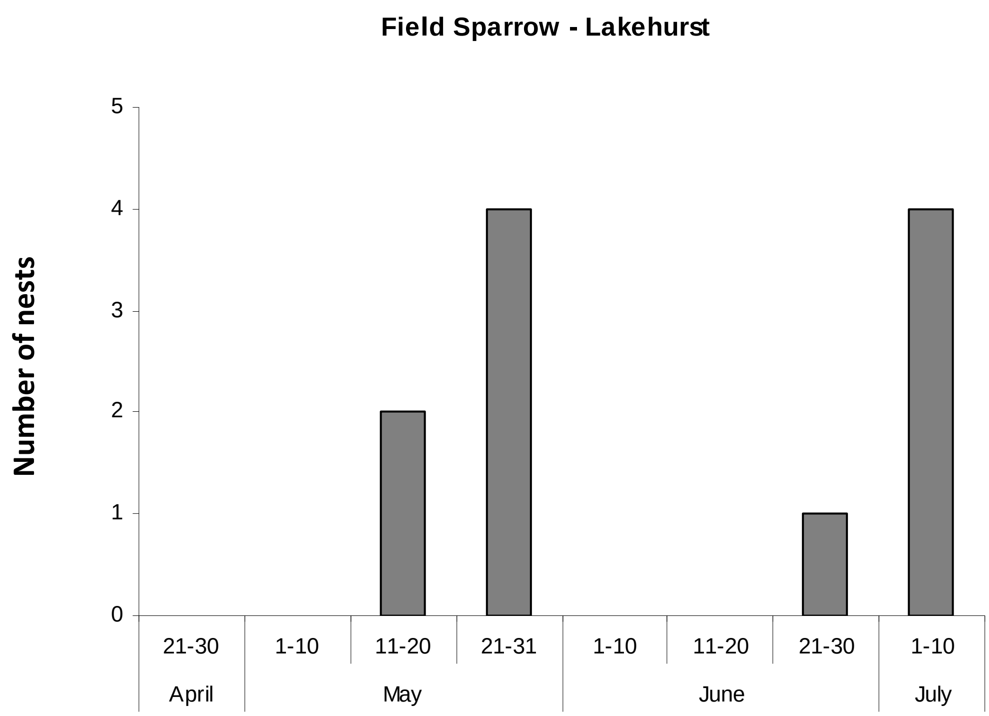


Figure 5. Estimated initiation dates (start of incubation) for savannah sparrow and field sparrow nests monitored at WARB and LNAES, respectively, in 2009.

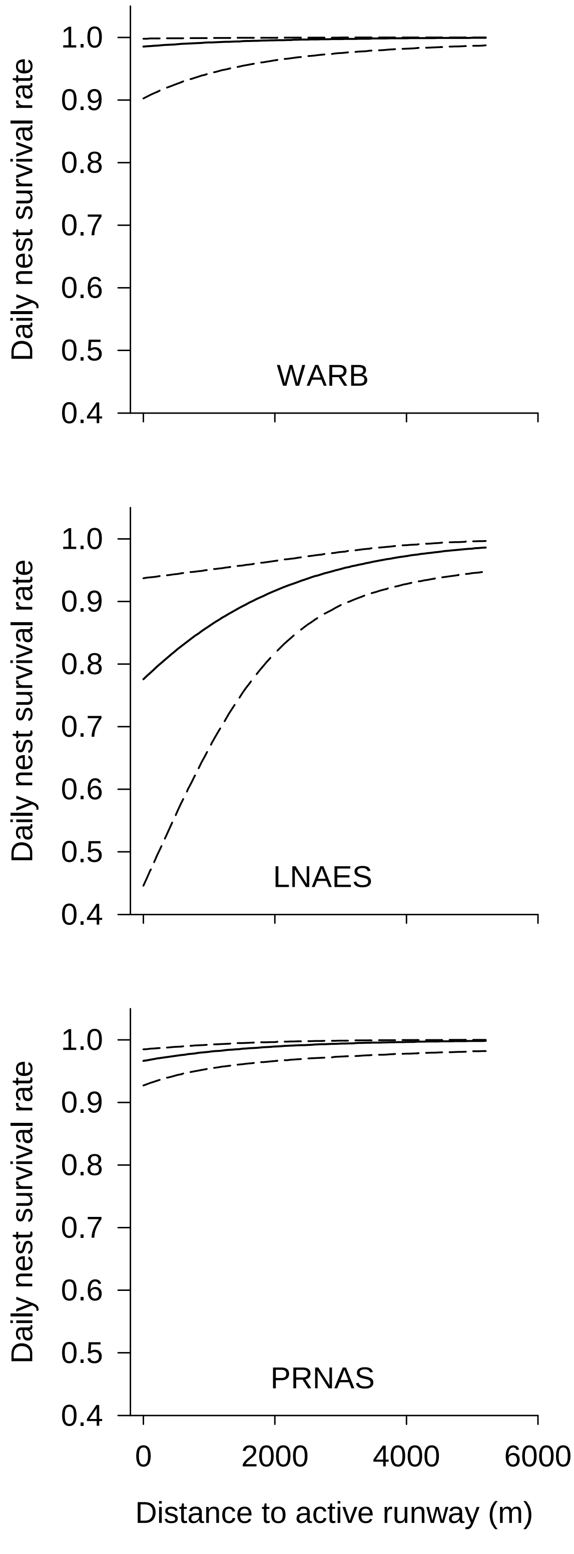


Figure 6. Predicted DSR for grasshopper sparrow nests (with 95% confidence limits) vs. distance to the nearest active runway surface.

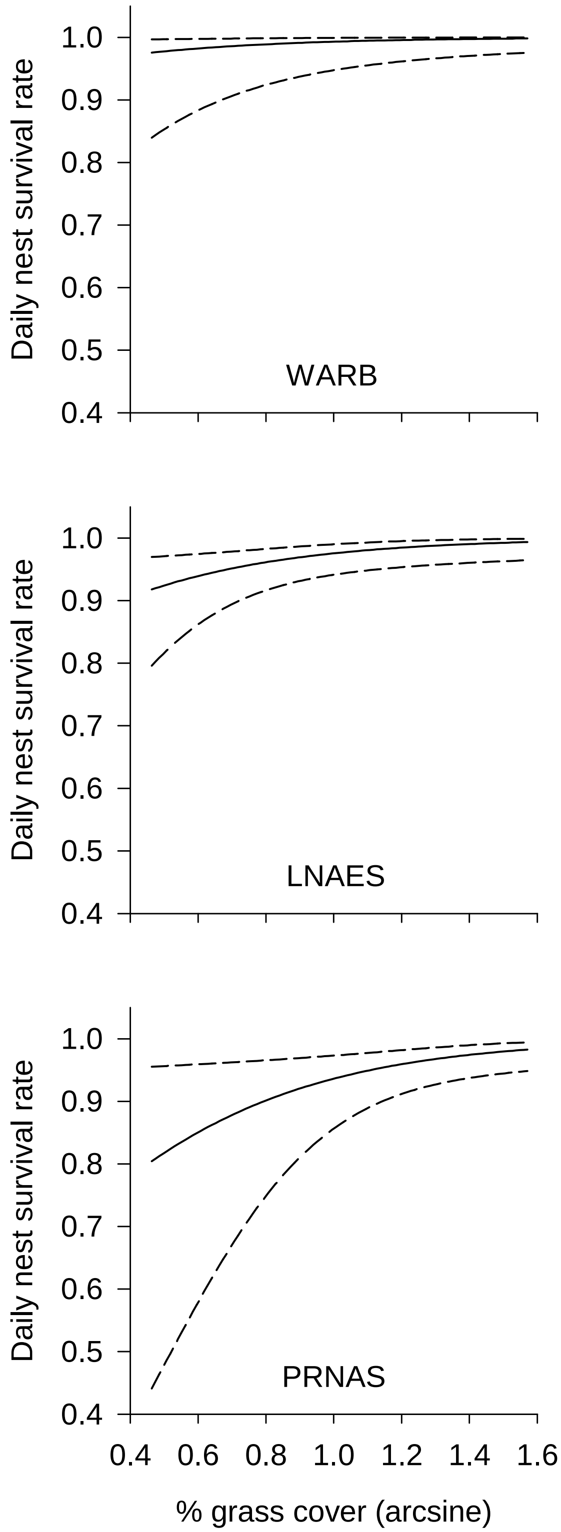


Figure 7. Predicted DSR (with 95% confidence limits) for grasshopper sparrow nests vs. percent grass cover at the nest site (arcsine transformed).

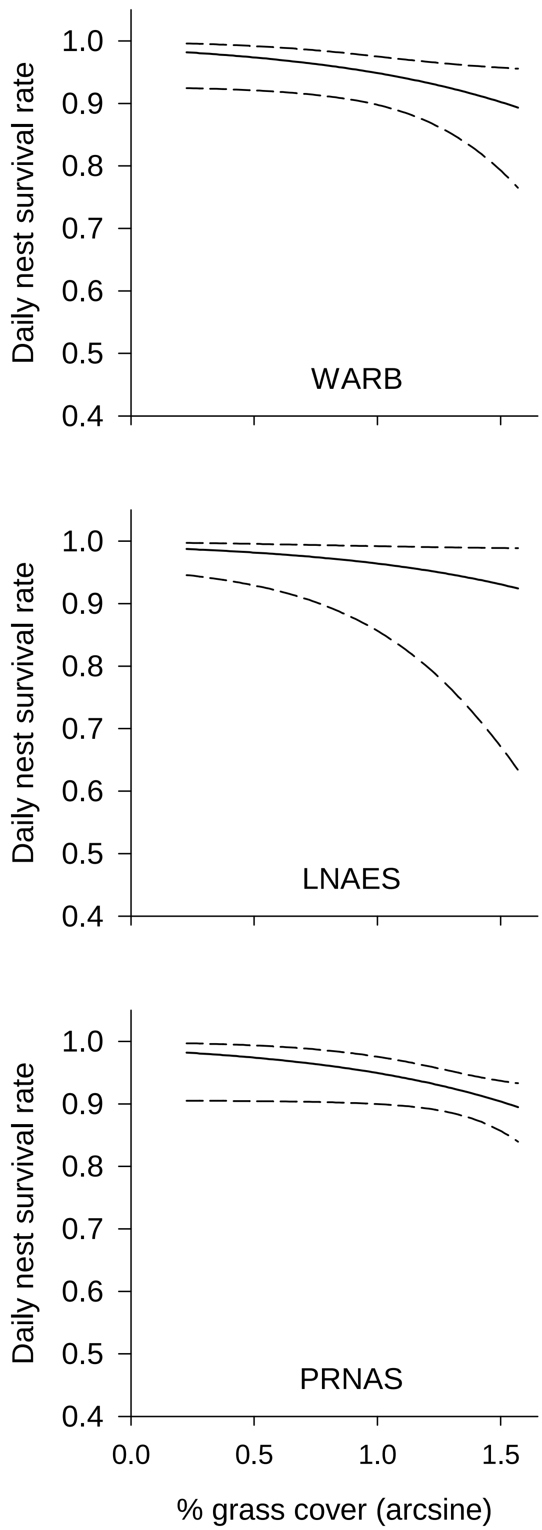


Figure 8. Predicted DSR for eastern meadowlark nests (with 95% confidence limits) vs. percent grass cover at the nest site (arcsine transformed).

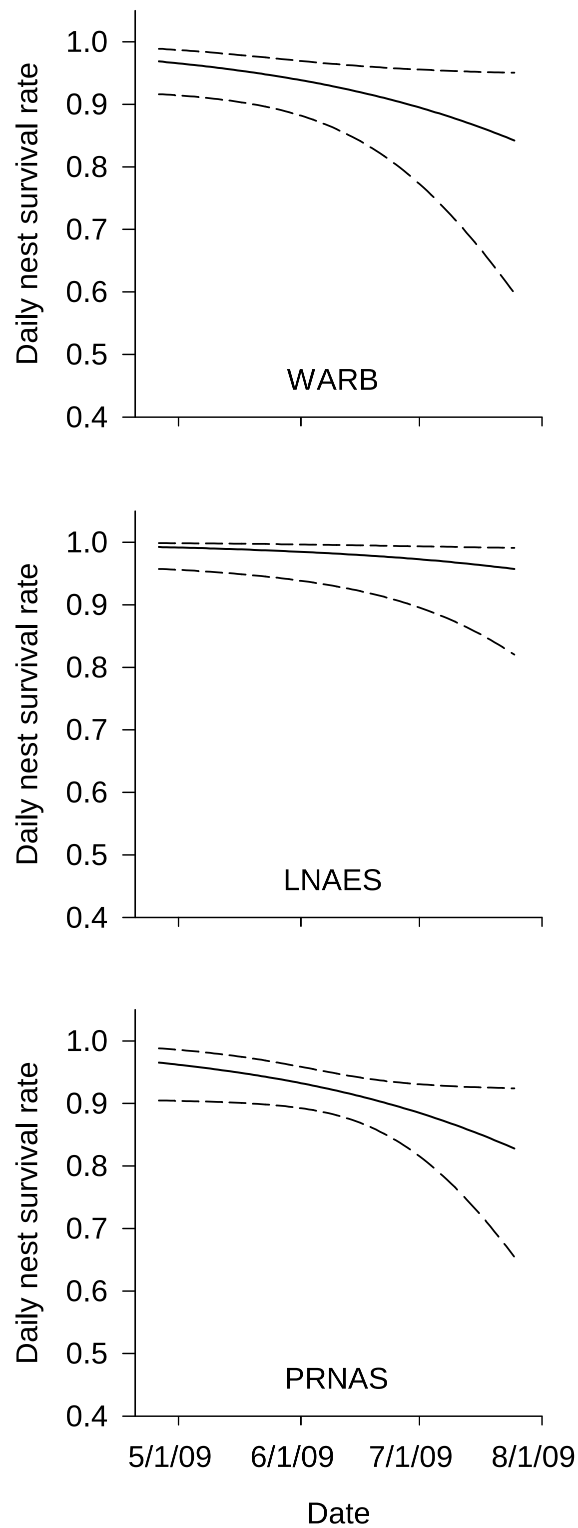


Figure 9. Predicted DSR for eastern meadowlark nests (with 95% confidence limits) vs. day of season.

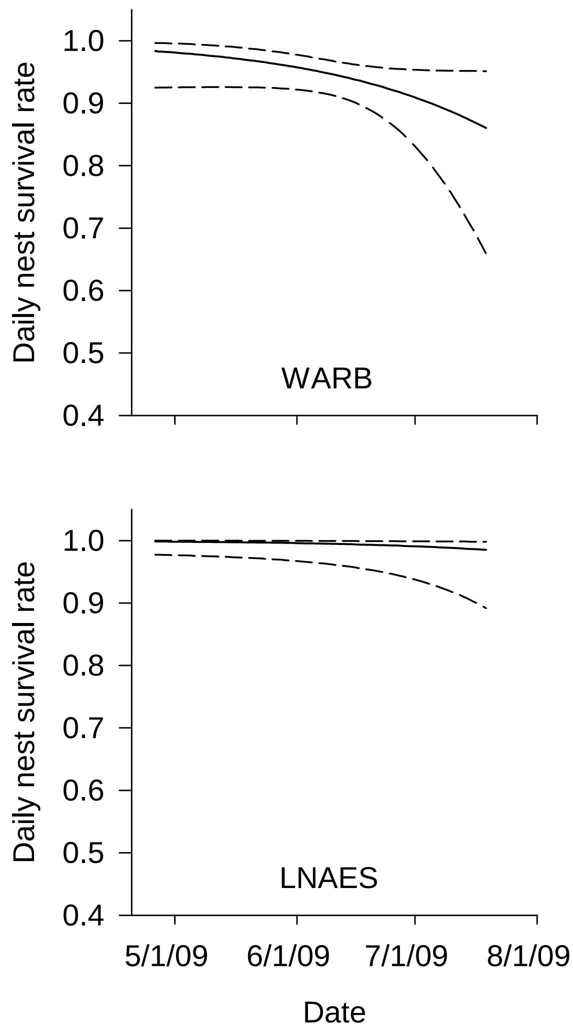


Figure 10. Predicted DSR for "other passerine" nests (with 95% confidence limits) vs. day of season. Species included savannah sparrow, bobolink, and horned lark on WARB, and field sparrow on LNAES.

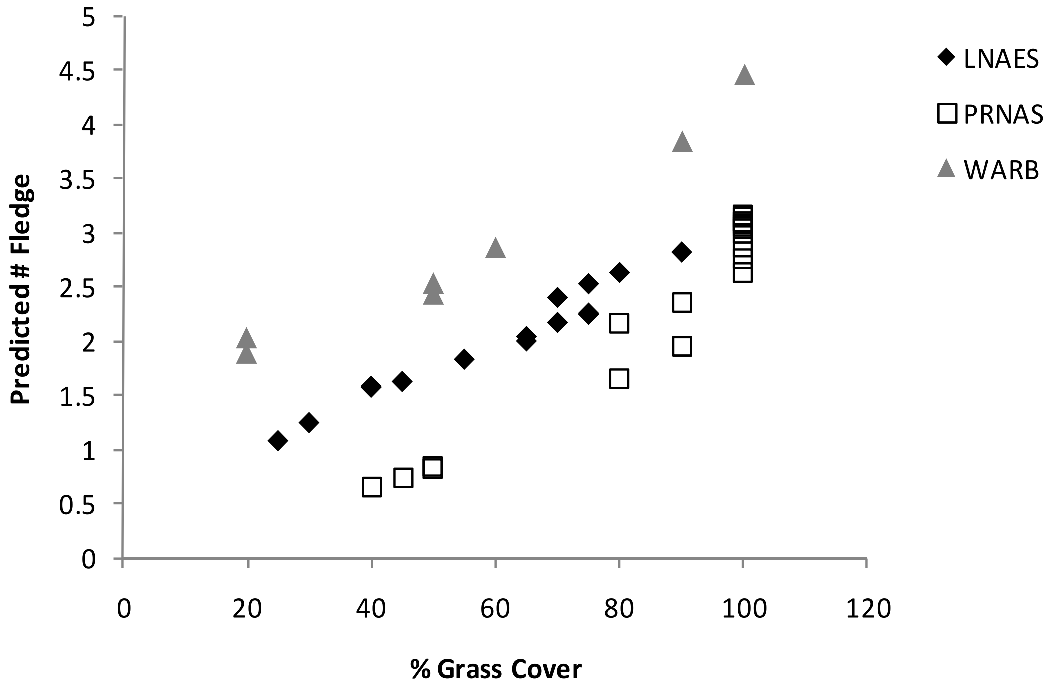


Figure 11. Predicted number of grasshopper sparrows fledged per nest in relation to horizontal grass cover. Predicted values based on the best performing general linear models listed in Table 13.

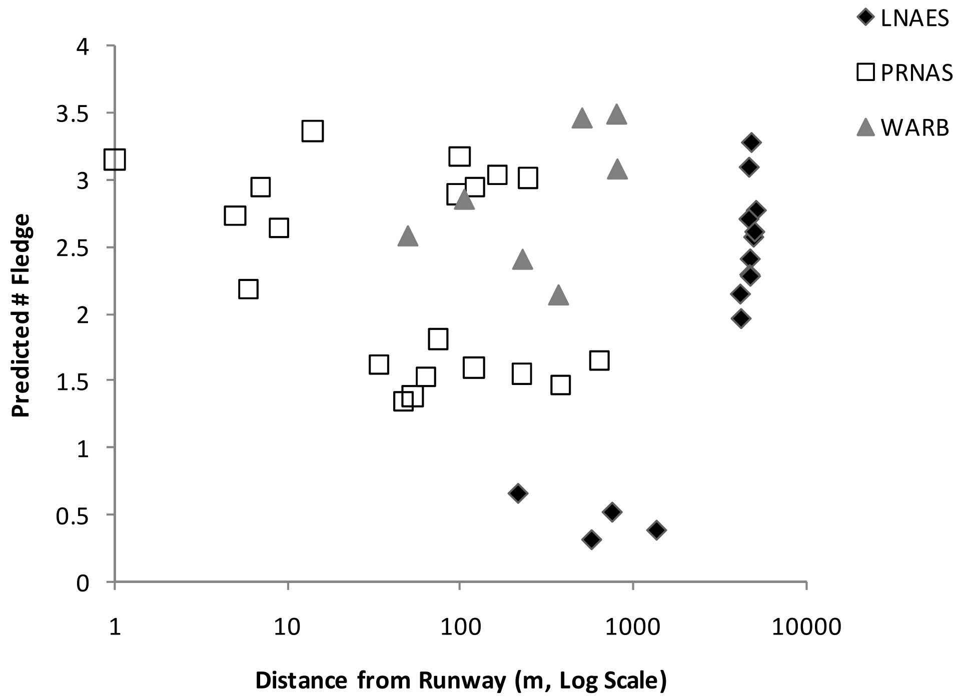


Figure 12. Predicted number of grasshopper sparrows fledged in relation to distance from nearest runway. Predicted values based on the best performing general linear models listed in Table 13.

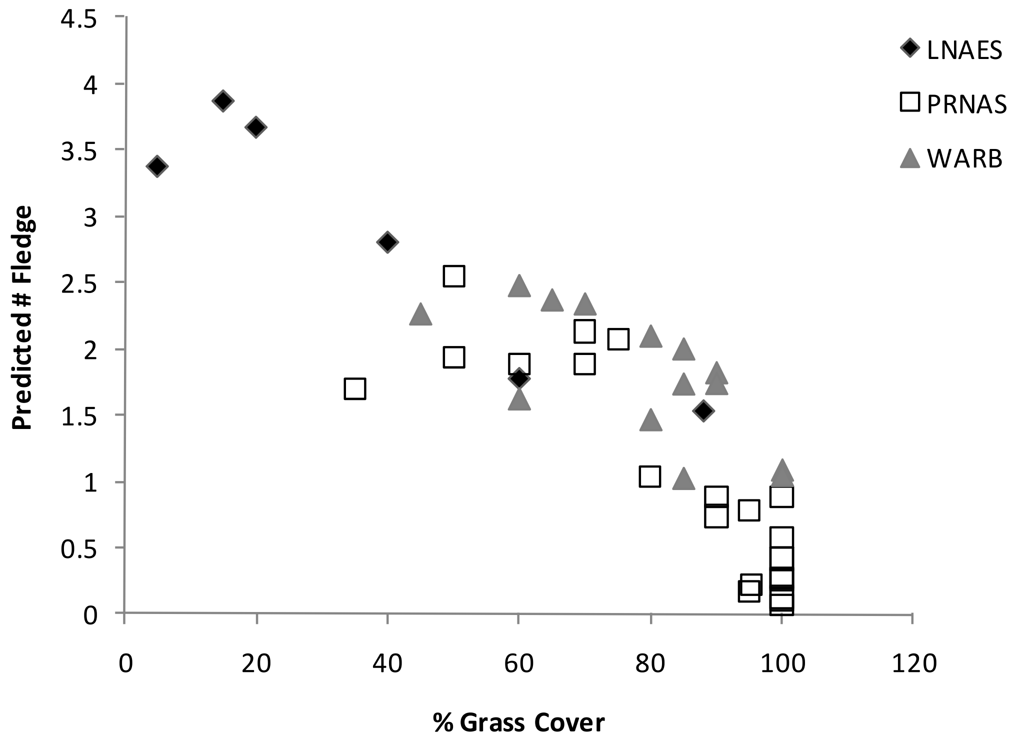


Figure 13. Predicted number of eastern meadowlarks fledged per nest in relation horizontal grass cover. Predicted values based on the best performing general linear model listed in Table 13.

Table 1. Summary statistics for vegetation characteristics at grasshopper sparrow nests during the 2009 breeding season.

Base	Variable	Mean	SD	CV	Minimum	Median	Maximum	n
Lakehurst	Initial Height	7.1	2.3	0.32	3.9	7.2	12.0	15
	Final Height	8.0	2.8	0.35	3.7	8.3	13.6	15
	% Bare	24.8	20.7	0.83	0.0	30.0	70.0	15
	% Grass	60.0	19.6	0.33	25.0	65.0	90.0	15
	% Forb	1.3	3.3	2.47	0.0	0.0	12.0	15
	% Shrub	17.0	13.1	0.77	0.0	15.0	50.0	15
	Clumpiness	2.3	0.7	0.31	1.0	2.0	3.0	15
Patuxent River	Initial Height	10.2	3.2	0.31	5.4	9.9	20.4	20
	Final Height	9.7	2.4	0.25	5.4	9.9	13.7	20
	% Bare	0.1	0.4	447.2	0.0	0.0	2.0	20
	% Grass	85.8	21.4	24.9	40.0	100.0	100.0	20
	% Forb	24.4	24.8	101.5	5.0	15.0	90.0	20
	% Shrub	9.0	16.7	185.0	0.0	2.5	60.0	20
	Clumpiness	2.1	0.5	24.9	1.0	2.0	3.0	20
Westover	Initial Height	10.0	4.8	0.48	6.5	9.1	20.3	7
	Final Height	11.5	3.2	0.28	8.3	9.9	16.9	7
	% Bare	16.4	16.3	99.0	0.0	15.0	40.0	7
	% Grass	55.7	31.0	55.7	20.0	50.0	100.0	7
	% Forb	30.0	24.3	81.1	5.0	25.0	70.0	7
	% Shrub	2.1	5.7	264.6	0.0	0.0	15.0	7
	Clumpiness	2.1	0.9	42.0	1.0	2.0	3.0	7

Table 2. Summary statistics for vegetation characteristics at eastern meadowlark nests during the 2009 breeding season.

Base	Variable	Mean	SD	CV	Minimum	Median	Maximum	n
Lakehurst	Initial Height	6.7	3.2	0.47	2.3	6.5	11.9	6
	Final Height	7.2	2.5	0.35	3.8	7.0	10.7	6
	% Bare	16.7	16.0	0.96	5.0	10.0	45.0	6
	% Grass	38.0	31.4	0.83	5.0	30.0	88.0	6
	% Forb	26.7	30.1	1.13	0.0	20.0	80.0	6
	% Shrub	22.5	27.2	1.21	0.0	12.5	60.0	6
	Clumpiness	2.3	0.8	0.35	1.0	2.5	3.0	6
Patuxent River	Initial Height	11.5	3.1	0.27	6.5	11.0	18.0	28
	Final Height	9.9	3.6	0.36	2.8	9.4	19.1	27
	% Bare	0.0	0.0	-	0.0	0.0	0.0	27
	% Grass	87.4	19.2	0.22	35.0	100.0	100.0	27
	% Forb	13.6	16.4	1.21	0.0	10.0	70.0	27
	% Shrub	20.2	25.4	1.26	0.0	10.0	90.0	27
	Clumpiness	1.9	0.6	0.32	1.0	2.0	3.0	27
Westover	Initial Height	9.0	4.0	0.44	4.3	8.1	17.5	14
	Final Height	10.4	3.0	0.29	5.3	10.5	15.6	14
	% Bare	2.5	4.3	1.71	0.0	0.0	10.0	14
	% Grass	78.2	16.1	0.21	45.0	82.5	100.0	14
	% Forb	23.4	15.7	0.67	2.0	20.0	50.0	14
	% Shrub	0.7	2.7	3.74	0.0	0.0	10.0	14
	Clumpiness	2.0	0.6	0.28	1.0	2.0	3.0	14

Table 3. Logistic models of daily survival rates for nests found at all bases in 2009 (sites combined). Models are ranked by ΔAIC_c.

Model	ΔAIC_c	AIC_c Weights	No. Parameters	Deviance	Pseudo R^{2a}
Grasshopper Sparrow (min AICc = 95.84; n = 42 nests)					
Site - D. To Runway	0.00	0.42	4	87.75	0.08
Site - % Grass	1.20	0.23	4	88.95	0.07
Null	1.81	0.17	1	95.64	-
Site - Day of Season	4.23	0.05	4	91.97	0.04
Site	4.44	0.05	3	94.23	0.01
Site - Nest Mowed	5.26	0.03	4	93.01	0.03
Site - Veg. Height	5.84	0.02	4	93.58	0.02
Site - Clumpiness	6.31	0.02	4	94.06	0.02
Site - Mowed Area	6.45	0.02	4	94.19	0.02
Eastern Meadowlark (min AICc = 187.49; n = 48 nests)					
Site - % Grass	0.00	0.32	4	179.40	0.05
Site - Day of Season	0.41	0.26	4	179.81	0.05
Site	2.01	0.12	3	183.45	0.03
Site - D. To Runway	3.39	0.06	4	182.79	0.03
Site - Mowed Area	3.40	0.06	4	182.80	0.03
Site - Veg. Height	3.81	0.05	4	183.22	0.03
Site - Nest Mowed	3.89	0.05	4	183.29	0.03
Null	3.90	0.05	1	189.38	-
Site - Clumpiness	3.95	0.04	4	183.35	0.03
Other Passerines (min AIC_c = 106.80; n = 41 nests)					
Site - Day of Season	0.00	0.32	3	100.74	0.10
Site	1.18	0.18	2	103.95	0.07
Site - Nest Mowed	2.12	0.11	3	102.86	0.08
Site - Veg. Height	2.37	0.10	3	103.11	0.08
Site - Mowed Area	2.59	0.09	3	103.33	0.08
Site - Clumpiness	2.87	0.08	3	103.61	0.07
Site - % Grass	3.09	0.07	3	103.83	0.07
Site - D. To Runway	3.18	0.06	3	103.92	0.07
Null	6.94	0.01	1	111.73	-

[a]McFadden's pseudo R^2 (likelihood ratio index).

Table 4. Parameter estimates from the best performing logistic models (≤ 2 ΔAIC_c) of grasshopper sparrow and eastern meadowlark daily nest survival rates in 2009 (sites combined).

Model	Independent Variable	*B*	SE	95% CI
Grasshopper Sparrow (n = 42 nests)				
Site - D. to Runway	Patuxent	-0.8474	1.0901	-2.9841, 1.2892
	Lakehurst	-2.9628	1.2152	-5.3446, -0.5809
	D. to Runway	0.0006	0.0002	0.0001, 0.0010
	Intercept	4.2025	1.0092	2.2244, 6.1805
Site - % Grass	Patuxent	-2.2706	1.1997	-4.622, 0.0808
	Lakehurst	-1.2705	1.0962	-3.4191, 0.8781
	% Grass	2.3760	1.0140	0.3886, 4.3634
	Intercept	2.5821	1.2294	0.1725, 4.9917
Null	Intercept	1.2250	0.0477	1.1315, 1.3186
Eastern Meadowlark (n = 49 nests)				
Site - % Grass	Patuxent	0.0174	0.4750	-0.9135, 0.9484
	Lakehurst	0.3771	0.8892	-1.3658, 2.1200
	% Grass	-1.3822	0.7224	-2.7982, 0.0337
	Intercept	4.2950	0.9004	2.5303, 6.0597
Site - Day of Season	Patuxent	-0.1030	0.4461	-0.9774, 0.7714
	Lakehurst	1.4322	0.8185	-0.1721, 3.0365
	Day of Season	-0.0195	0.0102	-0.0395, 0.0005
	Intercept	3.4477	0.5364	2.3963, 4.4992
Other Passerines (n = 41 nests)*				
Site - Day of Season	Lakehurst	2.3734	1.0532	0.3091, 4.4377
	Day of Season	-0.0269	0.0153	-0.0570, 0.0031
	Intercept	4.1092	0.8164	2.5090, 5.7093
Site	Lakehurst	2.12809	1.03602	0.0975, 4.1587
	Intercept	2.83472	0.25751	2.3300, 3.3394

* Includes field sparrow at Lakehurst, and savannah sparrow, horned lark, and bobolink at Westover.

Table 5. Daily survival rate (DSR) estimates for grasshopper sparrow nests monitored during the 2009 season.

Species - Mow Type	No. Nests	No. Failures	DSR	SE	95 CI - Lower	95 CI - Upper
Patuxent River						
Mowed areas	19	5	0.97221	0.01226	0.93498	0.98839
Non-mowed areas	1	1	0.84515	0.14286	0.39115	0.97889
Mowed nests	4	0	1.00000	0.00000	0.99999	1.00001
Non-mowed nests	16	6	0.95015	0.01985	0.89341	0.97744
All nests	20	6	0.96781	0.01293	0.93021	0.98547
Lakehurst						
All nests (non-mowed)	15	6	0.96447	0.01425	0.92317	0.98396
Westover						
Mowed areas	3	1	0.96428	0.03507	0.78581	0.99499
Non-mowed areas	4	0	1.00000	0.00000	1.00000	1.00000
Mowed nests	1	1	0.88889	0.10476	0.50014	0.98461
Non-mowed nests	6	0	1.00000	0.00000	1.00000	1.00000
All nests	7	1	0.98810	0.01183	0.92035	0.99833

Table 6. Daily survival rate (DSR) estimates for eastern meadowlark nests monitored during the 2009 season.

Species - Mow Type	No. Nests	No. Failures	DSR	SE	95 CI - Lower	95 CI - Upper
Patuxent River						
Mowed areas	27	21	0.91712	0.01734	0.87616	0.94537
Non-mowed areas	1	1	0.93095	0.06667	0.63846	0.99038
Mowed nests	14	11	0.91389	0.02485	0.85110	0.95170
Non-mowed nests	14	11	0.92149	0.02276	0.86369	0.95603
All nests	28	22	0.91786	0.01680	0.87836	0.94534
Lakehurst						
All nests (non-mowed)	7	2	0.98039	0.01373	0.92499	0.99509
Westover						
Mowed areas	7	5	0.92284	0.03320	0.82745	0.96756
Non-mowed areas	7	3	0.95709	0.02425	0.87516	0.98610
Mowed nests	0	0	-	-	-	-
Non-mowed nests	14	8	0.94062	0.02038	0.88568	0.97005
All nests	14	8	0.94062	0.02038	0.88568	0.97005

Table 7. Logistic models of daily survival rates for grasshopper sparrow nests monitored during the 2009 season. Models are ranked by ΔAIC_c.

Model[a]	ΔAIC_c	AIC_c Weights	No. Parameters	Deviance	Pseudo R^2
Patuxent River (min AIC_c = 38.48; n = 20 nests)					
% Grass	0.00	0.38	2	34.41	0.19
Nest Mowed	0.72	0.27	1	37.17	0.13
Day of Season	0.85	0.25	2	35.26	0.17
D. To Runway	5.05	0.03	2	39.46	0.07
Clumpiness	5.40	0.03	2	39.81	0.06
Null	6.07	0.02	1	42.53	-
Mowed Area	6.34	0.02	2	40.75	0.04
Veg. Height	7.87	0.01	2	42.28	0.01
Lakehurst (min AIC_c = 37.96; n = 15 nests)					
D. To Runway	0.00	0.74	2	33.89	0.17
Day of Season	4.58	0.07	2	38.47	0.06
Null	4.91	0.06	1	40.85	-
Veg. Height	5.37	0.05	2	39.25	0.04
% Grass	5.67	0.04	2	39.56	0.03
Clumpiness	6.50	0.03	2	40.38	0.01
Westover (min AIC_c = 8.33; n = 7 nests)					
D. To Runway	0.00	0.53	1	6.28	0.42
Nest Mowed	2.10	0.18	2	6.28	0.42
% Grass	3.43	0.10	2	7.61	0.30
Mowed Area	4.45	0.06	2	8.63	0.20
Null	4.57	0.05	1	10.85	-
Veg. Height	5.22	0.04	2	9.40	0.13
Day of Season	6.26	0.02	2	10.44	0.04
Clumpiness	6.59	0.02	2	10.77	0.01

[a]The models "Mowed Area" and "Nest Mowed" were not run for Lakehurst due to lack of mowing activity on the base.

Table 8. Parameter estimates from the best performing logistic models (≤ 2 ΔAIC_c) of grasshopper sparrow daily nest survival rates in 2009.

Model	B_1[a]	SE	95% CI	B_0	SE
Patuxent River (n = 20 nests)					
% Grass	3.49027	1.25718	1.0262, 5.9543	-0.94027	1.408471
Nest Mowed	17.9286	4044.02	-7908.35, 7944.21	2.947513	0.419088
Day of Season	0.0639	0.0283	0.0084, 0.1193	-0.1793	1.3913
Lakehurst (n = 15 nests)					
D. to Runway	0.0006	0.0002	0.0002, 0.0010	1.1789	0.7377
Westover (n = 7 nests)					
D. to Runway	0.37784	8.0E-05	0.3777, 0.3780	-16.8126	1.056646

[a]B_0 = intercept parameter estimate, B_1 = independent parameter estimate.

Table 9. Logistic models of daily survival rates for eastern meadowlark nests monitored during the 2009 season. Models are ranked by ΔAIC_c.

Model[a]	ΔAIC_c	AIC_c Weights	No. Parameters	Deviance	Pseudo R^2
Patuxent River (min AICc = 121.82; n = 28 nests)					
Day of Season	0.00	0.45	2	117.78	0.03
Null	1.97	0.17	1	121.78	-
Veg. Height	3.75	0.07	2	121.52	0.00
% Grass	3.76	0.07	2	121.54	0.00
Clumpiness	3.94	0.06	2	121.72	0.00
Nest Mowed	3.95	0.06	2	121.72	0.00
Mowed Area	3.96	0.06	2	121.74	0.00
D. to Runway	3.97	0.06	2	121.74	0.00
Lakehurst (min AICc = 15.06; n = 7 nests)					
% Grass	0.00	0.41	2	10.94	0.35
Clumpiness	0.05	0.40	2	10.99	0.35
Day of Season	3.27	0.08	2	14.20	0.16
Null	3.90	0.06	1	16.92	-
D. To Runway	5.82	0.02	2	16.76	0.01
Veg. Height	5.93	0.02	2	16.87	0.00
Westover (min AICc = 44.65; n = 14 nests)					
% Grass	0.00	0.29	2	40.56	0.09
Veg. Height	0.59	0.22	2	41.15	0.08
Clumpiness	1.14	0.17	2	41.70	0.07
D. To Runway	1.57	0.13	2	42.12	0.06
Null	2.14	0.10	1	44.76	-
Mowed Area	3.49	0.05	2	44.05	0.02
Day of Season	4.13	0.04	2	44.68	0.00

[a]The models "Mowed Area" and "Nest Mowed" were not run for Lakehurst due to lack of mowing activity. The "Nest Mowed" model was not run for Westover due to absence of mowed nests.

Table 10. Parameter estimates from the best performing logistic models (≤ 2 ΔAIC_c) of eastern meadowlark daily nest survival rates in 2009.

Model	B_1[a]	SE	95% CI	B_0	SE
Patuxent River (n = 28 nests)					
Day of Season	-0.0263	0.0134	-0.0525, -4.26E-07	3.6894	0.7273
Null	-	-	-	2.4137	0.2228
Lakehurst (n = 7 nests)					
% Grass	-5.3283	2.6192	-10.462, -0.1946	7.9496	2.7962
Clumpiness	-17.7672	0.0000	-17.7672, -17.7672	55.6976	0.0000
Westover (n = 14 nests)					
% Grass	-3.2460	1.5792	-6.3414, -0.1507	6.4930	1.9613
Veg. Height	-0.0987	0.0544	-0.2053, 0.0079	5.3904	1.6053
Clumpiness	1.2684	0.7260	-0.1545, 2.6914	0.3354	1.3446
D. to Runway	0.0037	0.0025	-0.0013, 0.0087	2.0762	0.5163

[a]B_0 = intercept parameter estimate, B_1 = independent parameter estimate.

Table 11. Logistic models of daily nest survival rates for "other passerines" monitored during the 2009 season. Species included field sparrow at Lakehurst, and savannah sparrow, horned lark, and bobolink at Westover. Models are ranked by $\Delta AIC_{c.}$

Model[a]	ΔAIC_c	AIC_c Weights	No. Parameters	Deviance	Pseudo R^2
Lakehurst (min AICc = 7.31; n = 11 nests)					
% Grass	0.00	0.76	1	5.28	0.46
Null	4.45	0.08	1	9.74	-
Day of Season	5.28	0.05	2	8.51	0.13
Clumpiness	5.88	0.04	2	9.10	0.07
Veg. Height	6.24	0.03	2	9.47	0.03
D. to Runway	6.36	0.03	2	9.59	0.02
Westover (min AICc = 95.91; n = 30 nests)					
Day of Season	0.00	0.20	2	91.87	0.02
D. to Runway	0.26	0.18	2	92.12	0.02
Null	0.32	0.17	1	94.21	-
Nest Mowed	1.26	0.11	2	93.12	0.01
Veg. Height	1.65	0.09	2	93.52	0.01
Mowed Area	1.73	0.09	2	93.59	0.01
Clumpiness	1.78	0.08	2	93.65	0.01
% Grass	1.88	0.08	2	93.75	0.00

[a]The models "Mowed Area" and "Nest Mowed" were not run for Lakehurst due to lack of mowing activity. No models were run for Patuxent site due to a lack of "other" species.

Table 12. Parameter estimates from the best performing logistic models (≤ 2 ΔAIC_c) of daily nest survival rates for "other passerines" in 2009. Species included field sparrow at Lakehurst, and savannah sparrow, horned lark, and bobolink at Westover.

Model	B_1[a]	SE	95% CI	B_0	SE
Lakehurst (n = 11 nests)					
% Grass	107.7438	0.0000	107.7438, 107.7438	2.7052	1.0343
Westover (n = 30 nests)					
Day of Season	-0.0242	0.01603	-0.0556, 0.0072	3.9706	0.8394
D. to Runway	0.0048	0.0035	-0.0021, 0.0117	2.3184	0.4210
Null	-	-	-	2.8347	0.2575
Nest Mowed	0.5927	0.5911	-0.5660, 1.7513	2.6503	0.2992
Veg. Height	0.0216	0.0278	-0.0328, 0.0761	2.3131	0.6927
Mowed Area	-0.5692	0.7715	-2.0814, 0.9430	3.3125	0.7205
Clumpiness	0.3200	0.4265	-0.5159, 1.1560	2.2359	0.8176
% Grass	-0.5985	0.8945	-2.3517, 1.1546	3.4221	0.9344

[a]B_0 = intercept parameter estimate, B_1 = independent parameter estimate.

Table 13. General Linear Models of mean chicks fledged per nest monitored in 2009. Models are ranked by ΔAIC_c.

Model	ΔAIC_c	AIC_c Weights	No. Parameters[a]	-2 Log Likelihood	Model R^2
Grasshopper Sparrow (min AICc = 47.62; n = 42 nests)					
Site - Date -Distance to Ruway	0.00	0.49	6	33.22	0.24
Site - Date - % Grass	0.69	0.35	6	33.91	0.23
Site - Initiation Date	3.89	0.07	5	39.84	
Site	5.22	0.04	4	43.76	
Site - Date - Veg. Height	5.97	0.02	6	39.20	
Site - Date - Nest Mowed	6.58	0.02	6	39.80	
Site - Date - Mowed Area	6.60	0.02	6	39.82	
Eastern Meadowlark (min AICc = 56.69; n = 49 nests)					
Site - Date - % Grass	0.00	0.67	6	42.64	0.32
Site - Initiation Date	3.77	0.10	5	49.04	
Site - Date - Veg. Height	3.90	0.10	6	46.54	
Site - Date - Mowed Area	5.18	0.05	6	47.83	
Site - Date -Distance to Ruway	5.90	0.04	6	48.54	
Site - Date - Nest Mowed	6.27	0.03	6	48.91	
Site	7.55	0.02	4	57.69	

[a]Number of estimable model parameters including error and intercept (k).

Table 14. Parameter estimates from the best performing generalized linear models (≤ 2 ΔAIC_c) of grasshopper sparrow and eastern meadowlark mean chicks fledged in 2009.

Model	Independent Variable	*B*	SE	95% CI		*P*
Grasshopper Sparrow (n = 42 nests)						
Site - D. to Runway	Julian Day[a]	0.03	0.01	0.01	0.06	0.02
	Patuxent	-0.58	0.70	-1.95	0.80	0.42
	Lakehurst	-2.50	1.03	-4.51	-0.49	0.02
	D. to Runway	0.0006	0.0002	0.0002	0.0010	0.02
	Intercept	-2.85	2.42	-7.60	1.90	0.24
Site - % Grass	Julian Day[a]	0.01	0.02	-0.02	0.04	0.55
	Patuxent	-1.57	0.79	-3.12	-0.02	0.055
	Lakehurst	-0.81	0.74	-2.26	0.63	0.28
	% Grass	2.26	0.95	0.39	4.13	0.02
	Intercept	-0.76	2.47	-5.59	4.08	0.76
Eastern Meadowlark (n = 49 nests)						
Site - % Grass	Julian Day[a]	-0.02	0.01	-0.04	0.00	0.12
	Patuxent	-0.36	0.58	-1.50	0.78	0.54
	Lakehurst	-0.81	0.74	-2.26	0.63	0.28
	% Grass	-2.09	0.84	-3.73	-0.44	0.02
	Intercept	6.94	1.89	3.24	10.64	0.0007

[a] Estimated start of incubation.

Appendix A. Nest location maps.

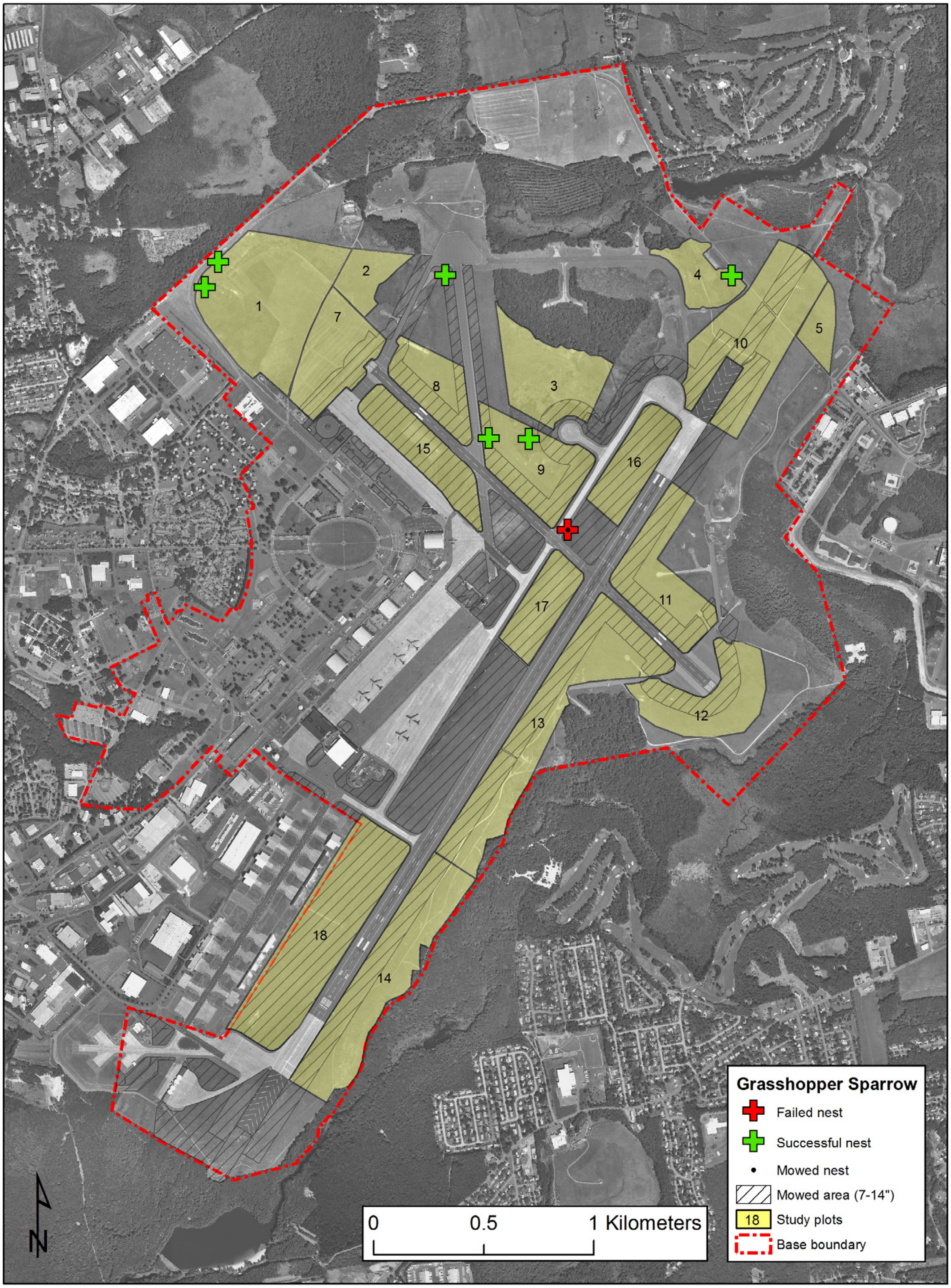


Figure A1. Locations of grasshopper sparrow nests monitored during summer 2009 on Westover Air Reserve Base, Chicopee, Massachusetts.

Appendix A. Nest location maps.

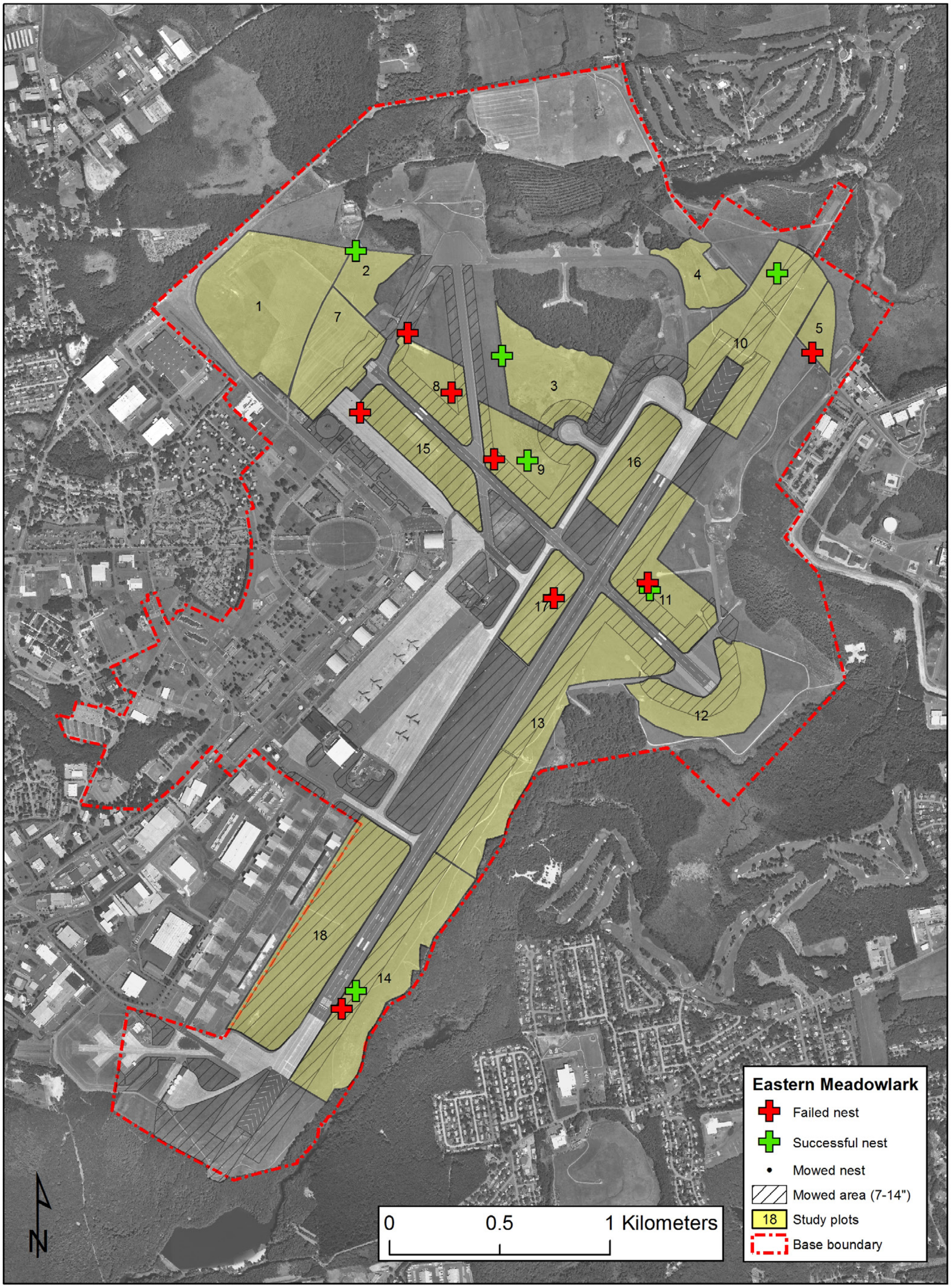


Figure A2. Locations of eastern meadowlark nests monitored during summer 2009 on Westover Air Reserve Base, Chicopee, Massachusetts.

Appendix A. Nest location maps.

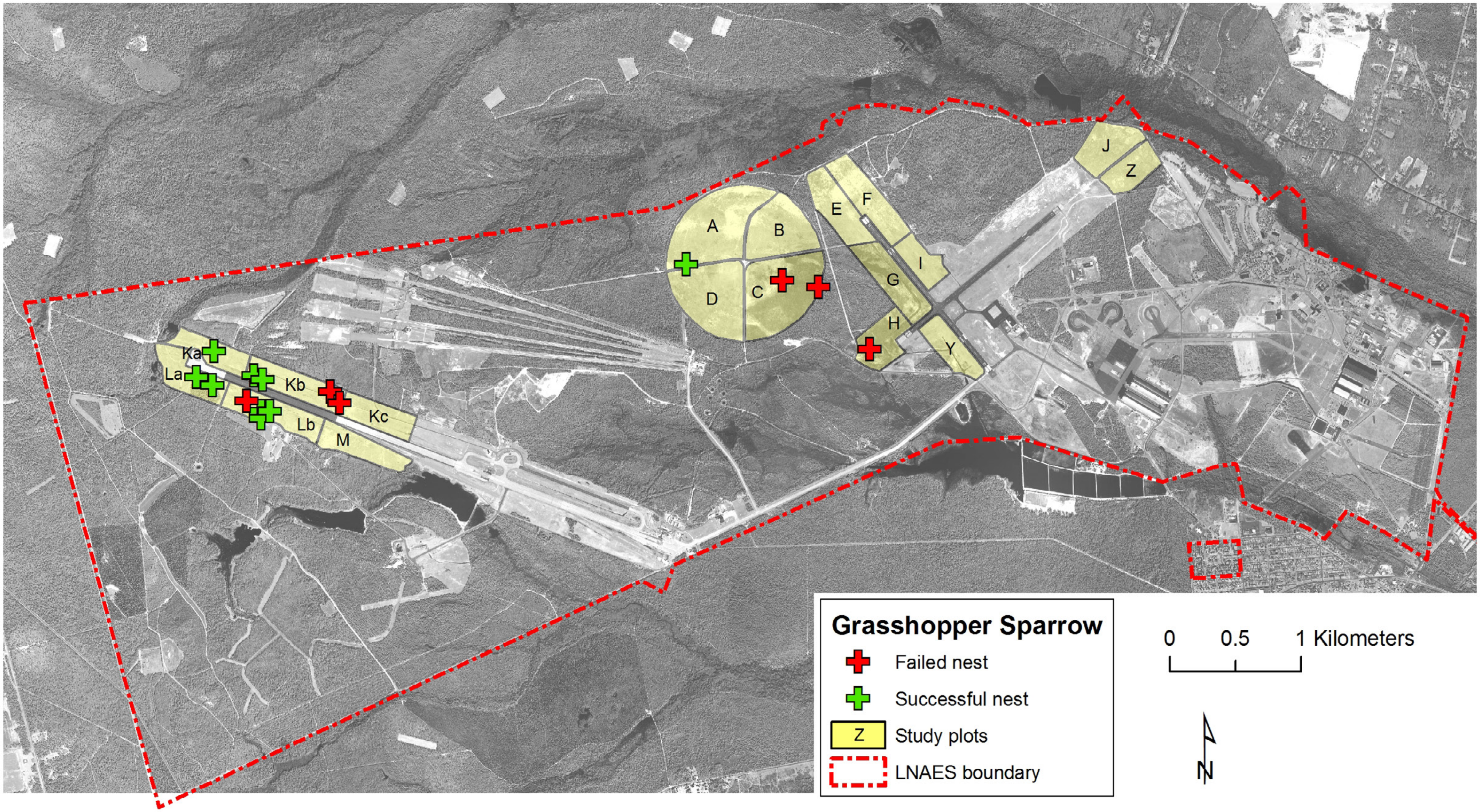


Figure A3. Locations of grasshopper sparrow nests monitored during summer 2009 on Lakehurst Naval Air Engineering Station, Lakehurst, NJ.

Appendix A. Nest location maps.

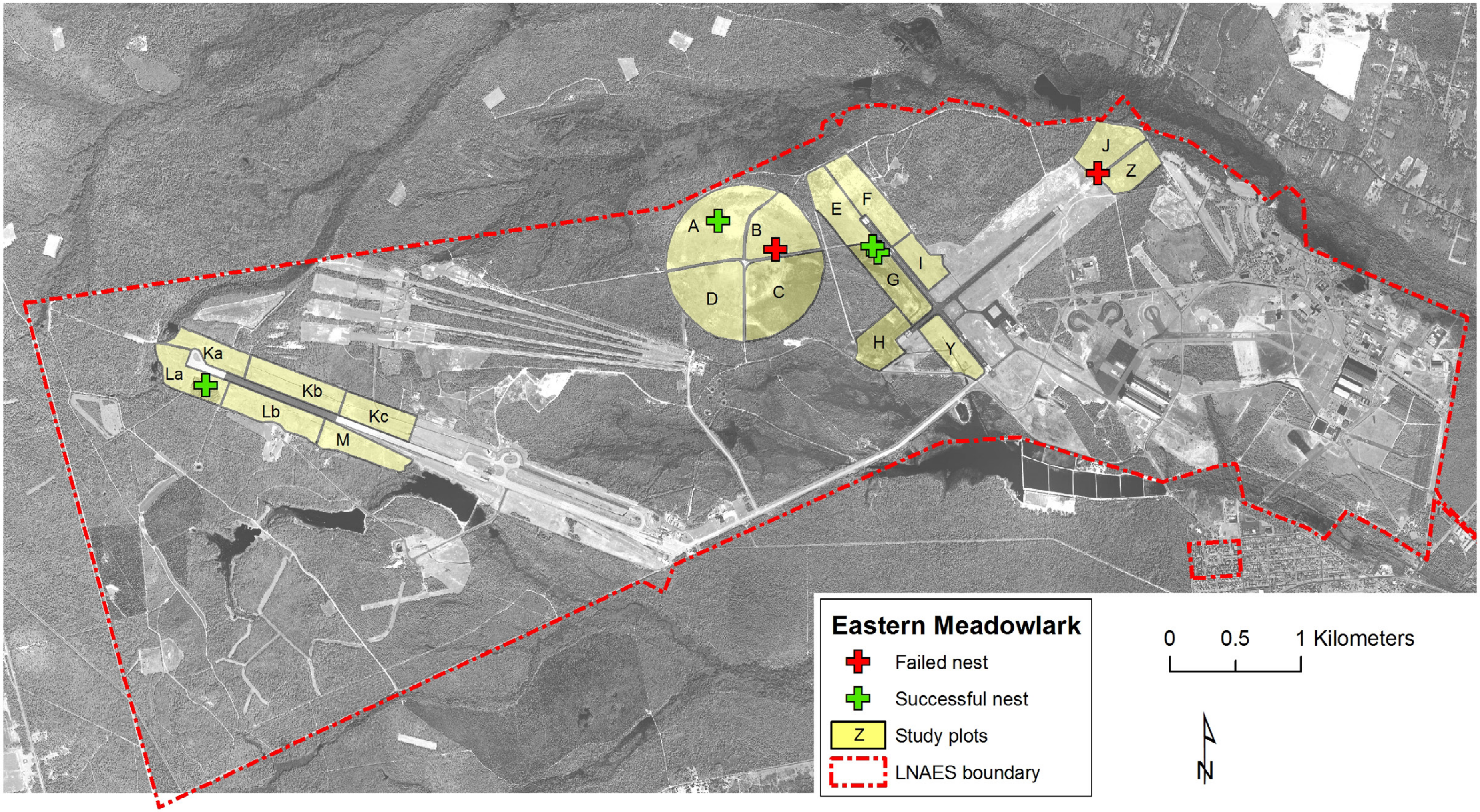


Figure A4. Locations of eastern meadowlark nests monitored during summer 2009 on Lakehurst Naval Air Engineering Station, Lakehurst, NJ.

Appendix A. Nest location maps.

Figure A5. Locations of grasshopper sparrow nests monitored during summer 2009 on Patuxent River Naval Air Station, Patuxent River, MD.

Appendix A. Nest location maps.

Figure A6. Locations of eastern meadowlark nests monitored during summer 2009 on Patuxent River Naval Air Station, Patuxent River, MD.