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Grassland Bird Productivity on Military Airfields in the Mid-Atlantic and Northeast Regions - Final 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 grassland birds which, as a group, are declining across North America. As grassland habitat area continues to decline in the region, the role 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 to maintain 7-14 inch vegetation, a practice presumed to reduce wildlife strike risks but that may 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 study of nesting success and productivity in 2009, 2010, and 2012 on three military airfields in the Mid-Atlantic and Northeast: Westover Air Reserve Base ('Westover'; Massachusetts), Joint Base McGuire-Dix-Lakehurst ('Lakehurst'; New Jersey), and Patuxent River Naval Air Station ('Patuxent'; Maryland). Approximately half of the study area on Westover, all of the area on Patuxent, and none of the area on Lakehurst were mowed during the breeding season.

Nests of two target species (Grasshopper Sparrow [*Ammodramus savannarum*] and Eastern Meadowlark [*Sturnella magna*]) and of other grassland species were located and monitored at regular intervals until success (fledging) or failure (predation, abandonment, or mower-caused). Through direct observation and cooperation with mowing crews we 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 following a mow. We estimated overall nest survival (the probability of nests surviving to fledge at least one young) and cause-specific failure rates using program MARK. Vegetation was measured around each nest and at random areas throughout the study plots. We examined potential effects of vegetation structure, mowing history, and other predictor variables on nest survival using logistic modeling in program MARK. A similar analysis was conducted on productivity (the number of young fledged per nest and per successful nest) using general linear models.

In the three years of the project we located and monitored 194 Grasshopper Sparrow nests and 131 Eastern Meadowlark nests across all three sites. Nests of four other species were also present at individual sites in adequate numbers for some analyses: Savannah Sparrow (*Passerculus sandwichensis*; Westover only), Field Sparrow (*Spizella pusilla*; Lakehurst only), Common Nighthawk (*Chordeiles minor*; Lakehurst only), and Upland Sandpiper (*Bartramia longicauda*, Westover only). Overall nest survival rates for Grasshopper Sparrows on non-mowed sections of Westover (53%) and on the non-mowed Lakehurst site (46%) were high compared with other studies; rates on the mowed section of Westover (28%) and the mowed Patuxent site (28%) were approximately average. Nest survival rates for Eastern Meadowlark in mowed sections of Westover (15%) and on the mowed Patuxent site (14%) were approximately average when compared with other studies, but were considerably lower than in the non-mowed section

of Westover (40%); survival was also high on the non-mowed Lakehurst site (53%), though sample sizes at this site were low (n = 10 nests).

On the mowed Patuxent site and in mowed areas on Westover, an estimated 8-11% of Grasshopper Sparrow nests and 15-19% of Eastern Meadowlark nests failed as a direct result of mowing (e.g., due to crushing or desertion immediately following mow). Predation was the most common cause of nest failure at all sites. At Westover, overall nest survival estimates were significantly higher in non-mowed than in mowed areas for Grasshopper Sparrow (53 vs. 28%) and Eastern Meadowlark (40 vs. 15%) when analyzed jointly. Furthermore, nests in mowed areas fledged fewer young per successful nest than those in non-mowed areas due to a combination of lower hatching success and higher partial brood mortality. Savannah Sparrow (the only other species at Westover with adequate sample sizes for comparison) showed similar nest survival rates between mowed and non-mowed areas (24 vs. 20%). At the Patuxent site, nest survival of the two target species was best predicted by a negative relationship with grass height. Percent grass cover (negative relationship) best predicted nest survival of these two species at the non-mowed Lakehurst site.

Military airfields have long been known to contain breeding grassland birds, but data on reproductive survival in these habitats has been limited. Our study is a first step in understanding whether these habitats are supporting viable self-sustaining populations or are acting as population sinks. Data on survival at other life stages, especially post-nesting juveniles, will be needed to determine what an adequate (sustainable) level of nest survival is. More research is also needed at these and other airfields to refine estimates of nest survival, to assess changes in cases of modifications to mowing regimes, and to extrapolate results across a wider geographic area.

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BACKGROUND AND OBJECTIVES

The Department of Defense (DoD) is the steward of approximately 28 million acres of military land, air, and water resources 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 for 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 supporting stable breeding populations of grassland birds, a guild that has experienced steep and geographically widespread population declines (Osborne and Peterson 1984, Askins 1993, 1996, Rich et al. 2004, Brennan and Kuvlesky 2005). Military airfields and associated training areas have also been specifically identified as important components in the conservation of rare grassland birds because of the sizeable populations and expansive habitats they contain (Melvin 1994, Brennan and Kuvlesky 2005, Askins et al. 2007, Giocomo et al. 2008, MDFW 2013).

Current DoD policy, under the Sikes Act, includes provisions for the protection and conservation of state-and federally-listed species, so long as such actions do not interfere with the military mission (e.g., USAF 2004a). At the same time, aviation safety procedures dictate that grassland management methods on USAF airfields comply with Bird/Wildlife Aircraft Strike Hazard regulations (BASH; USAF 2004b). Naval air stations also often follow Air Force BASH-recommended management strategies (K. Rambo, *personal comm.*), although Navy guidelines allow each installation the flexibility to develop its own site-appropriate mowing/management regime based on a Wildlife Hazard Assessment (CNIC 2010). BASH management generally consists of a strict mowing regime, with vegetation adjacent to aircraft movement areas maintained at 7-14 inches average height (USAF 2004b). Other tools, such as mechanical shrub removal and prescribed burning, are also used on airfields to enhance habitat for grassland bird species, control invasive plant species, and to encourage homogenous vegetation conditions recommended by BASH guidelines. These techniques are currently in use on several military airfields, including the Lakehurst unit of Joint-Base McGuire-Dix-Lakehurst (hereafter 'Lakehurst') in New Jersey and Westover Air Reserve Base ('Westover') in Massachusetts. Recent findings from the Northeast region indicate that current Air Force BASH guidelines may not necessarily be optimal for deterring birds most hazardous to aircraft, and that management standards should be assessed on a site-by-site basis (USFWS 2001, Peters et al. 2012). These findings also suggest that airfields may be maintained to provide habitat for small, low-risk grassland birds while simultaneously optimizing safety.

Several grassland bird species of regional and national concern breed on military airfields in the Mid-Atlantic and Northeast regions. These include Upland Sandpiper (*Bartramia longicauda*), Grasshopper Sparrow (*Ammodramus savannarum*), Henslow's Sparrow (*A. henslowii*), Eastern Meadowlark (*Sturnella magna*), Horned Lark (*Eremophila alpestris*), and Field Sparrow (*Spizella pusilla*), all of which are regarded as grassland obligates during the breeding season, except for Field Sparrow which is a facultative grassland species. For instance, Westover hosts the largest breeding population of Upland

Sandpipers and Grasshopper Sparrows in Massachusetts (MDFW 2013), and Lakehurst hosts the largest breeding population of Upland Sandpiper, and second largest population of Grasshopper Sparrow, in New Jersey (J. Joyce, *personal comm*.). Patuxent River Naval Air Station ('Patuxent') in Maryland also supports large breeding populations of Grasshopper Sparrows and Eastern Meadowlarks. To date, monitoring data from these three sites conducted by NJ Audubon indicate that the local densities of target grassland species are stable or increasing (Peters et al. 2012). However, based on abundance data alone it is difficult to assess whether these populations are in fact self-sustaining, successfully reproducing populations or are instead dependent upon outside immigration to maintain them. Grassland habitat is also increasingly rare in the heavily-developed Northeast and Mid-Atlantic regions, so a lack of alternative breeding habitat may be affecting site use (Melvin 1994, Askins 1996, Vickery and Dunwiddie 1997, Norment 2002).

It is widely accepted that avian abundance measures alone are not adequate for measuring habitat quality and, in particular, species response to anthropogenic habitat manipulation (Van Horne 1983). In addition, some sites may function as ecological traps (Battin 2004), 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 population sinks. In such cases, lower quality habitats (i.e., those with lower reproductive rates) could exhibit greater bird densities than high quality habitats. For instance, Kershner and Bollinger (1996) found that Eastern Meadowlarks were attracted to Illinois airfields, although mandated mowing practices were responsible for 44% of nest failures.

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). Similar findings have recently been documented in great tit (*Parus major*), where traffic noise was shown to reduce clutch size and number of fledglings independent of clutch size (Halfwerk et al. 2010). These effects were identified as occurring primarily when the frequency band of traffic noise overlapped that of the lower frequency segment of the great tit song, indicating potential interference in intraspecific communication. Comparatively little is understood about the potential effects of disturbance on grassland birds. The few studies that have addressed the issue have produced somewhat conflicting results. For instance, grassland birds appear to avoid areas near roads with heavy traffic (Forman et al. 2004), and American Kestrels are more likely to experience nest failure in noisier environments (Strasser and Heath 2013). Alternatively, military activity did not affect nest site selection or nesting success in Eastern Meadowlark or Grasshopper Sparrow on Fort Riley, Kansas (Hubbard et al. 2006).

In response to uncertainties about the suitability of human-altered habitats (e.g., airfield grasslands) 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). We initiated the current project in spring 2009. Our primary goal was to expand our current avian density monitoring program on Westover, Lakehurst, and Patuxent (Peters et al. 2012) to include demographic parameters for breeding grassland birds such as reproductive success. Target species were Grasshopper Sparrow and Eastern Meadowlark, both of which breed on all three sites. Grasshopper Sparrow is listed as "threatened" in Massachusetts and New Jersey, "at risk" in Maryland, and of regional concern in need of "immediate management" in the Mid-Atlantic and Northeast regions (Partners in Flight Bird Conservation Region 30). Eastern Meadowlark is considered a species of "special concern" in New Jersey, and "of management concern" in the Northeast (USFWS Region 5). Eastern Meadowlark 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 habitat-use and demographic dynamics of Grasshopper Sparrow and Eastern Meadowlark (our target species) and other species nesting on Westover, Lakehurst, and Patuxent, with the goal of better understanding the consequences of breeding-season mowing on military airfields. Our specific objectives were to: (1) characterize nesting habitat, phenology, and biology of the two target species at the sites, especially in relation to mowing history, (2) relate nesting success and productivity to mowing history, habitat structure, and other potentially important factors, and (3) obtain estimates of direct nest mortality rates due to mowing and other causes.

STUDY SITES

Joint Base McGuire-Dix-Lakehurst ('Lakehurst')

The Lakehurst section of Joint Base McGuire-Dix-Lakehurst in Lakehurst, New Jersey, consists of 7,400 acres and is located within the Pinelands National Reserve. The mission of the Lakehurst 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 that breed in grasslands on the site include Upland Sandpiper (state endangered), Grasshopper Sparrow (state threatened), Horned Lark (state threatened), and American Kestrel (*Falco sparverius*; state threatened). Lakehurst supports the largest known breeding population of Upland Sandpipers in New Jersey (ca. 10-15 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. About 750 – 1,000 acres of the grasslands are mowed each year during late-winter. No mowing is currently performed during the grassland bird breeding season (April – August).

Westover Air Reserve Base ('Westover')

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 non-native vegetation. Westover's grasslands provide breeding habitat to New England's largest populations of three rare species: Upland Sandpiper (state endangered), Grasshopper Sparrow (state threatened), and Phyllira tiger moth (*Grammia phyllira*; state endangered). The 1987 populations of 25 Upland Sandpipers and 55 singing male Grasshopper Sparrows increased to 150 and 182, respectively, by 2003 (Melvin 1994). More recent estimates are approximately 81 pairs of Upland Sandpiper, and 236 pairs of Grasshopper Sparrow (Melvin 2012). 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 (USFWS 1995), and a recent state grassland conservation plan ranked Westover highest in importance among all grasslands in Massachusetts (MDFW 2013). Mowing frequency for 523 acres of vegetation within approximately 300 feet of runways and taxiways is determined by the time it takes vegetation to approach an average height of 14 inches (approximately once per month; A. Milroy, *personal comm.*). The remaining 690 acres has been mowed after 1 August each year to avoid the grassland bird nesting season. Prescribed fire (~50-300 acres per year) was introduced in 2002, with subsequent burns in 2004, 2006, 2010, 2011, and 2012. Westover is building toward a three to five-year return interval for burning the grasslands. The variability is due to uncertainties of weather, funding, and availability of qualified personnel. Recently, the base has begun integrated pest management of invasive plant species.

Patuxent River Naval Air Station ('Patuxent')

Patuxent River Naval Air Station 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 Patuxent 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, and Northern Bobwhite (*Colinus virginianus*). The latter three are regarded as grassland obligates during the breeding season. Upland Sandpiper is considered endangered in Maryland (breeding population only) and a "species of high concern" continentally (Brown et al. 2001). Buff-breasted Sandpiper and Grasshopper Sparrow are considered species at risk of being listed in Maryland and globally (the former) or continentally (the latter; Brown et al. 2001, Rich et al. 2004). Concentrations of Upland Sandpipers at Patuxent typically reach into the 40s and 50s during migration

and numbers of Buff-breasted Sandpipers often are in the 30s. These are some of the highest 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, including 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 plots at each installation were selected prior to the first field season based on scheduled mowing regimes (Westover) or available grassland habitat (Lakehurst, Patuxent) and remained fixed throughout the three year study. Plots on Westover provided relatively equal representation of areas that were (1) intensively mowed to 7-14 inches during the breeding season (46% of plot area), and (2) not mowed during the breeding season (54% of plot area). All plots on Patuxent represented areas that were mowed to 7-14 inches, while no plots on Lakehurst were mowed during the breeding season. Plots on Lakehurst were located in three distinct areas: (1) an active airfield (Westfield Runways), (2) a less-used airfield (Test Site), or (3) an air drop area not associated with any runways (Jump Circle). Maps depicting search plots at each site are available in Appendix A.

At each site, two to three plots were searched per weekday for approximately two hours each, resulting in each plot being searched every one to two weeks throughout the season (16 April - 15 July in 2009, and 26 April – 15 July in 2010 and 2012). Various methods of locating nests were implemented including systematic area searches, behavioral observations, 'sticking' and rope-dragging. Specific methods were similar to those recommended by Winter et al. (2003). Systematic searches consisted of observers walking parallel transects within a study plot in order to flush adults off nests. Specific adult breeding behaviors noted included singing, calling, counter-calling, carrying nesting material or food, and defensive (i.e., agonistic) actions. “Sticking”, or flushing adults off the nest by agitating vegetation with a 2-meter bamboo stick, was the primary method of searching at Lakehurst, while rope-dragging (two observers dragging an approximately 20 m weighted rope) as well as sticking were used at Patuxent and Westover. Rope-dragging was not feasible at Lakehurst due to abundant woody vegetation. An attempt was made to employ equal searching effort across all plots within each site. Two plots at Lakehurst that were monitored in the first year of the study were not included in 2010 or 2012 because no nests were found there in 2009.

Mowing activities at Patuxent and Westover were tracked through communication with on-site management crews, and whenever possible observers visited known active nests in targeted areas immediately prior to and after mowing. Nests at Westover were ultimately categorized as "not in mowing plan area", "in mowing plan area but not directly mowed over", or "directly mowed over." Nests at Patuxent were simply categorized as "mowed over" or "not mowed over" as all nests were in mowed areas.

Nests that were directly mowed over were easily recognizable due to mower tracks, grass clippings and reduced vegetation height at and around the nest. A small number of nests were known or suspected to have been mowed over before discovery based on the stage of the nest and the known date of mowing in the area. As these nests had already survived the mowing, they were excluded from the "mowed over" nest category to avoid biasing daily survival rates for this group.

Once located, nests were monitored every 2-3 days through successful completion or failure. Based on conditions observed at and around nests, nest failures were categorized as depredated, abandoned (unknown cause), failed due to mowing, or failed due to researcher disturbance. Nests failed due to mowing included those crushed or destroyed directly by the mower, and nests that were abandoned (deserted) immediately following mowing. A very limited number of failures attributed to researcher disturbance were either inadvertently stepped on upon discovery (n = 1 Eastern Meadowlark, 3 Grasshopper Sparrow), or abandoned immediately after being discovered during egg-laying (n = 2 Grasshopper Sparrow, 1 Upland Sandpiper) and were not included in subsequent analyses. Successful nests were defined as those that fledged at least one chick for altricial species, and those that hatched at least one chick for precocial or semi-precocial species (e.g., Upland Sandpiper).

Clutch size calculations included only nests that were observed for two successive checks and did not fail during egg-laying. 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 Grasshopper Sparrow, and 13 and 10 days for Eastern Meadowlark, respectively (Vickery 1996, Jaster et al. 2012). The date of hatching or fledging (when not directly observed) was estimated as the mid-point between the two checks surrounding the event. Incubation initiation dates for nests discovered in the egg-laying stage were estimated by forward-dating assuming one egg laid per day (Vickery 1996, Jaster et al. 2012). For nests that were found and failed during incubation, we assumed that the mid-point of incubation occurred mid-way through the period it was monitored. Nests at which parents were not observed incubating for multiple successive checks, and at which eggs were cold to the touch, were classified as abandoned. In these cases, the date of termination was assumed to have occurred mid-way between the last date at which incubation activity was observed and the subsequent check date.

At all sites, we color-banded nestlings at age 4-7 days for Grasshopper Sparrow and 6-9 days old for Eastern Meadowlark, to examine future recruitment into the population. All nestlings were fitted with a USFWS aluminum leg band and batch-marked with a single site-specific color band (Lakehurst, green; Patuxent, dark blue; Westover, pink) to uniquely identify the site at which they were banded. General morphometric measurements were also taken, including mass (Ohaus balance scale to 0.01 g), wing (wing rule to 0.5 mm), tail and tarsus (calipers to 0.5 mm). Fat scores were assigned based on visible subcutaneous fat stores, and keel scores were assigned based on the prominence of the sternal keel (Appendix B).

Vegetation Sampling

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, open (non-vegetated), 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 0.5 m in each cardinal direction). This measure was performed again on the last day a nest was visited. In 2010 and 2012, during the final nest visit, we also measured litter depth (i.e., flattened, dead vegetation) at the same five sub-sample locations (to 1 cm). 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.

In 2010 and 2012, from 15 to 23 June, we also collected vegetation data at randomly selected sites within each search plot, in order to evaluate nest-site selection at the microhabitat scale. To select survey locations, we generated a list of multiple random points for each survey plot in a GIS (ArcGIS 9.3). In the field, we visited the points in each plot sequentially, and took vegetation measurements as long as a point did not fall on a road or other airfield infrastructure and was greater than 50 m from a previously-sampled point. If either of these occurred, we moved to the next point on the list until we had completed the desired number of samples per plot. At Patuxent and Lakehurst, five samples were completed per plot. At Westover, plots that were entirely mowed or non-mowed (n = 9) received five samples per plot, while plots that straddled mowed and non-mowed management areas (n = 8) received 10 measurements per plot: five in the mowed section and five in the non-mowed section. Measurements performed at random locations were identical to those taken at the nest quadrats.

Statistical Analyses

We modeled daily nest survival rate (DSR) using the logistic nest survival model within the program MARK (v. 6.0; White and Burnham 1999, Dinsmore et al. 2002) accessed through the RMark package in R (Laake et al. 2012). We focused on Grasshopper Sparrow and Eastern Meadowlark, which occurred at all three sites and had the largest sample sizes. We also include data on other grassland species with at least 10 nests, found at individual sites: Savannah Sparrow (*Passerculus sandwichensis*; Westover only), Upland Sandpiper (Westover only), Bobolink (*Dolichonyx oryzivorus*; Westover only), Field Sparrow (*Spizella pusilla*; Lakehurst only), and Common Nighthawk (*Chordeiles minor*; Lakehurst only). Altricial species were monitored through fledging, while Upland Sandpiper and Common Nighthawk (a precocial and semi-precocial species, respectively) were monitored through hatching (e.g., Perkins and Vickery 2007, Brown et al. 2012). Upland Sandpiper and Common Nighthawk nests found after hatching were therefore excluded from analyses as they contributed no exposure days. We also excluded nests that failed due to researcher disturbance, including those that were damaged upon discovery and those abandoned immediately after discovery with an incomplete clutch. Abandonment is not uncommon for grassland bird nests found prior to the onset of incubation (e.g., Martin and Gavin 1995, Grant et al. 2005, Jaster et al.

2012), and we did not want to bias survival estimates low by including likely researcher-caused failures. In general, however, regular nest checks have not been shown to negatively impact nesting success (Ibanez-Alamo et al. 2012).

We evaluated potential influences on nest survival of our target species Eastern Meadowlarks and Grasshopper Sparrows jointly, using a separate set of candidate models for each site. All models included the categorical variable species (Eastern Meadowlark or Grasshopper Sparrow). To allow for the possibility that within- and between-season temporal factors could be influencing nest survival along with other factors (e.g., Grant et al. 2005), we took a hierarchical modeling approach similar to Dinsmore and Dinsmore (2007). We first evaluated three temporal models each containing the variable species and one temporal variable (nest stage [egg vs. nestling], day of season, or year). If a model containing a temporal variable outperformed the species-only model by ≥ 2 Akaike Information Criterion units (AIC_c; Burnham and Anderson 2002) we retained that variable as part of a base model (along with "species") to which other variables of interest were added singly. More complex models were not attempted in most cases due to limited sample sizes. Continuous variables added to the base model included distance to an active runway (m), mean vegetation height (cm) in the 1 m^2 surrounding the nest, and the percent cover of grass, woody vegetation, forbs, and open ground (arcsine-square root transformed) in the 1 m^2 around the nest. Categorical variables included whether a nest was in a 7-14 inch mowed area or not (1 = yes, 0 = no), whether a nest was passed over by a mower while being monitored (1 = yes, 0 = no), and the extent of vegetation clumping such as formed by warm-season grasses (mostly in clumps, somewhat clumpy, or mostly homogenous).

Model sets differed slightly among sites due to differences in management regimes and other factors. The 'mowed area' variable occurred only at Westover as Patuxent and Lakehurst were entirely mowed or non-mowed, respectively. The 'nest mowed' variable was similarly not used at the non-mowed Lakehurst site, and at Westover it included three categories: mowed over nests in the mowed area, non-mowed nests in the mowed area, and non-mowed nests in the non-mowed area. At Lakehurst, nests occurred in three distinct locations on base, only one of which was directly adjacent to active runways, so we used the categorical variable 'location' in place of the variable distance to runway. The best performing model(s) in the final model set for each site were evaluated based on AIC_c, Akaike weights (w), slope parameter estimates (95% confidence intervals), and graphical examination.

At Westover, where multiple grassland obligate species occurred, we conducted a similar analysis including all grassland obligate species with at least 10 monitored nests (Grasshopper Sparrow, Eastern Meadowlark, Savannah Sparrow, Upland Sandpiper, and Bobolink). All species were included in one analysis with species as a covariate in each model. At Lakehurst, adequate sample sizes of two facultative grassland species were monitored: Field Sparrow and Common Nighthawk. These two species were modeled in a similar manner to Grasshopper Sparrow and Eastern Meadowlark at Lakehurst, but were analyzed using separate model sets due to their differing nesting biology (e.g., Field Sparrows are shrub-nesting while Common Nighthawks use bare ground).

Daily nest survival rates and 95% confidence intervals for species with at least 30 total nests were generated in program MARK (Dinsmore et al. 2002). The probability of a nest surviving for the entire nest cycle ("overall nest survival") was calculated by raising DSR to the estimated length in days of the full nest cycle (1st egg through fledging) based on the literature (Grasshopper Sparrow – 23 d, Eastern Meadowlark – 26 d, Upland Sandpiper – 27 d, Savannah Sparrow – 25 d, Field Sparrow – 23 d, Common Nighthawk – 19 d; Vickery 1996, Carey et al. 2008, Wheelwright and Rising 2008, Brigham et al. 2011, Houston et al. 2011, Jaster et al. 2012). "Apparent" nest survival rates (the simple percentage of successful nests) are also reported for comparison, though these are known to be upwardly biased (Mayfield 1961, Dinsmore et al. 2002). In addition to nest survival, we also used MARK to produce separate estimates of daily failure rates (DFR) for each cause of failure (e.g., Herkert et al. 2009, Renfrew and Ribic 2003), including predation, direct mortality due to mowing (e.g., crushing, immediate abandonment following mowing), and abandonments not directly linked to mowing. These allowed us to produce unbiased estimates of the percentage of nests expected to fail due to a given cause using the following formula:

$$F = f + fs + fs^2 + fs^3 + \ldots + fs^{(n-1)} = f\sum_{i=1}^{n-1} s^i$$

where F = the overall failure rate for a given cause, f = the cause-specific daily failure rate, s = the daily survival rate, and n = the number of days in a typical nest cycle.

In addition to nest survival and failure rates, we estimated the number of young successfully produced per nest ("productivity"). This variable was evaluated using general linear models (lm, R Development Core Team 2011) with identical model structures to those used in nest survival analyses, with the exception of no nest stage model. Separate analyses were conducted for all nests combined and for successful nests only (i.e., those that successfully produced at least one chick). To better interpret results, we also investigated individual components of productivity, including original clutch size, hatching success, and individual chick survival. These were examined using linear models for clutch size, logistic models for hatching success, and program MARK for individual chick survival (i.e., considering each chick as a "nest" to evaluate partial brood mortality not resulting in total nest failure).

FINDINGS

A total of 194 Grasshopper Sparrow nests (49 at Westover, 49 at Lakehurst, 96 at Patuxent) and 131 Eastern Meadowlark nests (40 at Westover, 10 at Lakehurst, 81 at Patuxent) were monitored during the three years of the study (including only those with adequate data for nest survival analyses). Of these, one Grasshopper Sparrow nest and two Eastern Meadowlark nests (both at Patuxent) were missing vegetation data and were excluded from analyses involving model comparisons. In addition to these target species, we monitored a three-year total of 66 Savannah Sparrow, 31 Upland Sandpiper,

and 11 Bobolink nests on Westover, and 63 Field Sparrow and 32 Common Nighthawk nests on Lakehurst. Maps of all monitored nests used in nest survival analyses can be viewed in Appendix A.

Nesting Phenology

Patterns of nest initiation dates at the three sites are illustrated in Figures 1-4. Nest initiations for Grasshopper Sparrow followed a bi-modal pattern at all sites, with a peak in late May and another in mid to late-June, suggesting two broods per season (Figure 1). The range of initiation dates for Grasshopper Sparrow (all years combined) was May 16th – July 12th at Westover, May 14th – July 7th at Lakehurst, and May 12th – July 16th at Patuxent. Eastern Meadowlarks began nesting earlier than Grasshopper Sparrows at all sites, generally in late April at Patuxent and in early May at Lakehurst and Westover (Figure 2). Meadowlark nest initiations were also bimodal at Westover, with a peak in early May and another in June, but showed a more even distribution of initiations at Patuxent. Sample sizes were limited (n = 10 nests) at Lakehurst, but peaks in early May and June were also observed. The range of initiation dates for Eastern Meadowlarks was April 25th – July 1st at Westover, May 9th – July 19th at Lakehurst, and April 19th – July 9th at Patuxent. Initiation dates for Savannah Sparrow at Westover (range: May 11th – July 13th) and field sparrow at Lakehurst (range: May 4th – July 18th) were also characterized by what appear to be within-season cycles of nesting activity (Figures 3 and 4). Upland Sandpiper at Westover and Common Nighthawk at Lakehurst both showed unimodal patterns of initiation with median initiation dates of May 17th (range: May 5th – June 15th) and June 1st (range: May 16th – July 5th), respectively (Figures 3 and 4).

Nest Site Characteristics

Summary statistics for habitat structure variables around Grasshopper Sparrow and Eastern Meadowlark nests and at random areas can be found in Tables 1-3. At Westover, both Grasshopper Sparrows and Meadowlarks had taller final vegetation heights around nests in non-mowed areas than in mowed areas, and Grasshopper Sparrows had less grass cover, more shrub cover, and more clump-forming vegetation in non-mowed areas (Wilcoxon Rank Sum tests, $P < 0.05$; Tables 1-2). In both mowed and non-mowed areas on Westover, vegetation around Grasshopper Sparrow and Meadowlark nests was shorter than in random areas (Figure 5, Tables 1-2). Meadowlark nests also had greater amounts of grass cover and less bare ground, than random areas. At Lakehurst, Grasshopper Sparrow nests had less bare ground, more grass cover, and more clumpy vegetation than random areas; Eastern Meadowlark nests also had less bare ground cover than random areas (Figure 5, Tables 1-2). At Patuxent, Grasshopper Sparrow nests had more bare ground and forb cover and less woody vegetation than random areas; Meadowlark nests had taller vegetation, less bare ground cover, and deeper litter than random areas (Figure 5, Tables 1-2).

Nest Survival

Overall nest survival estimates (i.e., the probability of fledging at least one young based on DSR) for Grasshopper Sparrow were 37% at Westover (95% CI: 22-53%; n = 49), 46% at Lakehurst (CI: 29-61%; n = 49), and 28% at Patuxent (CI: 18-38%; n = 96; Table 4, Figure 6). Overall nest survival rates for Eastern Meadowlark were 24% at Westover (95% CI: 11-40%; n = 40), 53% at Lakehurst (CI: 19-79%; n = 10), and 14% at Patuxent (CI: 8-22%; n = 81; Table 4, Figure 6). Results for all species, including daily survival rates and apparent rates, can be found in Tables 4-5.

Grasshopper Sparrow and Eastern Meadowlark
Results of evaluating competing nest survival models for Grasshopper Sparrow and Eastern Meadowlark at each site can be found in Tables 6 and 7, and Figure 7. At Westover, two models were within two ΔAIC_c units of the top in the final model set (the models "species + distance to runway" and "species + % grass cover"), and a third model ("species + mowed area") was close ($\Delta AIC_c = 2.2$; Figure 7). The variable of interest (i.e., the variable other than species) in all three of these models had beta estimate 95% confidence intervals that did not overlap zero (Table 7). These models predicted greater nest survival further from runways (Wald test, P = 0.018), in areas of sparser grass cover (P = 0.015), and in non-mowed vs. mowed areas (P = 0.030). Further examination of the data revealed that these three covariates were confounded; i.e., nests in mowed areas were significantly closer to the runway (glm, Wald test, P < 0.001) and had significantly greater grass cover (P = 0.026) than nests in non-mowed area. Model-averaging of parameter estimates (Burnham and Anderson 2002) was not used in order to avoid collinearity (Freckleton 2011).

At Lakehurst, two models ("species + site" and "species + % grass cover") were competitive in the final model set. Because a model with both of these covariates seemed plausible (i.e., "species + site + % grass cover") we included it in the final model set for this site, and it performed considerably better than all other models ($w = 0.85$, nearest $\Delta AIC_c = 5.2$). Both site (P = 0.005) and a negative effect of grass cover (P = 0.011) were significant in this model (Table 7, Figure 7). Percent grass cover around nests did not differ among sites on Lakehurst (glm, Walt test, P = 0.97).

At Patuxent, a strong effect of year was found in the initial phase of modeling ($w = 0.92$, nearest $\Delta AIC_c = 6.3$), so models added to the final set all included terms for both species and year. One model ("species + year + vegetation height") clearly out-performed others in the final model set ($w = 0.85$, nearest $\Delta AIC_c = 5.8$; Table 6), and predicted greater nest survival in taller vegetation (P = 0.004; Table 7, Figure 7). A significant difference in daily survival rate between species was also indicated by this model (Grasshopper Sparrow > Eastern Meadowlark; P = 0.006), an effect that was not seen in top models at the other sites ($P \geq 0.26$).

Other Species
When a combined analysis including nests from five obligate grassland species at Westover was run, two models were competitive in the final model set: "species + %

forb cover" (w = 0.39, nearest ΔAIC_c = 0) and "species + % grass cover" (w = 0.19, ΔAIC_c = 1.48). The top nest survival model predicted a positive association between nest survival and forb cover (P = 0.015), while the second model predicted a negative association between nest survival and grass cover (P = 0.029). Further examination revealed a negative relationship between the variables forb cover and grass cover (r = 0.51, P < 0.001). Grass cover was found to be greater at nests in mowed areas (P = 0.050; similar to above), while forb cover was not (P = 0.33).

The model comparing nest survival of the five grassland obligate species in mowed and non-mowed areas at Westover performed poorly in the final model set (w = 0.03, ΔAIC_c = 5.5). The slope parameter estimate (-0.22) suggested lower survival in mowed areas, but 95% confidence intervals widely overlapped zero ([-0.69, 0.25]; P = 0.36). Separate analyses of the three most abundant species at Westover (Grasshopper Sparrow, Eastern Meadowlark, and Savannah Sparrow) revealed that this may have been due to differing responses among species. Both Grasshopper Sparrow and Eastern Meadowlark had lower overall nest survival in mowed areas vs. non-mowed areas: 28 vs. 53% for Grasshopper Sparrow, and 15 vs. 40% for Eastern Meadowlark (Table 4). In contrast, overall nest survival for Savannah Sparrow was similar between mowed and non-mowed areas: 24 vs. 20% (P = 0.78; Table 5). Other species at Westover had insufficient sample sizes to compare individually. The separate (i.e., single-species) models comparing Grasshopper Sparrow and Eastern Meadowlark nest survival in mowed vs. non-mowed areas were not significant at alpha = 0.05 (Wald tests, P = 0.15 and 0.12, respectively). This contrasts with the joint Grasshopper Sparrow and Eastern Meadowlark analysis (see above and Table 7), in which the effect of "mowed area" was significant (P = 0.030).

Modeling results for Field Sparrow at Lakehurst revealed a significant effect of year on nest survival (P = 0.006). All other variables in the final model set had parameter estimate confidence intervals that overlapped zero. Similarly, for Common Nighthawks at Lakehurst the null model performed best in the final model set and all parameter estimate confidence intervals overlapped zero.

Cause-Specific Failure Rates and Direct Effects of Mowing

Predation was the main cause of failure for both Grasshopper Sparrow and Eastern Meadowlark at all sites. For Grasshopper Sparrows, predators terminated an estimated 45% of nests on Lakehurst, 47% of nests in non-mowed areas of Westover, 47% in mowed areas of Westover, and 55% of nests on Patuxent (Table 8, Figure 6). For Eastern Meadowlarks an estimated 47% of nests on Lakehurst, 60% of nests in non-mowed areas of Westover, 56% in mowed areas of Westover, and 69% of nests on Patuxent failed due to predation (Table 8, Figure 6). Estimated non-mower-caused nest abandonment rates for Grasshopper Sparrow and Eastern Meadowlark were: 9% and 0% at Lakehurst, respectively; 0% and 0% in non-mowed areas of Westover, respectively; 16% and 13% in mowed areas of Westover, respectively; and 10% and 2% at Patuxent, respectively (Table 8, Figure 6). These failures were either due to infertile eggs or to desertion (e.g., abandonment or parental death) though it was usually not possible to determine which as

most nests were not monitored from the beginning of the incubation cycle. Predation and abandonment rates for other species can be found in Table 9.

In mowed areas of Westover, mowing was the direct cause of nest failure for an estimated 11% of Grasshopper Sparrow nests, 19% of Eastern Meadowlark nests, and 10% of Savannah Sparrow nests. Only nine Upland Sandpiper nests occurred in mowed areas of Westover resulting in imprecise estimates for this species (Table 9). At the entirely mowed Patuxent site, mowing was the direct cause of failure at an estimated 8% of Grasshopper Sparrow nests and 15% of Eastern Meadowlark nests (Table 9, Figure 6). No mowing occurred at Lakehurst during the breeding season.

At Westover, 29 (59%) of 49 Grasshopper Sparrow nests were located in mowed areas, and 12 (41%) of these 29 were known to be passed over by a mowed over. The remaining 17 nests either completed nesting (fledged or failed) in the intervals between mowing, or their mowing history prior to discovery could not be determined. Two (20%) of the 10 nests that were mowed over while being monitored (i.e., excluding two mowed prior to discovery) failed as a direct result of mowing (Table 8). Twenty-five (63%) of 40 Eastern meadowlark nests were located in mowed areas at Westover, and nine (36%) of those 25 were known to be passed over by a mower (one prior to discovery). Three of the eight nests mowed over while being monitored failed due to mowing (one destroyed by the mower, and two abandoned immediately following mowing; Table 8). Most Savannah Sparrow nests (51 of 66) were found in mowed areas at Westover and 20 of these were known to be passed over by a mower (one prior to discovery). Four of the 19 mowed over while being monitored failed directly due to mowing (crushed by tires; Table 9). For species with lower sample sizes, mowing directly terminated one of six Upland Sandpiper nests mowed over while being monitored, zero of two Horned Lark nests, zero of one Bobolink nests, and one of one American Woodcock nest.

At Patuxent, 22 (23%) of 96 Grasshopper Sparrow nests were mowed over (four before discovery), while the remaining 74 either fledged or failed between mowing rounds, or their mowing history prior to discovery was unable to be determined. Five (28%) of the 18 nests that were mowed over while being monitored failed as a direct result of mowing (all destroyed by the mower; Table 8). For Eastern Meadowlarks, 32 (40%) of 81 nests were mowed over (seven prior to discovery), and ten (40%) of the 25 nests mowed over while being monitored failed due to mowing: nine were destroyed by the mower, and one was undamaged but deserted immediately after being mowed over. Nests of no other species were mowed over while being monitored at Patuxent.

If data from the two sites are combined, 25% of 28 Grasshopper Sparrow nest mowing events directly resulted in failure, while 39% of 33 Eastern Meadowlark nest mowing events did. Of all species at all sites, 30% of nests that were mowed over failed as a direct result (25 of 84 nests, including 4 of 19 Savannah Sparrow, 1 of 1 American Woodcock, 0 of 1 Bobolink, and 0 of 2 Horned Lark nests).

Productivity

The mean number of Grasshopper Sparrow fledglings produced per nest ranged from 1.7 at Patuxent to 2.3 at Lakehurst, while the mean number produced per successful nest ranged from 3.2 (Westover and Patuxent) to 3.6 (Lakehurst). For Eastern Meadowlark, the mean number of fledglings produced per nest ranged from 1.0 (Patuxent) to 2.1 (Lakehurst), and the mean number produced per successful nest ranged from 3.4 (Westover) to 3.6 (Patuxent; see Table 10).

At Westover, Grasshopper Sparrow and Eastern Meadowlark productivity was best predicted by whether the nest was in a mowed area or not, for both all nests and successful nests only (Table 11). The model including distance to runway also performed well for all nests ($w = 0.29$, $\Delta AIC_c = 0.9$), but not for successful nests ($w = 0.02$, $\Delta AIC_c = 6.8$). The "mowed area" models predicted significantly fewer chicks fledged in mowed vs. non-mowed areas for all nests ($P = 0.004$) and within successful nests only ($P = 0.003$). The model including distance to runway predicted significantly fewer chicks fledged closer to the runway ($P = 0.007$). Distance to runway was confounded with the "mowed area" variable, as discussed above. Further examination of the data revealed that strong differences existed in productivity between mowed areas and non-mowed areas for Eastern Meadowlark (all nests: $P = 0.021$, successful nests: $P < 0.001$), but not for Grasshopper Sparrow ($P > 0.08$; Figures 8 and 9). A model evaluated containing both species and an interaction term (mowed area x species) revealed a marginally non-significant interaction effect within successful nests ($P = 0.054$), but not for all nests ($P = 0.48$). Grasshopper Sparrow and Eastern Meadowlark productivity at Lakehurst, in all nests and in successful nests, was best predicted by location on base ($w > 0.6$), with no other competitive models (Table 11). Productivity for these species within all nests at Patuxent was best predicted by percent bare ground cover near the nest (Table 11), with higher productivity predicted in areas of sparser ground cover ($P = 0.004$; Table 12). Within successful nests at Patuxent, no models performed well relative to the species only model ($w \leq 13$; Table 11).

The top model for productivity analyses including all five grassland obligate species at Westover ($w = 0.54$) predicted an increase in productivity for all nests with increasing forb cover ($P = 0.003$). The second-ranked model, while greater than 2 AIC_c units from the top ($w = 0.11$, $\Delta AIC_c = 3.1$) predicted significantly lower productivity in mowed vs. non-mowed areas ($P = 0.019$). As noted above, forb cover was similar between mowed and non-mowed areas. The top-ranked model for successful nests only ($w = 0.73$) predicted lower productivity in mowed vs. non-mowed areas ($P < 0.001$) for the five species, with no other competitive models.

Closer examination of the components of productivity for our two target species revealed potential mechanisms. Reduced productivity for Eastern Meadowlarks in mowed areas on Westover was apparently due to a combination of lower hatching success and higher partial brood mortality (individual chicks found dead in the nest), though neither of these differed significantly between mowed and non-mowed areas on their own ($P > 0.07$; Figure 8). Dead chicks were found in or near the nest with no signs of injury, and

mowers did not generally directly cause partial brood mortality for Eastern Meadowlarks or Grasshopper Sparrows (n = 1 Grasshopper Sparrow chick). No chick disappearance (chicks missing from nests before fledging age) was noted for Eastern Meadowlarks at Westover (Figure 8). Grasshopper Sparrows also exhibited non-significantly higher rates of hatching failure in mowed vs. non-mowed areas of Westover, but showed very little difference in partial brood mortality (Figure 9). Grasshopper Sparrows exhibited somewhat higher rates of chick disappearance in mowed vs. non-mowed areas of Westover, though this difference was also non-significant (P = 0.14; Figure 9).

Productivity differences between mowed and non-mowed areas were not due to differences in mean initial clutch size, which showed very little difference for both Grasshopper Sparrows and Eastern Meadowlarks (Figures 8 and 9). Initial clutch size did differ significantly among sites for both species (Figures 8 and 9), though the range of mean values was not large. For Eastern Meadowlark, mean initial clutch size was 3.8 on Lakehurst (SD = 1.6, range = 1-5, n = 10), 4.2 on Patuxent (SD = 0.6, range = 2-5, n = 70), and 4.5 on Westover (SD = 0.5, range = 2-5, n = 34). For Grasshopper Sparrow, means were 3.89 on Patuxent (SD = 0.6, range = 2-5, n = 91), 4.0 on Lakehurst (SD = 0.72, range = 1-5, n = 47), and 4.2 on Westover (SD = 0.6, range = 3-5; n = 47).

Nestling Morphometrics

A total of 216 Grasshopper Sparrow and 117 Eastern Meadowlark nestlings were processed and banded during the three years of the study. Sample sizes and summary statistics for each site can be found in Table 13. When nestling mass was examined by approximate age (days), Grasshopper Sparrow mass increase was very similar among sites, while Eastern Meadowlark chicks showed somewhat more variation (Figure 10). Based on our findings of lower productivity in mowed vs. non-mowed areas on Westover, we ran models comparing Eastern Meadowlark and Grasshopper Sparrow nestling mass between these two management areas, controlling for the categorical variable age (i.e., mass = beta1*age + beta2*mowed area). This revealed significantly lower Eastern Meadowlark chick mass in mowed areas compared with non-mowed areas (beta2 = -5.4, P = 0.047), though the overall model was marginally non-significant ($F_{2,38}$ = 2.5, P = 0.095; Figure 11). No difference was found for Grasshopper Sparrow chicks (P = 0.85).

DISCUSSION

During three years of nest searching and monitoring at our three airfield study sites, we have greatly improved our understanding of airfield grassland bird nesting microhabitat, nest survival, and productivity. This was particularly true for our two target species, Grasshopper Sparrow and Eastern Meadowlark, which occurred at all three sites in the largest numbers. Although sample sizes were limited in some instances (e.g., Eastern Meadowlarks at Lakehurst), a clearer picture has emerged regarding the implications of management actions on grassland bird breeding success on regional DoD airfields.

Nesting Phenology and Timing of Mowing

Grasshopper Sparrow appears to be double-brooded on all sites, with a generally similar pattern of nest initiation dates across all three sites: an initial peak in late May, followed by a lull in early June and another peak in late June (Figure 1). Eastern Meadowlark showed a similar though less pronounced bimodal distribution, and began nesting about 10-20 days earlier than Grasshopper Sparrows (Figure 2). Jones et al. (2010) reported a similar late May peak in Grasshopper Sparrow nest initiations in Montana, though they found no second peak in June. Similarly, histograms of nest initiations from Oklahoma also show a late May peak for Grasshopper Sparrow and an early May peak for Eastern Meadowlark, though also apparently no second peaks (Reinking et al. 2009). Other species, such as Upland Sandpiper on Westover and Common Nighthawk on Lakehurst, showed indications of being single-brooded, with a single peak in nesting activity (Figures 3 and 4).

The timing of nesting for grassland species on airfields has implications for their vulnerability to being mowed over and the potential for re-nesting. In our study, the first mowing of the season in the 7-14 inch managed areas on Westover usually began in late May or early June and finished over the course of about two weeks (Figure 12). At Patuxent, mowing typically began earlier, varying between early and late May depending on the year. At both sites, individual plots were re-mowed approximately every three to four weeks depending on the grass growth rate (i.e., the time required for grass to exceed 14 inches) and logistical constraints. This schedule resulted in individual plots being mowed about two to three times during the breeding season (April through July). Based on the later nesting phenology of Grasshopper Sparrow compared with Eastern Meadowlark, timing the initial mowing of the season earlier in May would likely result in fewer Grasshopper Sparrow nests being mowed over, but not necessarily fewer Eastern Meadowlarks . In fact, a lower proportion of Grasshopper Sparrow nests were mowed over at Patuxent (23%) where mowing generally begins in early to mid-May, than at Westover (41%) which generally begins in late May after many Grasshopper Sparrows have begun nesting (Figures 1 and 12). Approximately the same proportion of Eastern Meadowlark nests were mowed over at Westover (36%) and Patuxent (37%).

Other studies of disturbance to nesting grassland birds during the breeding season (mainly hay harvesting and grazing) have emphasized the importance of re-nesting as a factor in overall population viability (Perlut et al. 2006, Perlut and Strong 2011). Species-specific behavioral differences are also important. In Vermont's Champlain Valley, Savannah Sparrows re-nested soon after destruction due to hay harvesting, while Bobolinks generally abandoned the field for at least two weeks before returning to re-nest (Perlut et al. 2006). Hay harvesting involves near total removal of vegetation at a lower height than the 7-inch mowing practiced at military airfields, and therefore may have involved longer re-nesting intervals than at our sites where vegetation following mowing was left more intact, but more study is needed. In a study of grazing effects on Savannah Sparrow and Bobolink nest survival, Perlut and Strong (2011) recommend rotating cattle on a 42-50 day schedule to allow ample time for re-nesting after trampling by cattle. Lengthening the interval between mowing events on Westover and Patuxent would likely

improve overall grassland bird productivity on those sites by allowing birds that re-nested following mowing-induced failure to complete a second nesting attempt.

Nest Site Characteristics

At least one pattern of nest site characteristics existed across all sites: an apparent preference by Eastern Meadowlarks for denser vegetation and/or avoidance of areas with bare ground. Meadowlark nest sites had less bare ground and more grass cover than random locations at all sites, and also had less bare ground cover than Grasshopper Sparrow nests within each site (Figure 5). This apparent preference for denser vegetation could be a reason we found only 10 Meadowlark nests in three years on Lakehurst, our most sparsely vegetated site (mean bare ground cover in random areas = 42%; Table 3). Grasshopper Sparrows had less bare ground than random areas at Lakehurst, and more bare ground at Patuxent (our densest site: mean bare ground = 10%), possibly indicating a preference for intermediate amounts of bare ground. Other studies have noted sparse, bunch-forming vegetation as typical habitat for Grasshopper Sparrow (Dechant et al. 2002), and dense, lush grasslands as typical for Eastern Meadowlarks (Jaster et al. 2012). No consistent vegetation height preference was noted across sites, but interestingly both Eastern Meadowlark and Grasshopper Sparrow nest sites had significantly shorter vegetation than random areas in both mowed and non-mowed areas of Westover. Because random vegetation measurements were taken in mid-June while nest vegetation measurements were taken throughout the season it is possible that this effect could be a sampling artifact, particularly for Meadowlarks, which had a median initiation date about a month earlier than the random vegetation measurements (15 May vs. 15-23 June). Grasshopper Sparrow's median initiation date (June 12th) more closely coincided with the timing of random measurements. This effect would mainly be a concern in non-mowed areas where grass height increases steadily throughout the season. However, when nest vegetation height was plotted by date in non-mowed areas, predicted vegetation height at Westover for both Meadowlark and Grasshopper Sparrow nests in mid-June was still about 15-25 cm lower than the average height in random areas (Figure 13). There is also the possibility that nests in tall, dense vegetation were less likely to be found by observers than were those in shorter vegetation. We don't believe this to be a major factor at Westover where most habitats were fairly open and nests were typically identified by flushing incubating or brooding females.

Nest Survival and Cause-specific Failure Rates

Overall nest survival rates (i.e., probability of fledging at least one young, calculated based on DSR) for Grasshopper Sparrow at all three sites were above average when compared with rates from other studies (median from 20 studies = 24%; Figure 14). Overall nest survival rates on non-mowed sections of Westover (53%) and on the non-mowed Lakehurst site (46%) were exceptionally high compared with these studies, while rates on the mowed section of Westover (28%) and the mowed Patuxent site (28%) were approximately average (Figure 14). Overall nest survival rates for Eastern Meadowlark in mowed areas of Westover (15%) and on the mowed Patuxent site (14%) were somewhat below average when compared with rates from 14 other studies (median =

18%; Figure 15), but were very similar to that found on mowed commercial airfields in Illinois (14%; Kershner and Bollinger 1996). In contrast, the overall nest survival rate from the non-mowed section of Westover (40%) was among the highest of these 14 studies (Figure 15). Meadowlark nest survival was also high on the non-mowed Lakehurst site (53%), though sample sizes were low (n = 10 nests).

Daily nest survival rates for Grasshopper Sparrow and Meadowlark were best predicted by several factors confounded with mowing at the partially-mowed Westover site: distance to runway (positive), grass cover (negative), and occurrence within mowed areas (lower within). Given our study design, it is not possible to say which of these factors was more important. However, given the direct mortality observed in mowed areas (an estimated 11 and 19% of nesting attempts for Grasshopper Sparrow and Meadowlarks, respectively), "mowed areas" as a driver of nest survival is an attractive hypothesis. In addition, nest abandonment was a source of nest mortality in mowed areas (13-16%), but not in non-mowed areas on Westover for these species (Table 8, Figure 6). Predation rates were very similar between mowed and non-mowed areas (Figure 6), suggesting that increased visibility to scavenging predators is less of a problem in this system than in some grass-based agricultural systems (e.g., Bollinger et al. 1990, Perlut et al. 2006). The similarity in overall nest survival of Savannah Sparrows between mowed and non-mowed areas (despite an estimated 11% direct mowing-related nest mortality) deserves further study; the compensating factor seemed to be higher predation rates in non-mowed areas, though sample sizes in this group were low (n = 15 nests; Table 9).

Overall nest survival estimates for Grasshopper Sparrow and Meadowlark were substantially lower in mowed areas than in non-mowed areas at Westover – 28 vs. 53% for Grasshopper sparrow, 15 vs. 40% for Meadowlarks. These differences were statistically significant when the two species were analyzed jointly (P = 0.030; Table7), but not when separate analyses were run for each species (P = 0.15 and 0.12, respectively). Though the differences are likely biologically/ecologically significant, the power to detect them for individual species at alpha = 0.05 is relatively low given our sample sizes of 15-29 nests per group. Hensler and Nichols (1981) estimate that the probability of detecting a true difference in DSR of approximately what we observed (ΔDSR = 0.03-0.04 for DSR = 0.95, n = 20 nests per group) would be only 30-67%. This increases to 92-99% for samples of 75 nests per group. Cumulative nest survival estimates for Meadowlarks and Grasshopper Sparrows at Westover have been higher in non-mowed areas than in mowed areas during all three years of the study (Peters and Allen 2010, 2011), and confidence intervals have narrowed each year (Figure 16).

At the entirely-mowed Patuxent site, vegetation height best explained Eastern Meadowlark and Grasshopper Sparrow nest survival, with lower survival predicted at shorter vegetation heights. Given this result and because grass height is associated with mowing frequency during the growing season, it was surprising that the more direct model comparing nests mowed over with those not mowed over performed poorly (w = 0.01, ΔAIC_c = 8.8). This was also the case at Westover (w = 0.06, ΔAIC_c = 4.0). It is possible that the relatively low sample sizes of mowed nests (n = 8-25 per species per site) hindered our ability to detect an effect, as mowing was indeed a source of direct

mortality for nests of these species: an estimated 8 and 11% of Grasshopper Sparrow nests and 15 and 19% of Eastern Meadowlark nests at Patuxent and Westover, respectively (Table 8). The observed grass height effect at Patuxent could also be related to less direct factors such as greater visibility to predators. While we found little evidence of this at Westover (e.g., no difference in predation rates between mowed and non-mowed areas), predator communities likely differ between these two geographically and physiographically distinct sites. Bollinger et al. (1990) observed significant opportunistic predation of surviving Bobolink nests immediately following hay harvesting, particularly by the visually-oriented predators Ring-billed Gull (*Larus delawarensis*) and American Crow (*Corvus brachyrhynchos*). Similarly, after hay cutting in Vermont, nearly all surviving Savannah Sparrow and Bobolink nests were scavenged by predators (Perlut et al. 2006).

No effect of grass height was observed at Lakehurst, where nest survival was instead predicted to decrease with greater amounts of grass cover near the nest (Table 7). This result (which was shared with the second-ranked model at Westover) was somewhat unexpected given that higher amounts of grass cover might be expected to conceal nests. One possibility is that certain species of nest predators (e.g., rodents; Renfrew and Ribic 2003) could be more abundant in areas of dense grass.

Ours is one of very few studies to assess grassland bird nest survival or productivity on active airfields (Kershner and Bollinger 1996, Jones 2000, USFWS 2001), with only one previous study to our knowledge (Kershner and Bollinger 1996) involving large enough sample sizes to draw conclusions about the effects of mowing. Kershner and Bollinger (1996) found 14% overall nest survival for Eastern Meadowlarks on commercial airfields in Illinois, very similar to rates we observed for Meadowlarks in mowed areas of Westover (15%) and on the mowed Patuxent site (14%). While these values seem low, it appears from the literature that poor nest survival of Eastern Meadowlarks is not uncommon. The observed rates are only slightly below average in a comparison of 14 studies in a variety of natural and anthropogenic habitats (median = 18%; Figure 15). Kershner and Bollinger (1996) found a higher proportion of failures attributable to mowing than we did: 44% of failures, compared with 15% of failures at Patuxent and 19% of failures in mowed areas on Westover (Table 8). This could be due to a greater frequency of mowing on their sites (as often as once per week), as they observed a negative correlation between mowing frequency and nest success. Mowing heights at their sites were also generally lower than ours (as low as 4 cm compared with 18 cm at ours). However, Kershner and Bollinger (1996) did not provide cause-specific failure rates, so it is also possible that their sites experienced lower rates of other failure causes, making the relative contribution of mowing failures higher.

One of the goals of this study was to estimate mowing 'take', or numbers of nests lost due to grassland management activities. Combining all years of the study, estimated direct mowing-related nest mortality for Grasshopper Sparrows was 8% of nests at Patuxent and 11% of nests in mowed areas on Westover. Estimates for Eastern Meadowlarks were somewhat higher, with 15% of nests on Patuxent and 19% of nests in mowed areas on Westover expected to fail due to mowing. These estimates (Table 8) should be refined

with further years of monitoring; however, as an example of their impact, recent abundance estimates indicated that there are approximately 236 breeding pairs of Grasshopper Sparrows on Westover (Melvin 2012). If the 6% direct failure rate that we observed for this species (across both mowed and non-mowed areas) is assumed, expected loss due directly to mowing would be approximately 14 Grasshopper Sparrow nests per breeding season. Due to changing Air Force policies, the mowed area on Westover is likely to expand in the near future to include nearly all grasslands on the airfield (A. Milroy, *personal comm.*). If this occurs and all areas experience the estimated 11% direct mowing failure rate of mowed areas, the expected loss due to mowing would be about 26 Grasshopper Sparrow nests per season.

Productivity

One of the more intriguing findings in this study was that the number of young produced per successful nest both for target species and for all species at Westover was lower in mowed areas than in non-mowed areas. Eastern Meadowlarks showed the strongest response with 2.6 chicks fledged per successful nest in mowed areas vs. 4.3 in non-mowed areas (Table 10, Figure 8). This was not a result of differing initial clutch sizes, but seemed to be related to a combination of lower hatching success and a higher incidence of individual chick deaths in the nest (Figure 8). Chick mortality was possibly the result of starvation or disease as all dead chicks were found in or near the nest with no signs of injury. Partial brood mortality (i.e., death of one or more chick, not resulting in total nest failure) due to the mower was rare (n = 1 Grasshopper Sparrow chick). The hypothesis that chick deaths may be related to food limitations is supported by the lower mean chick mass we observed within Eastern Meadowlark nests in mowed areas, though this trend should be supported with more data (Figure 11). Zalik and Strong (2008) found lower invertebrate abundance in hay fields after mowing along with lower nestling provisioning rates for Savannah Sparrows, though this did not translate into reduced chick mass. In addition to chick mortality, a lack of food availability could reduce hatching success by causing females to neglect incubation in order to find enough food for themselves (MacDonald et al. 2013). Nests and eggs with less concealing vegetation due to mowing may also be more exposed to wind and sun (e.g., With and Webb 1993). The higher rates of nest abandonment observed for Meadowlarks and Grasshopper Sparrows in mowed areas of Westover may be related to these factors (i.e., through hatching failure), though it was generally not possible to determine why nests were abandoned. Increased sample sizes of nests, and especially of successful nests, would allow more detailed investigations into species-specific productivity responses.

Conclusions

In this study, we focused on nest survival and productivity at three active airfields with varied management regimes. However, source-sink population dynamics also depend on other factors more difficult to measure. These include the number of broods attempted per year, as well as year-round juvenile and adult survival (Perlut et al. 2008, Perlut and Strong 2011). For example, poor post-fledgling survival due to direct mower mortality or mowing-related habitat alteration would have a negative effect on population health

similar to poor nest survival. There is evidence that Grasshopper Sparrow and Eastern Meadowlark can produce two broods at our sites (e.g., Figures 1 and 2; also Jones 2000 [Westover]), which would allow a higher annual productivity for pairs that do escape the mower. Re-nesting also likely compensates for some nests destroyed by mowers, especially those destroyed earlier in the season (Perlut and Strong 2011). These factors would all be useful subjects for future study. Because airfields are thought to be important 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 become available. Given the limited geographic coverage of our study and others (Kershner and Bollinger 1996), data from more locations would strengthen conclusions regarding the effects of airfield management and operations on grassland bird reproductive success. Data from more sites with both mowed and non-mowed management areas (similar to Westover) would be especially useful.

Besides improving the precision of nest survival and failure rate estimates in mowed and non-mowed areas, potential areas of future research include: 1) investigating the apparent disparity in direct mowing-related nest mortality rates between Grasshopper Sparrow and Eastern Meadowlark; 2) further investigating causes of reduced productivity (e.g., hatching success, nestling survival) of Eastern Meadowlark and other species in mowed areas; 3) focusing research on rates and timing of re-nesting, annual productivity, and post-fledging survival in mowed and non-mowed areas; 4) evaluating how timing of mowing may be altered to minimize the effects on species of greatest conservation concern; and 5) expanding research to more airfields to broaden the scope of inference.

Benefits to the Military

Taken in conjunction with a parallel study conducted on the same three sites that focused on management effects on habitat use by species of Bird Air-Strike Hazard (BASH) risk and those of conservation priority (Peters et al. 2012), findings from this research can aid in generating comprehensive management plans for grassland birds on DoD lands.

In previous reports we made several suggestions for enhancing DoD management decisions regarding airfield safety and habitat management, with the goal of minimizing the likelihood of problem species occurrence and maximizing positive effects on conservation concern species (Peters et al. 2012). Data obtained in this study will provide DoD airfield managers with an increased general understanding of how mowing and other management activities on their lands affect sensitive grassland bird populations. Results from this study also identified nesting microhabitat preferences of species of conservation concern on airfields and provided site-specific information on the timing of nesting. Data collected through this project can be used to develop best management practices that may serve as guidelines for airfield managers wishing to minimize impacts on sensitive grassland species. For instance, resource managers may be able to respond by altering mowing regimes (e.g., to avoid critical nesting periods) or by manipulating habitat to draw birds away from active runways.

Ultimately, a clearer understanding of how airfield habitat management practices affect species of conservation concern will be essential to developing Integrated Natural Resources Management Plans (INRMPs) for Navy, Air Force and Army bases. Additional 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. A logical next step in this process could be to integrate findings from various monitoring studies into a Structured Decision Making (SDM) process (review in Peters et al. 2012) that recognizes all potential objectives, engages various stakeholders, and uses the best available science to determine optimal management plans for individual DoD airfields.

LITERATURE CITED

Ammer, F. K. 2003. Population level dynamics of grasshopper sparrow populations breeding on reclaimed mountaintop mines in West Virginia. Dissertation. West Virginia University, Morgantown.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1-34.

Askins, R. A. 1996. History and conservation of grassland birds in the northeastern United States. In The ecology and conservation of grasslands and heathlands in the northeastern United States (P. D. Vickery, P. Dunwiddie, C. Griffin, Eds.). Massachusetts Audubon Society, Lincoln, MA.

Askins, R. A., F. Chavez-Ramirez B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. Conservation of grassland birds in North America: Understanding ecological processes in different regions. Ornithological Monographs 64:1-46.

Bairlein, F. 1995. European-African songbird migration network manual of field methods. Institut für Vogelforschung, Wilhelmshaven, Germany.

Battin, J. 2004. When good animals love bad habitats: Ecological traps and the conservation of animal populations. Conservation Biology 18:1482-1491.

Bollinger, E. K., P. B. Bollinger, and T. A. Gavin. 1990. Effects of Hay-Cropping on Eastern Populations of the Bobolink. Wildlife Society Bulletin 18:142-150.

Brawn, J. 2009. Upland bird survey at Nachusa Grasslands, Final Report. Submitted to The Nature Conservancy, Illinois.

Brennan, L. A. and W. P. Kuvlesky. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management 69:1-13.

Brigham, R. M., Janet Ng, R. G. Poulin and S. D. Grindal. 2011. Common Nighthawk (*Chordeiles minor*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/213

Brown, S., C. Hickey, B. Harrington, and R. Gill, eds. 2001. The U.S. Shorebird Conservation Plan, 2nd ed. Manomet Center for Conservation Sciences, Manomet, MA.

Brown, S., R. Lanctot, B. Sandercock, R. Gates, J. Liebezeit, P. Smith, and B. Hill. 2012. Arctic shorebird demographics network breeding camp protocol, version 3. Manomet Center for Conservation Sciences, Plymouth, MA.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach – 2nd ed. Springer Science & Business Media, Inc., New York, NY.

Carey, M., D. E. Burhans and D. A. Nelson. 2008. Field Sparrow (Spizella pusilla), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/103

Carney, K. M. and W. J. Sydeman. 1999. A review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22: 68-79.

CNIC [Commander, Navy Installations Command]. 2010. Bird/Animal Aircraft Strike Hazard (BASH) Manual. http://www.public.navy.mil/navsafecen/Pages/aviation/AirfieldOperations.aspx (accessed 12/15/2013).

Conway, C. and T. E. Martin. 1999. The value of monitoring demographic parameters and associated habitat: the BBIRD program. *In* R. Bonney, D. N. Pashley, R. J. Cooper, L. Niles, eds., Strategies for bird conservation: the Partners in Flight planning process. Cornell Lab of Ornithology. <http://birds.cornell.edu/pifcapemay>

Davison, W. B. and E. Bollinger. 2000. Predation rates on real and artificial nests of grassland birds. Auk 117:147-153.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, M. P. Nenneman, and B. R. Euliss. 2002. Effects of management practices on grassland birds: Grasshopper Sparrow. Northern Prairie Wildlife Research Center, Jamestown, ND. 28 pages.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476-3488.

Dinsmore, S. J., and J. J. Dinsmore. 2007. Modeling avian nest survival in program MARK. Studies in Avian Biology 34:73-83.

Forman, R. T., B. Reineking, and A. M. Hersperger. 2004. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. Environmental Management 29:782-800.

Freckleton, R. P. 2011. Dealing with collinearity in behavioural and ecological data: model averaging and the problems of measurement error. Behavioral Ecology and Sociobiology. 65:91-101.

Galligan, E. W., T. L. Devault, and S. L. Lima. 2006. Nesting success of grassland and savanna birds on reclaimed surface coal mines of the Midwestern United States. Wilson Journal of Ornithology 118:537-546.

Giocomo, J. J., E. D. Moss, D. A. Buehler, and W. G. Minser. 2008. Nesting biology of grassland birds at Fort Campbell, Kentucky and Tennessee. Wilson Journal of Ornithology 120:111-119.

Granfors, D. A., K. E. Church, and L. M. Smith. 1996. Eastern meadowlarks nesting in rangelands and conservation reserve program fields in Kansas. Journal of Field Ornithology 67:222-235.

Grant, T. A., T. L. Shaffer, E. M. Madden, and P. J. Pietz. 2005. Time-specific variation in passerine nest survival: new insights into old questions. Auk 122:661-672.

Graves, B. M. 2007. Grassland bird conservation on reclaimed surface mines: evaluating the influence of vegetation structure on distribution, nest placement and nesting success. Thesis. Ohio State University.

Halfwerk, W., L. J. M. Holleman, C. M. Lessells, and H. Slabbekoorn. 2010. Negative impact of traffic noise on avian reproductive success. Journal of Applied Ecology 48(1):210-219.

Hensler, G. L. and J. D. Nichols. 1981. The Mayfield method of estimating nesting success: a model, estimators and simulation results. Wilson Bulletin 93: 42-53.

Herkert, J. R., D. L. Reinking, D. A. Wiedenfeld, M. Winter, J. L. Zimmerman, W. E. Jensen, E. J. Finck, R. R. Koford, D. H. Wolfe, S. K. Sherrod, M. A. Jenkins, J. Faaborg, and S. K. Robinson. 2009. Effects of prairie fragmentation on the nest success of breeding birds in the midcontinental United States. Conservation Biology 17:587-594.

Houston, C. S. and D. E. Bowen, Jr. 2001. Upland Sandpiper (Bartramia longicauda), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/580.

Hovick, T. J., J. R. Miller, S. J. Dinsmore, D. M. Engle, D. M. Debinski, and S. D. Fuhlendorf. 2012. Effects of fire and grazing on grasshopper sparrow nest survival. 76:19-27.

Hubbard, R. D., D. P. Althoff, K. A. Blecha, B. A. Bruvold, and R. D. Japuntich. 2006. Nest site characteristics of eastern meadowlarks and grasshopper sparrows in tallgrass prairie at the Fort Riley military installation, Kansas. Transactions of the Kansas Academy of Science, 109:168-174.

Ibanez-Alamo, J. D., O. Sanllorente, and M. Soler. 2012. The impact of researcher disturbance on nest predation rates: a meta-analysis. Ibis 154:5-14.

Jaster, L. A., W. E. Jensen and W. E. Lanyon. 2012. Eastern Meadowlark (Sturnella magna), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/160

Jensen, W. E. 1999. Nesting habitat and responses to habitat edges of three grassland passerine species. Thesis. Emporia State University, Kansas.

Jones, A. L. 2000. Grasshopper sparrow (*Ammodramus savannarum*) metapopulation dynamics and conservation strategies in Massachusetts. Master of Science Thesis. University of Massachusetts Amherst, Department of Natural Resources Conservation.

Jones, S. L., J. S. Dieni, and P. J. Gouse. 2010. Reproductive biology of a grassland songbird community in northcentral Montana. Wilson Journal of Ornithology 122:455-464.

Kershner, E. L., and E. K. Bollinger. 1996. Reproductive success of grassland birds at east-central Illinois airports. American Midland Naturalist 136:358-366.

Koford, R. R. 1999. Density and fledging success of grassland birds in Conservation Reserve Program fields in North Dakota and west-central Minnesota. Studies in Avian Biology 19:187-195.

Laake, J., E. Rakhimberdiev, B. Collier, J. Rotella, and A. Paul. 2012. RMark: R Code for MARK Analysis. R package version 2.1.3. http://CRAN.R-project.org/package=RMark

MacDonald, E. C., A. F. Camfield, J. E. Jankowski, and K. Martin. 2013. Extended incubation recesses by alpine-breeding horned larks: a strategy for dealing with inclement weather? Journal of Field Ornithology 84:58-68.

Martin, T. E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management? Pages 455-473 *in* J. M. Hagan and D. W. Johnston, eds. Ecology and Conservation of Neotropical Migrants. Smithsonian Institution Press, Washington, DC.

Martin, S. G. and T. A. Gavin. 1995. Bobolink (*Dolichonyx oryzivorus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/176

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

McCoy, T. D., M. R. Ryan, E. W. Kurzejeski, and L. W. Burger. 1999. Conservation Reserve Program: Source or sink habitat for grassland birds in Missouri? Journal of Wildlife Management 63:530-538.

Melvin, S. M. 1994. Military bases provide habitat for rare grassland birds. Natural Heritage News, Massachusetts Division of Fish and Wildlife 4:3.

Melvin, S. M. 2012. 2012 Breeding season survey of grassland birds at Westover Air Reserve Base, Massachusetts. Report of the Massachusetts Natural Heritage and Endangered Species Program, Westborough, MA.

MDFW [Massachusetts Division of Fish and Wildlife]. 2013. An action plan for the conservation of state-listed obligate grassland birds in Massachusetts. Report submitted to the Massachusetts Environmental Policy Act Office, Boston, MA. May 22, 2013.

Norment, C. 2002. On grassland bird conservation in the Northeast. Auk 199:271-279.

Norment, C. J., M. C. Runge, and M. R. Morgan. 2010. Breeding biology of grassland birds in western New York: conservation and management implications. Avian Conservation and Ecology 5:3 [online].

Osborne, D. R. and A. T. Peterson. 1984. Decline of the upland sandpiper (*Bartramia longicauda*) in Ohio: an endangered species. Ohio Journal of Science 84:8-10.

Patterson, M. P. and L. B. Best. 1996. Bird abundance and nesting success in Iowa CRP fields: The importance of vegetation structure and composition. American Midland Naturalist 135:153-167.

Perkins, D. W. and P. D. Vickery. 2007. Nest Success of Grassland Birds in Florida Dry Prairie. Southeastern Naturalist 6:283-292.

Perkins, D. W., P. D. Vickery, and W. G. Shriver. 2003. Spatial dynamics of source-sink habitats: Effects on rare grassland birds. Journal of Wildlife Management 67:588-599.

Perlut, N. G. and A. M. Strong. 2011. Grassland birds and rotational-grazing in the Northeast: breeding ecology survival and management opportunities. Journal of Wildlife Management 75:715-720.

Perlut, N. G., A. M. Strong, T. M. Donovan, and N. J. Buckley. 2006. Grassland songbirds in a dynamic management landscape: Behavioral responses and management strategies. Ecological Applications 16:2235-2247.

Perlut, N. G., A. M. Strong, T. M. Donovan, and N. J. Buckley. 2008. Grassland songbird survival and recruitment in agricultural landscapes: implications for source–sink demography. Ecology 89:1941-1952.

Peters, K. A., M. C. Allen, and N. Tsipoura. 2012. Avian response to grassland management around military airfields in the Mid-Atlantic and Northeast regions. Final Report. Submitted to the Department of Defense Legacy Resource Management Program. Project # 10-381.

Peters, K. P. and M. Allen. 2011. Grassland Bird Productivity on Military Airfields in the Mid-Atlantic and Northeast Regions. Interim Report 2. Submitted to the Department of Defense Legacy Resource Management Program. Project # 09-408.

Peters K. P., and M. Allen. 2010. Grassland Bird Productivity on Military Airfields in the Mid-Atlantic and Northeast Regions - Interim Report 1. Submitted to the Department of Defense Legacy Resource Management Program. Project # 08-408.

R Development Core Team. 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Rahmig, C. J., W. E. Jensen, and K. A. With. 2009. Grassland Bird Responses to Land Management in the Largest Remaining Tallgrass Prairie. Conservation Biology 23:420-432.

Reinking, D. L., D. H. Wolfe, and S. K. Sherrod. 2009. Nest monitoring, point counts, and habitat of tallgrass prairie breeding birds of northeastern Oklahoma, 1992-1996. Publications of the Oklahoma Biological Survey, 2nd Series. 9:1-12.

Renfrew, R. B. and C. A. Ribic. 2003. Grassland passerine nest predators near pasture edges identified on videotape. Auk 120:371-383.

Ribic, C. A., M. J. Guzy, T. J. Anderson, D. W. Sample, and J. L. Nack. 2012. Bird productivity and nest predation in agricultural grasslands. Studies in Avian Biology 43:119-134.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D.W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology. Ithaca, NY.

Rohrbaugh, R. W., D. L. Reinking, D. H. Wolfe, S. K. Sherrod, and M. A. Jenkins. 1999. Effects of prescribed burning and grazing on nesting and reproductive success of three grassland passerine species in tallgrass prairie. Studies in Avian Biology 19:165-170.

Sutter, B. and G. Ritchison. 2005. Effects of grazing on vegetation structure, prey availability, and reproductive success of Grasshopper Sparrows. Journal of Field Ornithology 76:345-351.

Stauffer, G. E., D. R. Diefenbach, M. R. Marshall, and D. W. Brauning. 2011. Nest success of grassland sparrows on reclaimed surface mines. Journal of Wildlife Management 75:548-557.

Strasser, E. H., and J. A. Heath. 2013. Reproductive failure of a human-tolerant species, the American kestrel, is associated with stress and human disturbance. Journal of Applied Ecology 50:912-919.

USAF [United States Air Force]. 2004a. Air Force Instruction (AFI) 32-7064. Integrated Natural Resources Management. Department of the Air Force. Government Printing Office. Washington, D.C.

USAF [United States Air Force]. 2004b. Air Force Pamphlet (AFPAM) 91-212. Bird/Wildlife Aircraft Strike Hazard (BASH) Management Techniques. Department of the Air Force. Government Printing Office. Washington, D.C.

USFWS [United States Fish & Wildlife Service]. 1995. The Silvio O. Conte National Fish and Wildlife Refuge. Final action plan and environmental impact statement (EIS). Turners Falls, Massachusetts, USA.

USFWS [United States Fish & Wildlife Service]. 2001. The effects of mowing on grassland birds. Report prepared for Niagra Falls Air Reserve Station by U.S. Dept. of Interior Fish and Wildlife Service Lower Great Lakes Fisheries Resources Office, Amherst, NY

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

Vickery, P. D. 1996. Grasshopper sparrow (Ammodramus savannarum). In The Birds of North America, No. 239 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists' Union, Washington, DC.

Vickery,P. D., and P. A. Dunwiddie, eds. 1997. Grasslands of Northeastern North America. Massachusetts Audubon Society, Lincoln, Massachusetts.

Walk, J. W., E. L. Kershner, T. J. Benson and R. E. Warner. 2010. Nesting success of grassland birds in small patches in an agricultural landscape. Auk 127:328-334.

Wheelwright, N. T. and J. D. Rising. 2008. Savannah Sparrow (*Passerculus sandwichensis*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/045

White, G. C. and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46: 120-139.

Winter, M. and J. Faaborg. 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology 13:1424-1436.

Winter, M., S. E. Hawks, J. A. Shaffer, and D. H. Johnson. 2003. Guidelines for finding nests of passerine birds in tallgrass prairie. Prairie Naturalist 35:197-211.

With, K. A., and D. R. Webb. 1993. Microclimate of ground nests - the relative importance of radiative cover and wind breaks for 3 grassland species. Condor 95:401-413.

Wray, T., II, K. A. Straight, and R. C. Whitmore. 1982. Reproductive success of grassland sparrows on a reclaimed surface mine in West Virginia. Auk 99:157-164.

Zalilk, N. J. and A. M. Strong. 2008. Effects of hay cropping on invertebrate biomass and the breeding ecology of Savannah Sparrows (*Passerculus sandwichensis*). Auk 125:700-710.

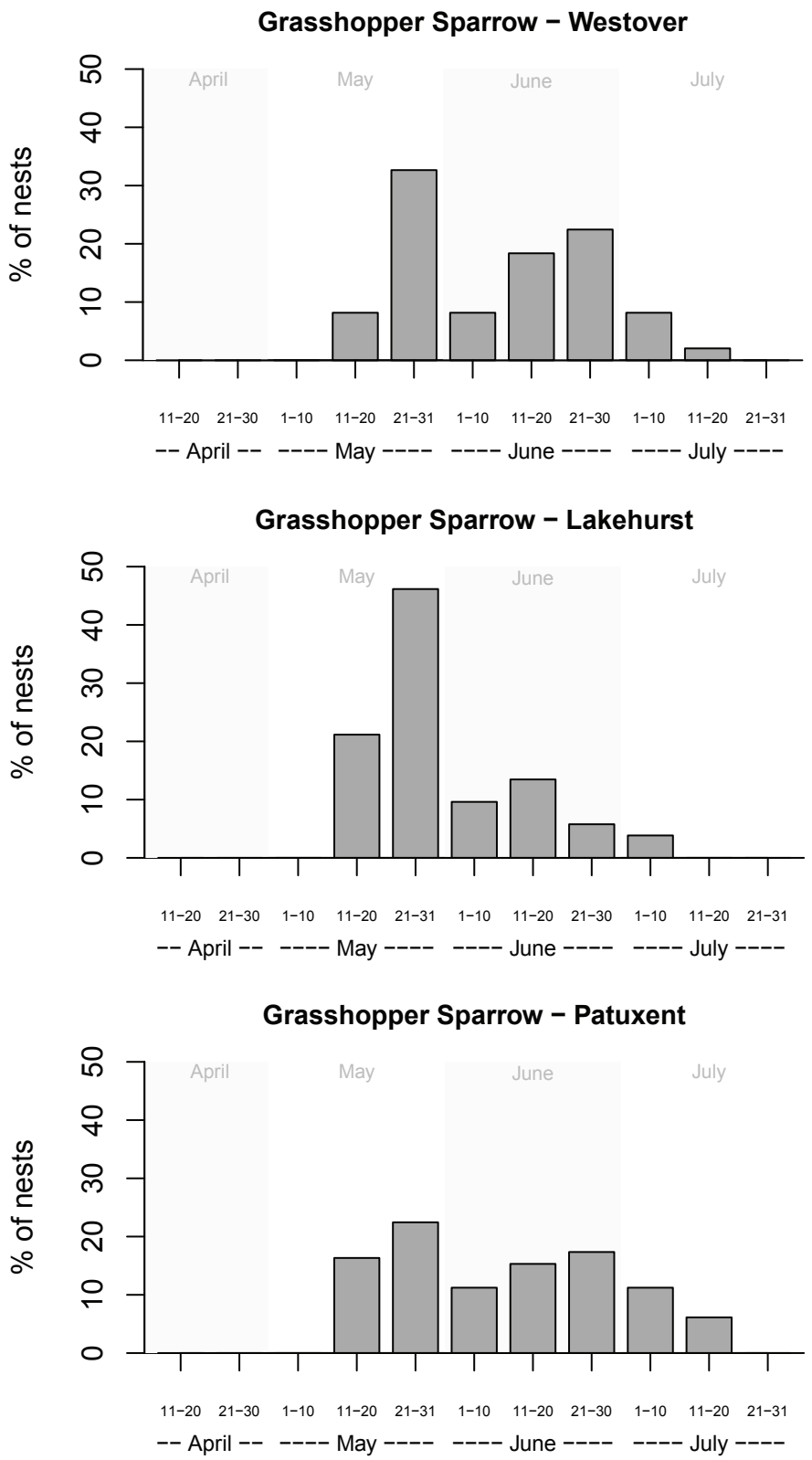


Figure 1. Estimated initiation dates (start of incubation) for Grasshopper Sparrow nests monitored during 2009, 2010, and 2012 at the Westover, Lakehurst, and Patuxent sites.

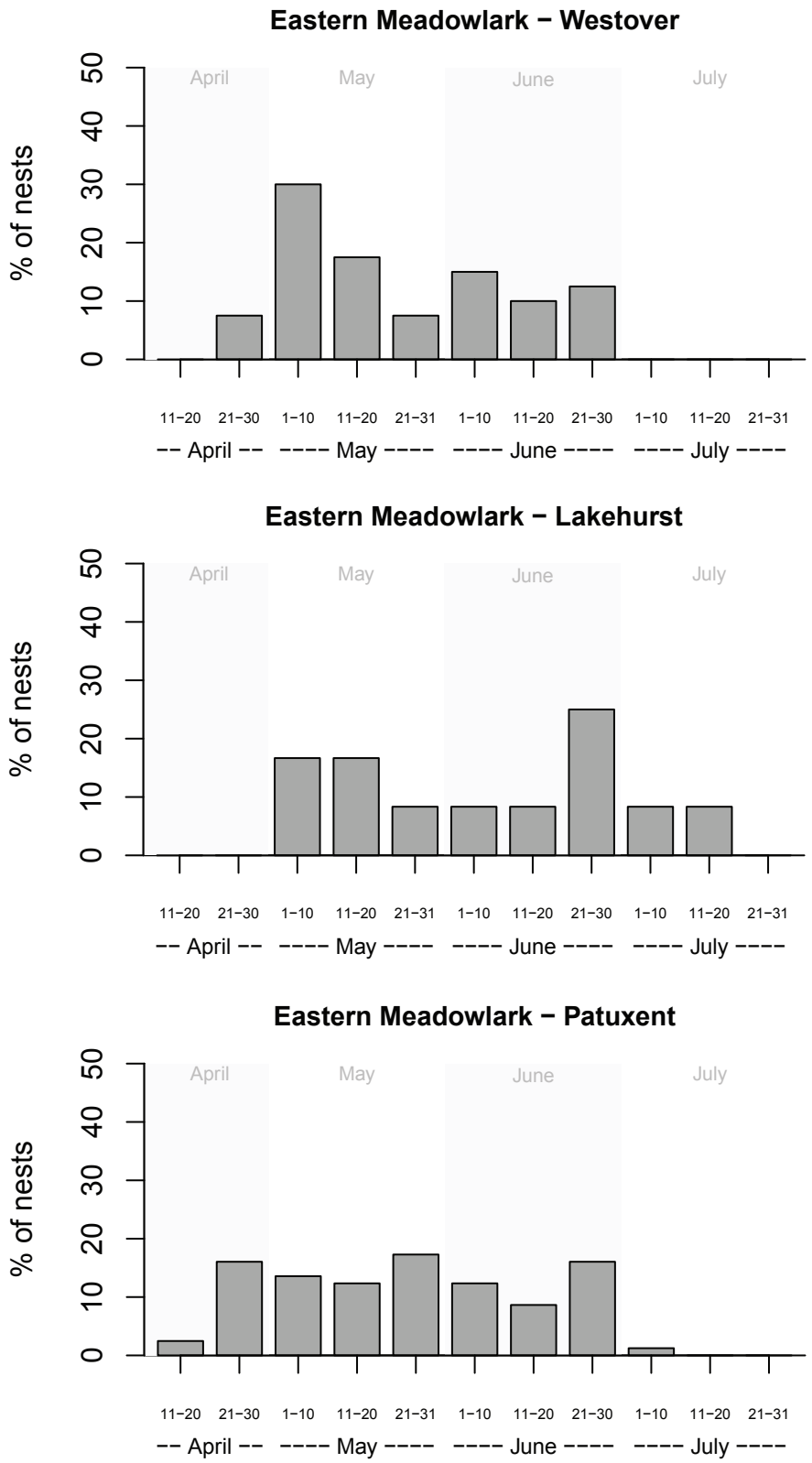


Figure 2. Estimated initiation dates (start of incubation) for Eastern Meadowlark nests monitored during 2009, 2010, and 2012 at the Westover, Lakehurst, and Patuxent sites.

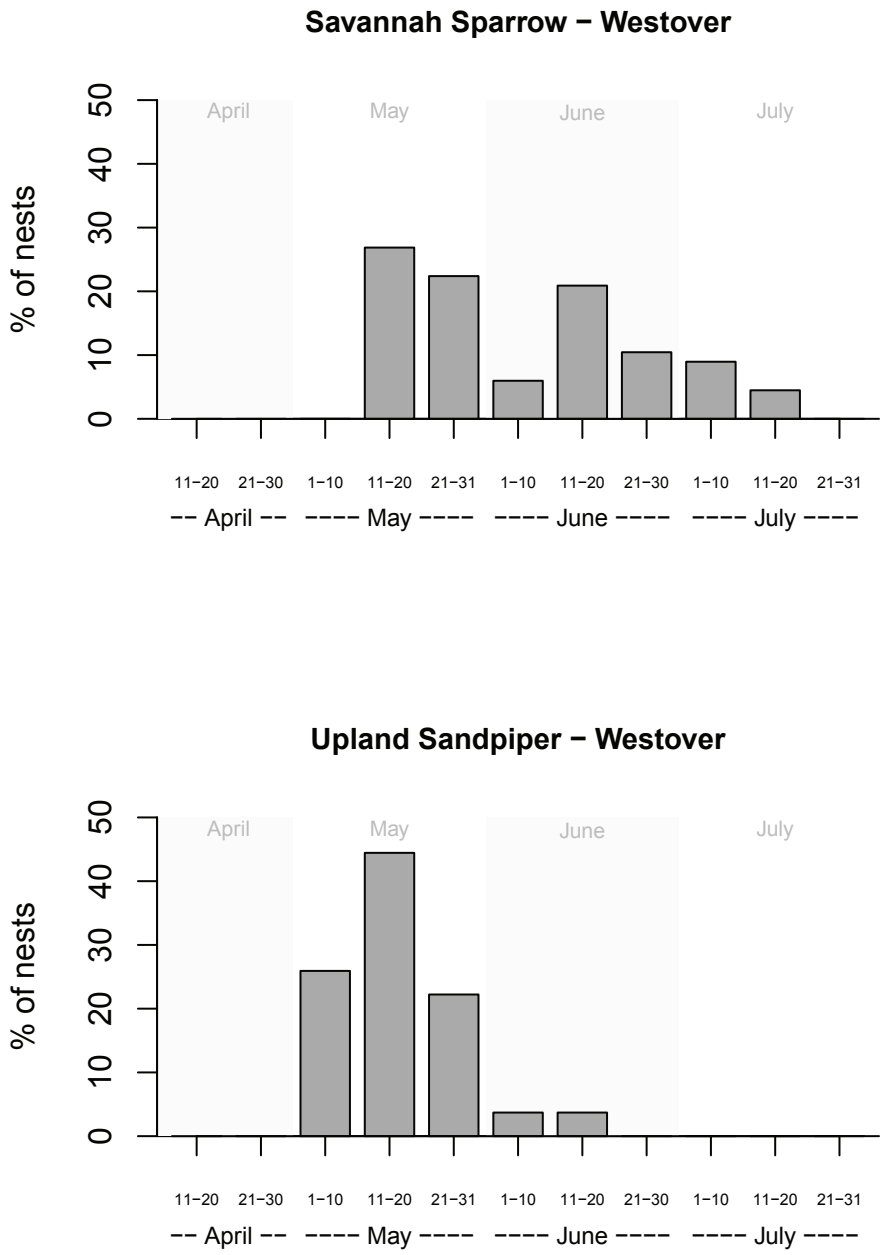


Figure 3. Estimated initiation dates (start of incubation) for Savannah Sparrow and Upland Sandpiper nests monitored during 2009, 2010, and 2012 at Westover Air Reserve Base, MA.

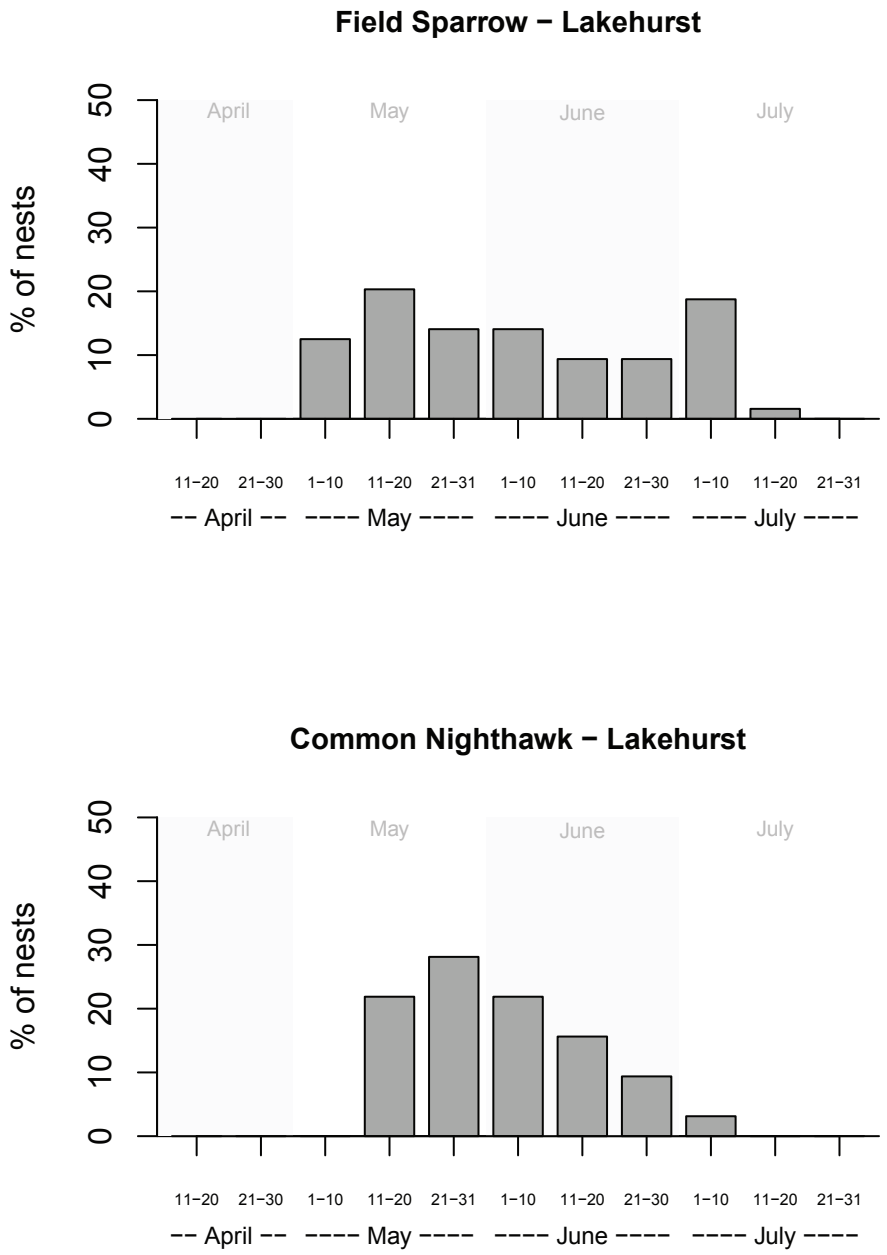


Figure 4. Estimated initiation dates (start of incubation) for Field Sparrow and Common Nighthawk nests monitored during 2009, 2010, and 2012 at Joint Base McGuire-Dix-Lakehurst, Lakehurst section, NJ.

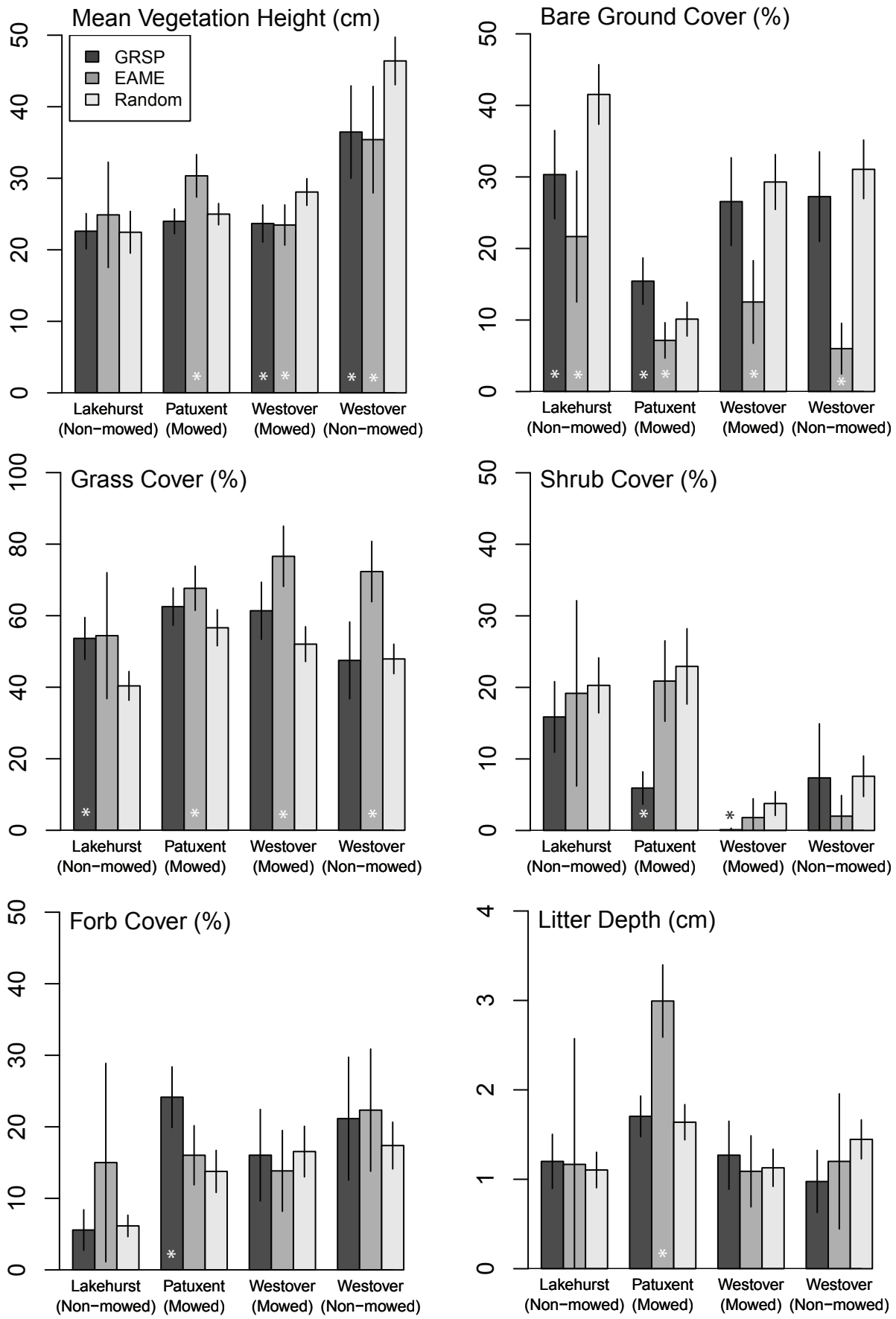


Figure 5. Mean vegetation characteristics at Grasshopper Sparrow (GRSP) nests, Eastern Meadowlark (EAME) nests, and random locations within nest searching plots. Means are shown +/- 2 SE. Significant differences between GRSP or EAME nests and random locations ($P < 0.05$, Wilcoxon rank sum test) are shown with an asterisk (*). For sample sizes see Tables 1-3.

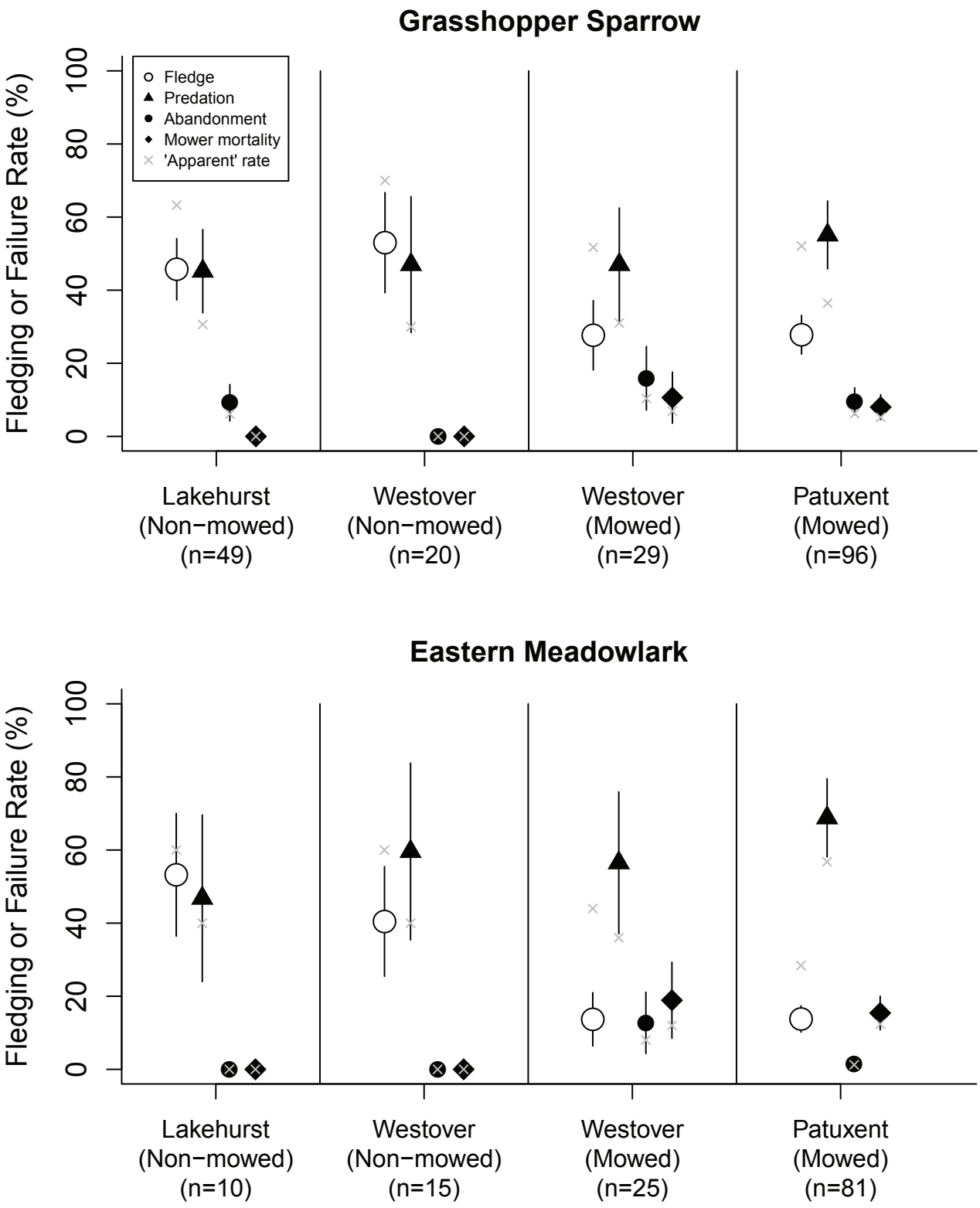


Figure 6. Overall nest survival and failure rate estimates (+/- 1 SE) by site and mow history for Grasshopper Sparrow and Eastern Meadowlark. Overall survival and failure estimates are based on daily rates as described in the Methods. Gray X's show 'apparent' rates (simple percentage of total).

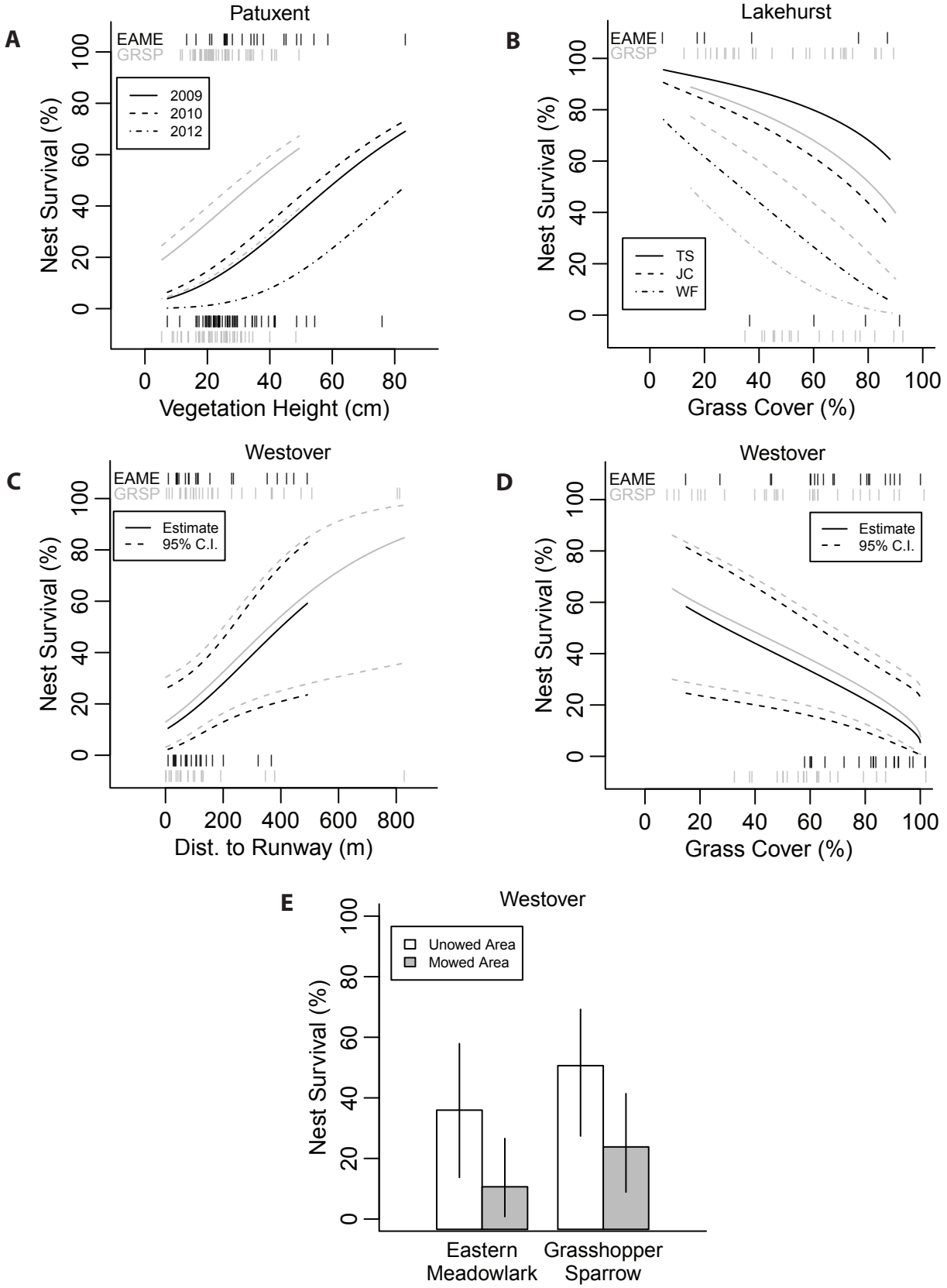


Figure 7. Best performing models of Grasshopper Sparrow and Eastern Meadowlark nest survival (gray and black lines, respectively, in A-D). All models have significant parameter estimates (95% CI not overlapping zero, Wald chi-squared tests, $P < 0.05$); see see Tables 6-7 for details. Estimates were based on daily survival rates extrapolated over the complete nest cycle (26 days for Eastern Meadowlark, 23 for Grasshopper Sparrow). Successful and failed nests are shown at the top and bottom, respectively, of graphs A-D to show sample sizes (noise introduced in Grass Cover to make all points visible).

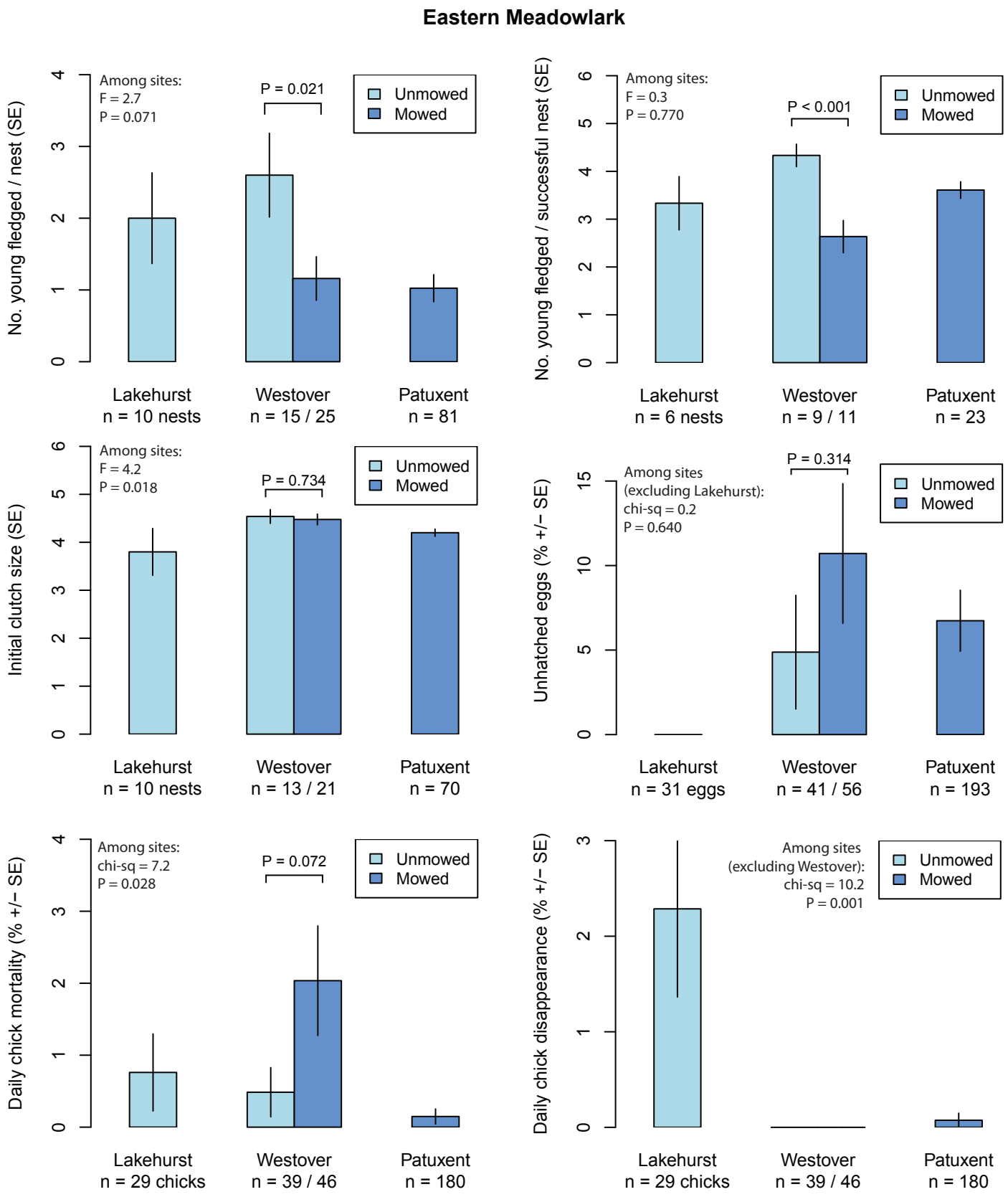


Figure 8. Eastern Meadowlark productivity and related factors. Results of models testing for differences among sites are in the upper left; tests between mowed and unmowed areas on Westover are above the brackets. F-tests were used for linear models (number of young, clutch size), and Wald chi-squared tests were used for logistic models (sites with zero failures were excluded to allow model fitting). Chick mortality = chicks found dead in the nest, excluding total brood mortality (e.g., abandonment); chick dissapearance = chicks missing prior to fledging age, excluding total brood disappearance.

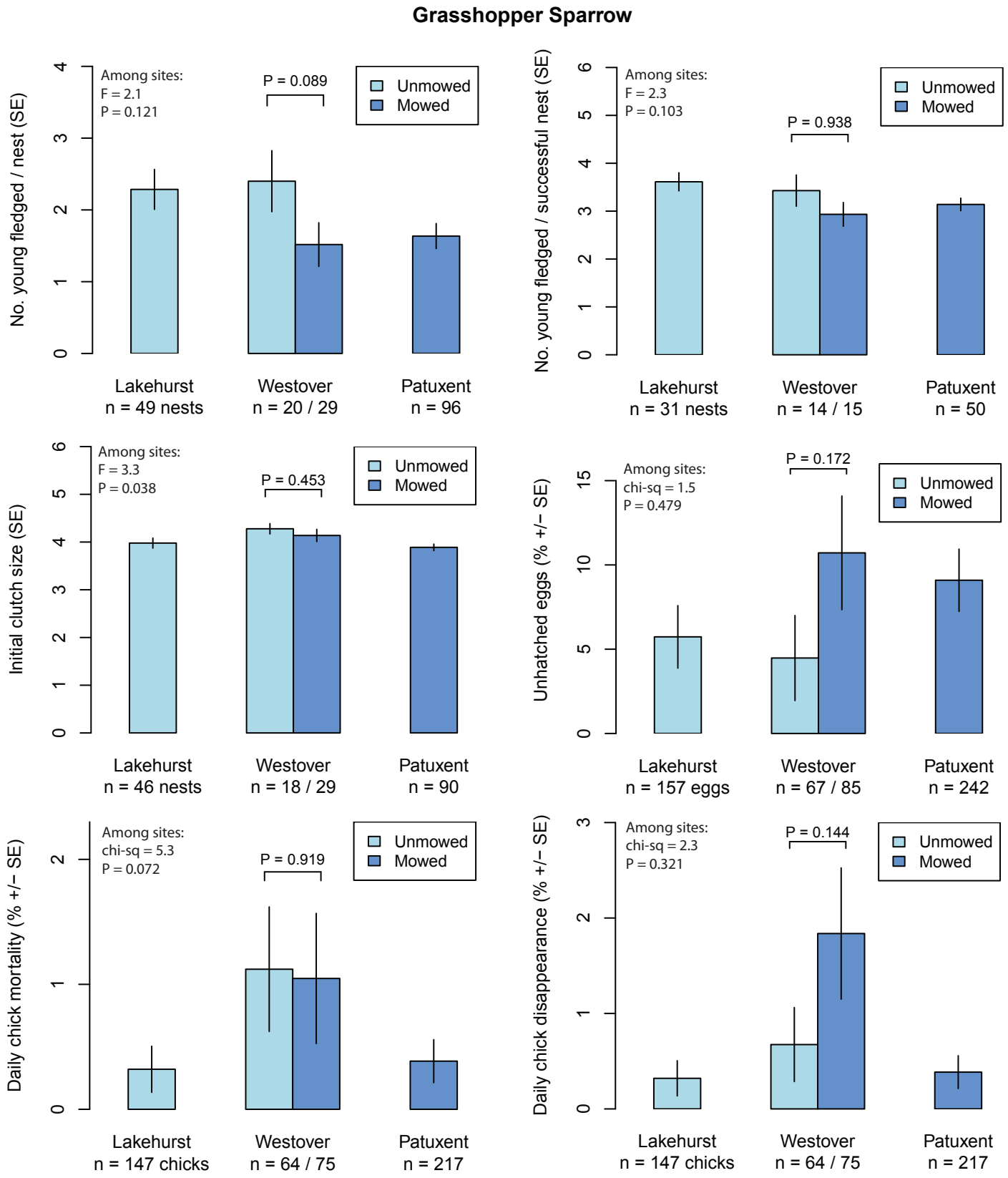


Figure 9. Grasshopper Sparrow productivity and related factors. Results of models testing for differences among sites are in the upper left; tests between mowed and unmowed areas on Westover are above the brackets. F-tests were used for linear models (number of young, clutch size), and Wald chi-squared tests were used for logistic models. Chick mortality = chicks found dead in the nest, excluding total brood mortality (e.g., abandonment); chick dissapearance = chicks missing prior to fledging age, excluding total brood disappearance.

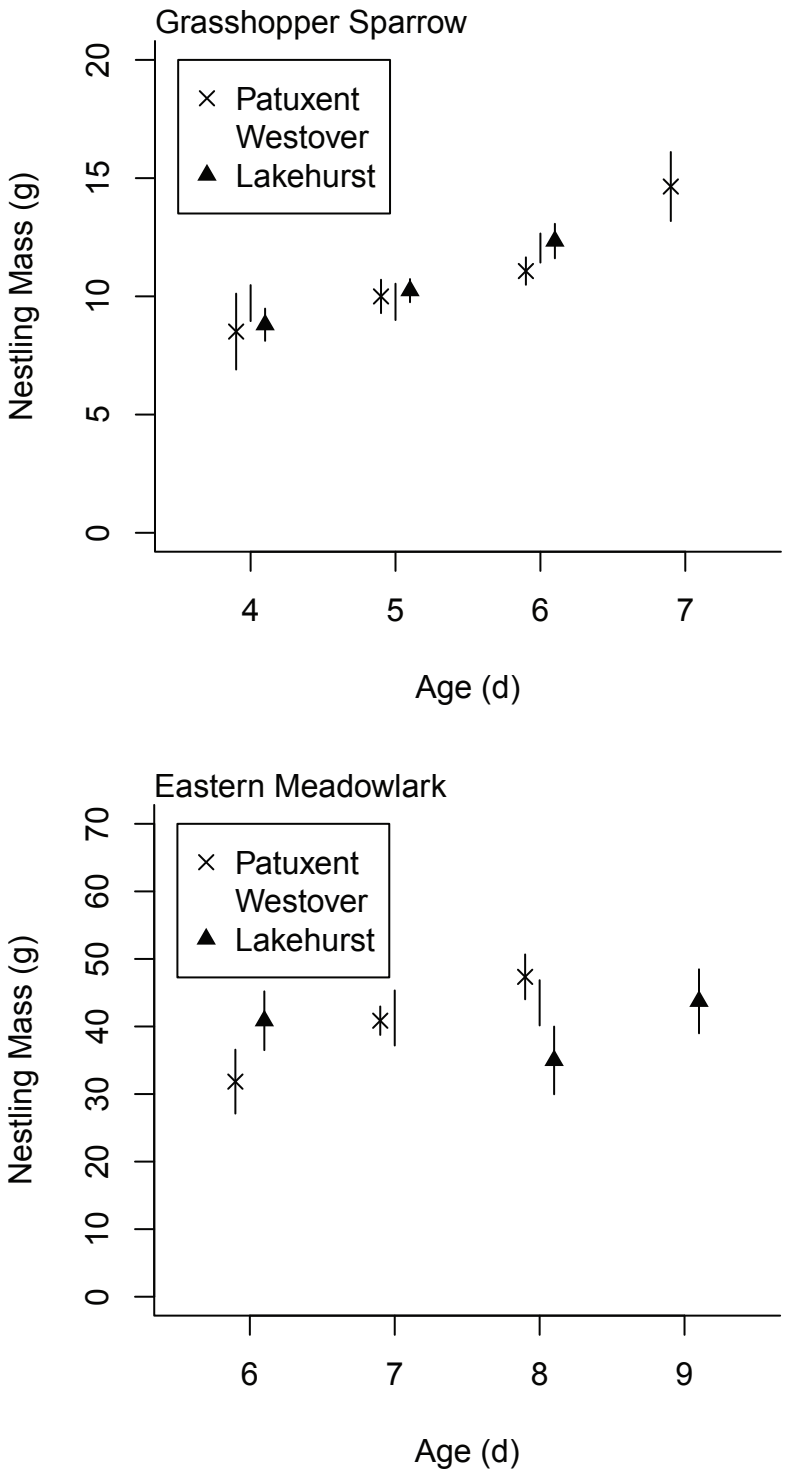
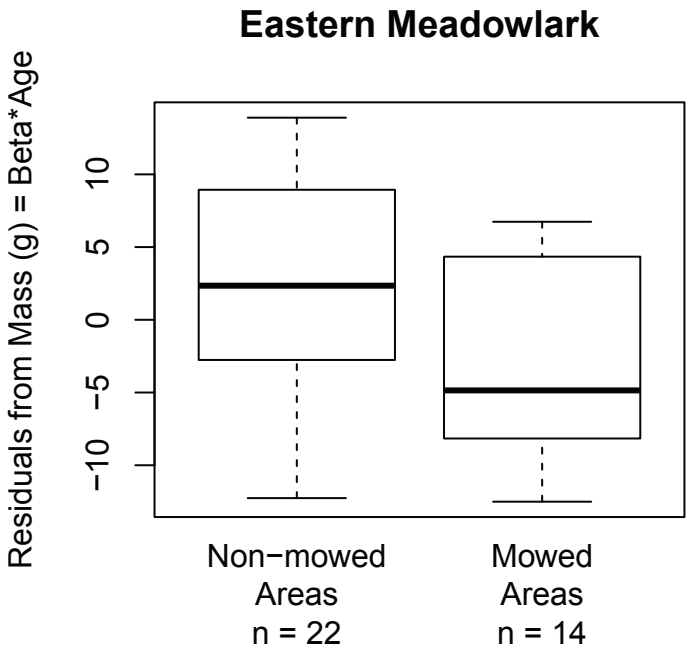


Figure 10. Mass of Grasshopper Sparrow and Eastern Meadowlark nestlings by site and approximate age in days. Means are shown plus/minus two standard errors.



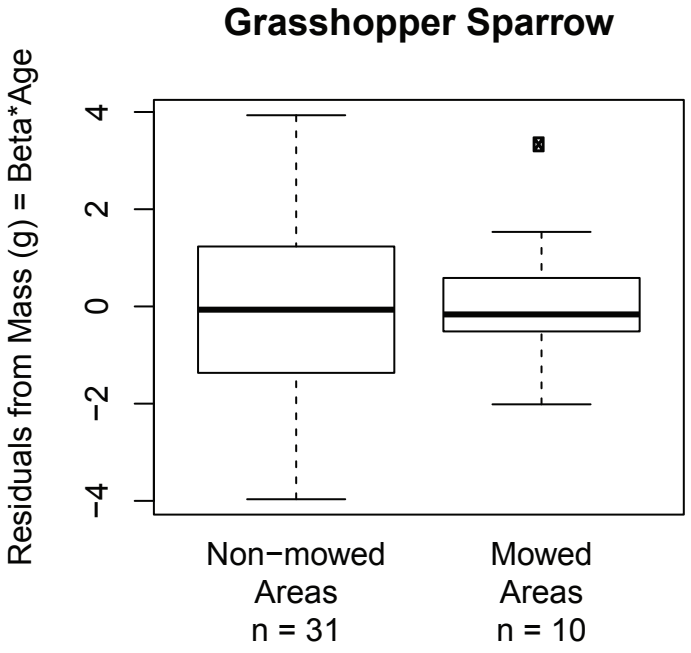


Figure 11. Mass of Eastern Meadowlark and Grasshopper Sparrow nestlings in mowed and non-mowed areas of Westover Air Reserve Base, MA. Masses are shown as residuals corrected for age, i.e., in number of grams above or below the mean value of their age category (7 or 8 days for Meadowlarks, 4 or 5 days for Grasshopper Sparrows).

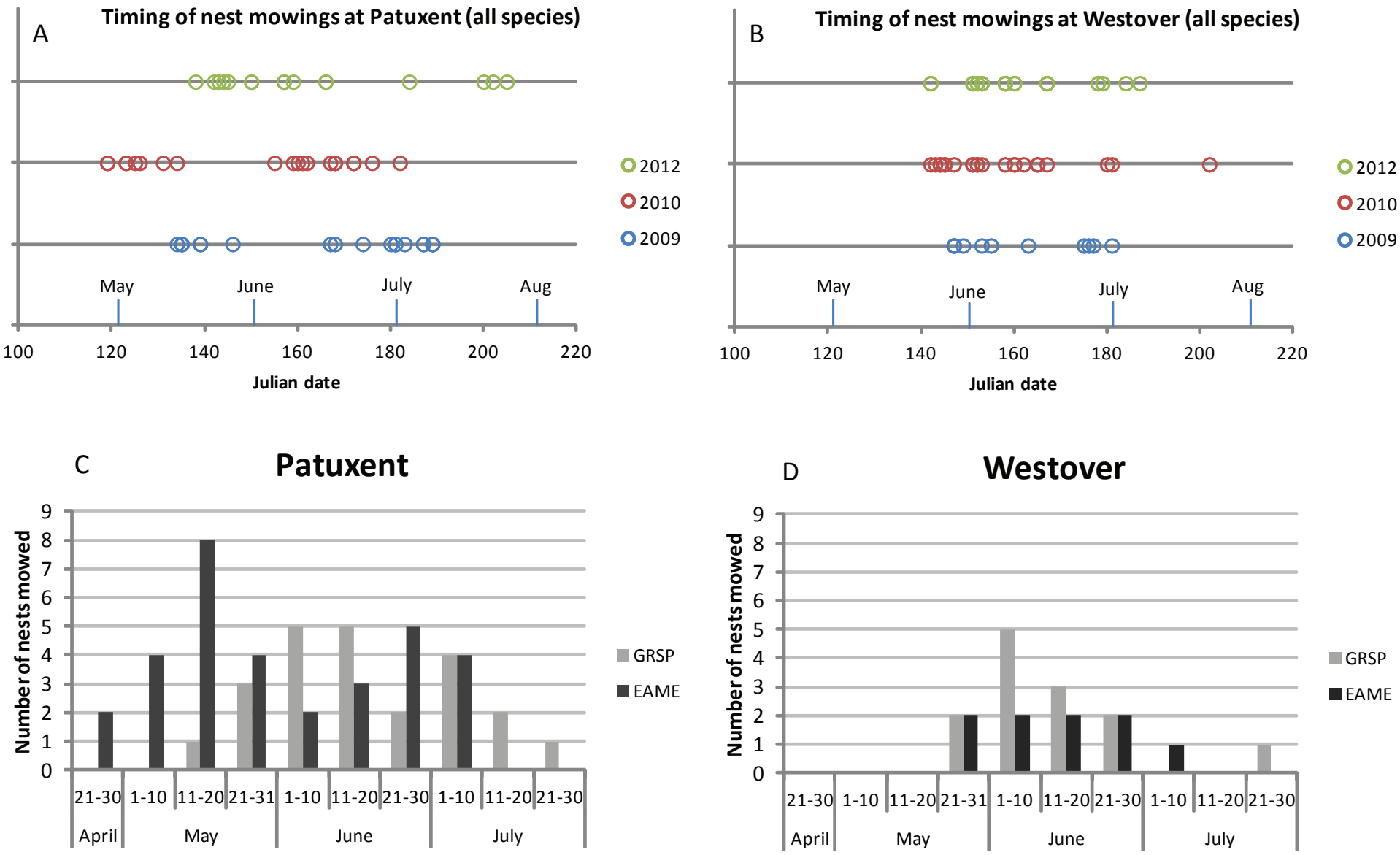


Figure 12. Timing of nest mowing events at Patuxent River Naval Air Station (Patuxent, A and C) and Westover Air Reserve Base (Westover, B and D) in 2009, 2010, and 2012.

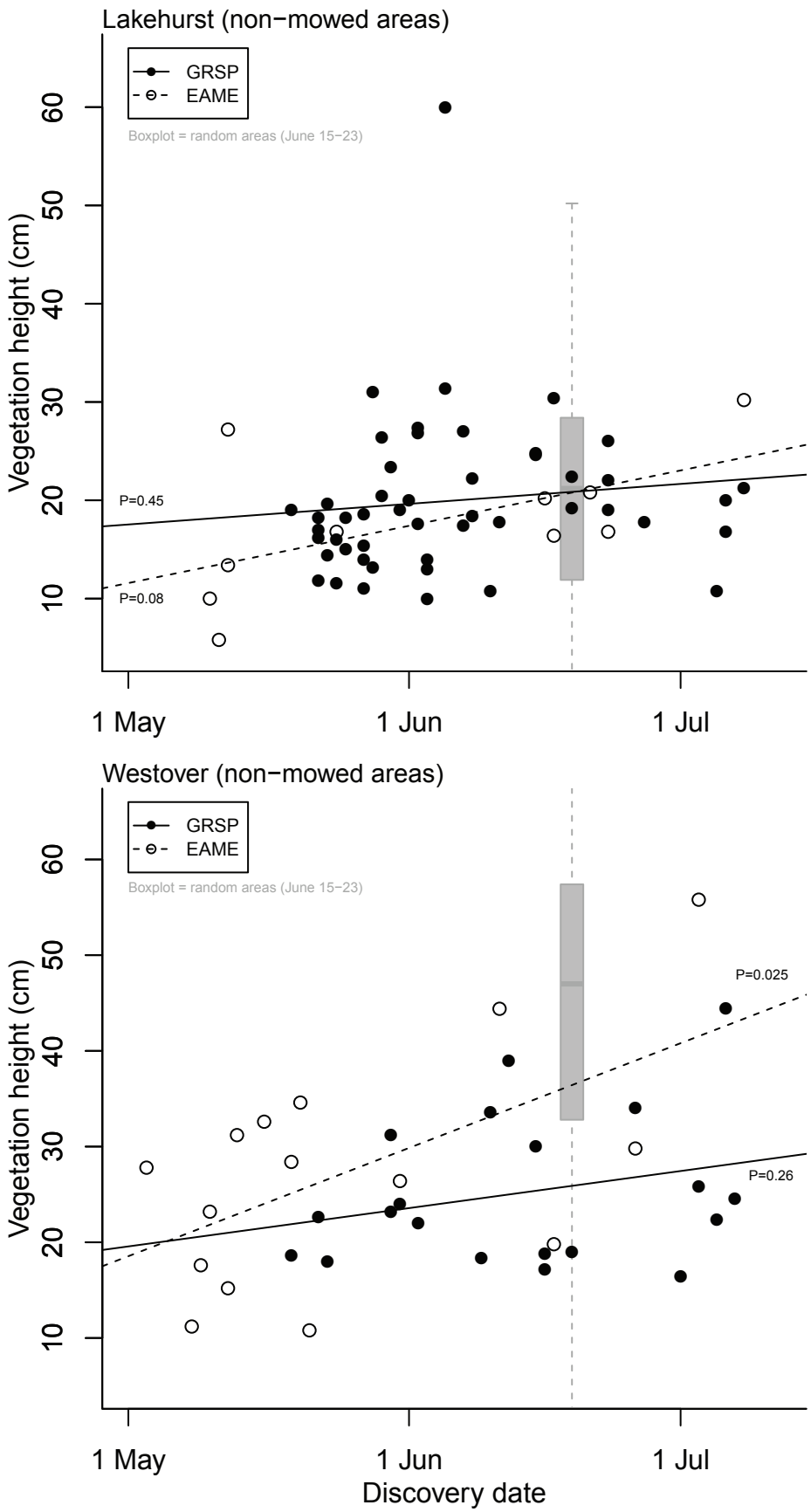


Figure 13. Vegetation height around Grasshopper Sparrow and Eastern Meadowlark nests in non-mowed areas in relation to date of discovery. P-values for the linear regression are shown near each line. Random vegetation measurements are shown as a boxplot and were taken between June 15th and 23rd in 2010 and 2012.

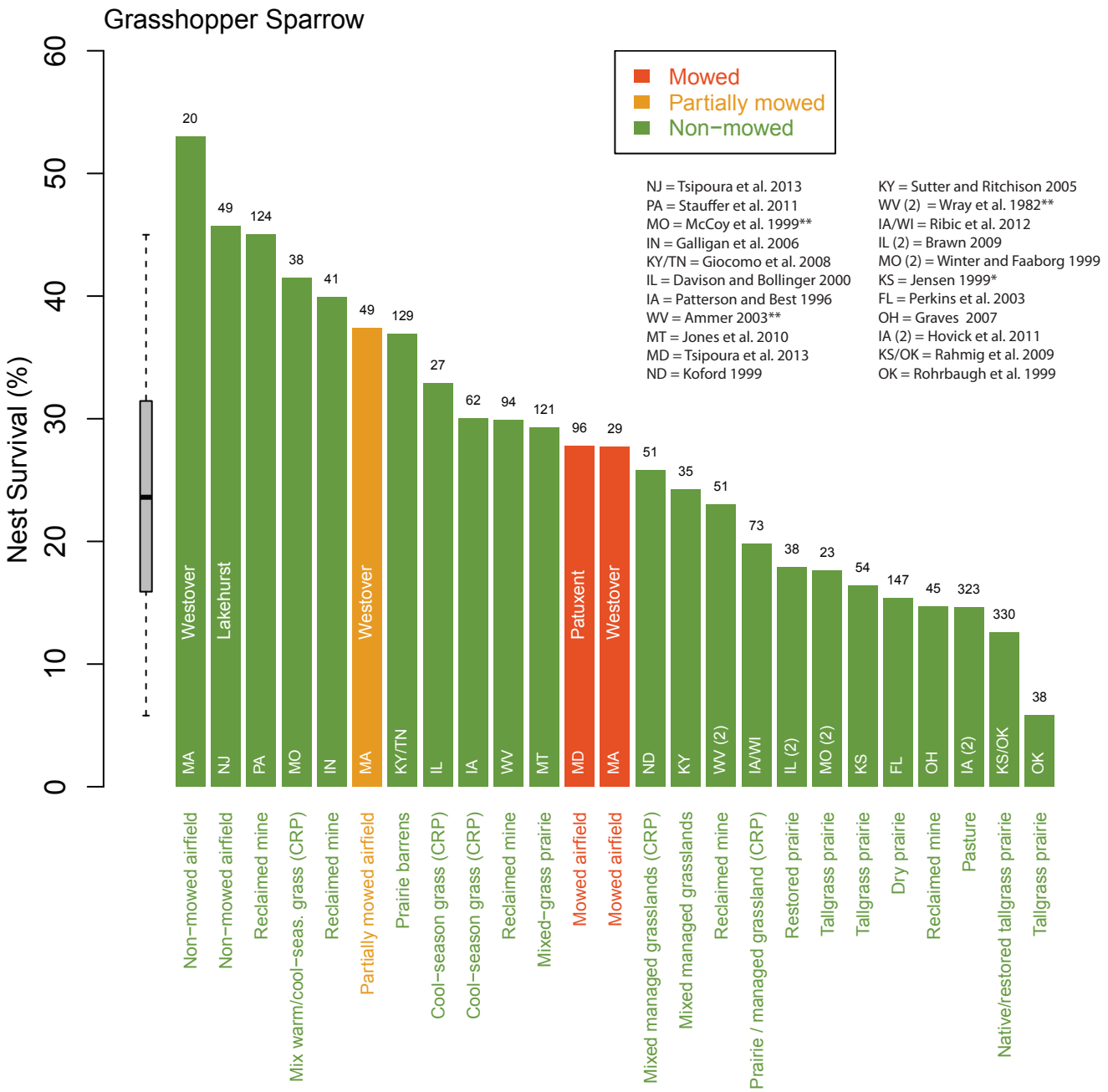


Figure 14. Nest survival rates for Grasshopper Sparrow in relation to other reported values in the literature. Red bars show sites mowed during the breeding season and green bars show sites not mowed. The orange bar shows mowed and non-mowed areas on Westover combined. Studies with a single asterisk (*) included only predation failures in calculations. All estimates were calculated from daily survival rate assuming a 23 day nest cycle. Studies with a double asterisk (**) provided estimates of success with no cycle length; these were assumed to be based on a 23 day cycle. Sample sizes of nests are shown above each bar. The boxplot shows the median, 1st and 3rd quartiles, and range for locations other than MA, NJ, and MD (Tsipoura et al. 2013) which are from the present study.

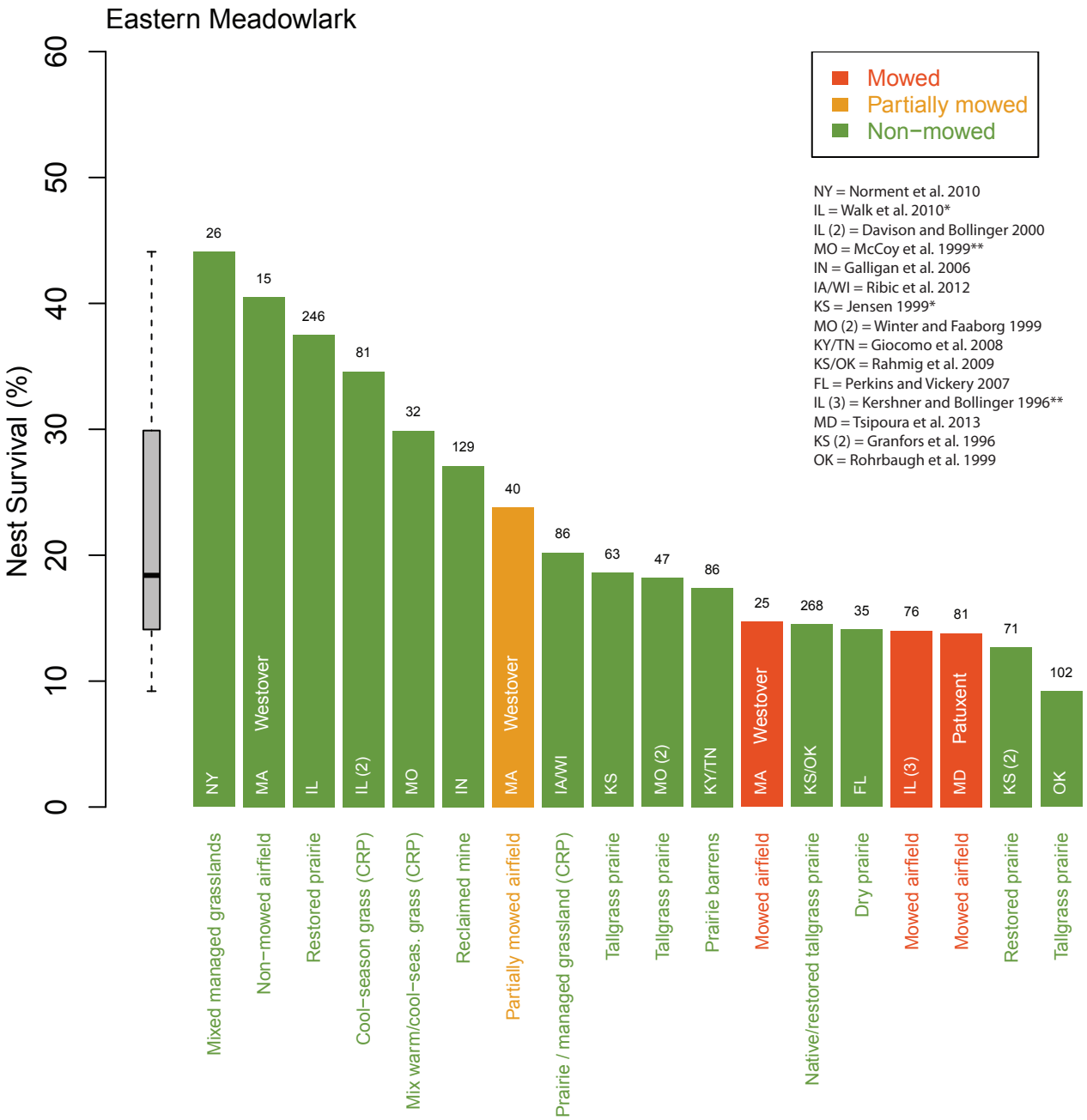


Figure 15. Nest survival rates for Eastern Meadowlark in relation to other reported values in the literature. Red bars show sites mowed during the breeding season and green bars show sites not mowed. The orange bar shows mowed and non-mowed areas on Westover combined. Studies with a single asterisk (*) included only predation failures in calculations. All estimates were calculated from daily survival rate assuming a 26 day nest cycle. Studies with a double asterisk (**) provided estimates of success with no cycle length; these were assumed to be based on a 26 day cycle. Sample sizes of nests are shown above each bar. The boxplot shows the median, 1st and 3rd quartiles, and range for locations other than MA, NJ, and MD (Tsipoura et al. 2013) which are from the present study.

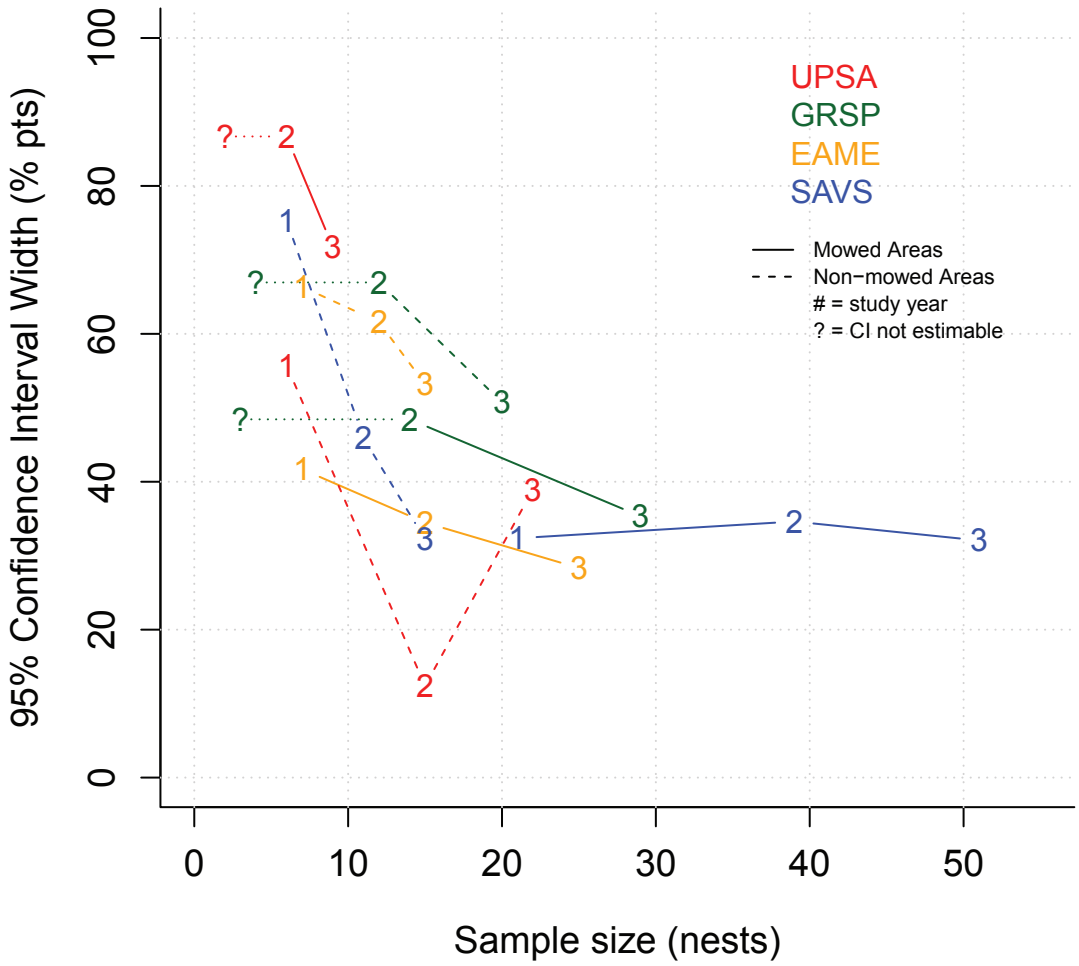


Figure 16. Confidence interval widths for nest survival estimates in mowed and non-mowed areas on Westover Air Reserve Base, MA. Numbers represent study year (1 = 2009, 2 = 2010, and 3 = 2012), and sample sizes are the cumulative number of nests found up to and including that year. Three confidence intervals were not estimable due to low sample sizes and are represented by question marks (?).

Table 1. Summary statistics for vegetation characteristics around Grasshopper Sparrow nests in 2009, 2010, & 2012 on Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD).

Measurement	Mean	Std. Dev.	C.V.	Min	Med	Max	n	Random*
Westover								
Initial Veg. Height (cm)	23.2	7.6	0.33	10.0	22.4	51.6	49	-
Mowed Areas	21.8	7.3	0.33	10.0	22.0	51.6	29	-
Non-mowed Areas	25.2	7.8	0.31	16.4	22.9	44.4	20	-
Final Veg. Height (cm)	28.9	12.3	0.43	12.6	24.8	68.0	49	-
Mowed Areas†	23.7	7.0	0.29	12.6	22.4	40.4	29	-
Non-mowed Areas†	36.5	14.4	0.40	18.0	34.9	68.0	20	-
% Bare	26.8	15.4	0.57	0.0	25.0	50.0	49	
Mowed Areas	26.6	16.5	0.62	0.0	25.0	50.0	29	
Non-mowed Areas	27.3	14.0	0.51	0.0	25.0	50.0	20	
% Grass	55.7	23.4	0.42	10.0	60.0	100.0	49	
Mowed Areas†	61.4	21.5	0.35	10.0	60.0	100.0	29	
Non-mowed Areas†	47.5	24.0	0.51	10.0	50.0	85.0	20	
% Forb	18.1	18.0	1.00	0.0	10.0	75.0	49	
Mowed Areas	16.0	17.2	1.07	0.0	10.0	70.0	29	
Non-mowed Areas	21.2	19.2	0.91	0.0	15.0	75.0	20	
% Shrub	3.1	11.3	3.68	0.0	0.0	70.0	49	-
Mowed Areas†	0.1	0.6	5.39	0.0	0.0	3.0	29	-
Non-mowed Areas†	7.4	16.9	2.30	0.0	0.0	70.0	20	
Clumpiness	2.0	0.7	0.35	1.0	2.0	3.0	49	
Mowed Areas†	1.8	0.7	0.39	1.0	2.0	3.0	29	
Non-mowed Areas†	2.5	0.5	0.21	1.0	2.0	3.0	20	
Litter Depth (cm)	1.2	0.9	0.76	0.0	1.0	3.6	42	
Mowed Areas	1.3	1.0	0.76	0.0	1.1	3.6	26	
Non-mowed Areas	1.0	0.7	0.71	0.2	0.8	2.6	16	
† Indicates significant difference between mowed and non-mowed areas (P < 0.05, Wilcoxon rank sum test).								
Lakehurst								
Initial Veg. Height (cm)	20.1	7.8	0.39	10.0	19.0	60.0	52	
Final Veg. Height (cm)	22.6	8.9	0.39	5.0	21.6	61.6	52	
% Bare	30.3	22.2	0.73	0.0	30.0	80.0	52	-
% Grass	53.7	21.1	0.39	15.0	52.5	90.0	52	+
% Forb	5.6	10.2	1.83	0.0	0.0	50.0	52	
% Shrub	15.9	17.8	1.12	0.0	10.0	80.0	52	
Clumpiness	2.4	0.6	0.27	1.0	2.0	3.0	52	+
Litter Depth (cm)	1.2	0.9	0.77	0.0	1.0	4.2	37	
Patuxent								
Initial Veg. Height (cm)	25.7	8.9	0.35	9.4	24.8	58.2	97	
Final Veg. Height (cm)	24.0	8.6	0.36	5.4	22.8	49.4	97	
% Bare	15.4	16.0	1.04	0.0	10.0	80.0	97	+
% Grass	62.5	25.6	0.41	10.0	70.0	100.0	97	
% Forb	24.1	20.9	0.86	0.0	20.0	90.0	97	+
% Shrub	5.9	11.2	1.89	0.0	0.0	60.0	97	-
Clumpiness	1.8	0.5	0.29	1.0	2.0	3.0	97	
Litter Depth (cm)	1.7	1.0	0.59	0.0	1.6	5.4	77	

* Indicates significant differences (P < 0.05; Wilcoxon rank sum test) with corresponding Random Vegetation measurement (see Table). A plus (+) indicates significantly greater than random, and a minus (-) indicates significantly less than random.

Table 2. Summary statistics for vegetation characteristics around Eastern Meadowlark nests in 2009, 2010, & 2012 on Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD).

Measurement	Mean	Std. Dev.	C.V.	Min	Med	Max	n	Random*
Westover								
Initial Veg. Height (cm)	25.6	10.3	0.40	10.8	23.2	55.8	40	-
Mowed Areas	24.6	9.2	0.37	11.4	22.2	47.0	25	-
Non-mowed Areas	27.3	12.1	0.44	10.8	27.8	55.8	15	-
Final Veg. Height (cm)	27.9	11.8	0.42	11.6	26.2	62.0	40	-
Mowed Areas†	23.5	7.0	0.30	11.6	22.0	39.6	25	-
Non-mowed Areas†	35.4	14.4	0.41	13.4	33.4	62.0	15	-
% Bare	10.1	12.5	1.24	0.0	5.0	50.0	40	-
Mowed Areas	12.5	14.5	1.16	0.0	10.0	50.0	25	-
Non-mowed Areas	6.0	6.9	1.14	0.0	5.0	20.0	15	-
% Grass	75.0	19.3	0.26	15.0	80.0	100.0	40	+
Mowed Areas	76.6	21.1	0.28	15.0	80.0	100.0	25	+
Non-mowed Areas	72.3	16.4	0.23	45.0	70.0	95.0	15	+
% Forb	17.0	15.4	0.91	0.0	10.0	50.0	40	
Mowed Areas	13.8	14.1	1.02	0.0	10.0	50.0	25	
Non-mowed Areas	22.3	16.5	0.74	2.0	20.0	50.0	15	
% Shrub	1.9	6.2	3.29	0.0	0.0	30.0	40	-
Mowed Areas	1.8	6.6	3.66	0.0	0.0	30.0	25	
Non-mowed Areas	2.0	5.6	2.80	0.0	0.0	20.0	15	
Clumpiness	1.9	0.6	0.35	1.0	2.0	3.0	40	
Mowed Areas	1.9	0.7	0.35	1.0	2.0	3.0	25	
Non-mowed Areas	1.9	0.6	0.34	1.0	2.0	3.0	15	
Litter Depth (cm)	1.1	0.9	0.80	0.0	1.2	2.8	26	
Mowed Areas	1.1	0.8	0.77	0.0	1.2	2.4	18	
Non-mowed Areas	1.2	1.1	0.89	0.0	1.1	2.8	8	

† Indicates significant difference between mowed and non-mowed areas ($P < 0.05$, Wilcoxon rank sum test).

Lakehurst								
Initial Veg. Height (cm)	21.1	10.4	0.49	5.8	18.5	42.4	12	
Final Veg. Height (cm)	24.9	12.8	0.51	9.6	22.7	58.4	12	
% Bare	21.7	15.9	0.73	5.0	20.0	50.0	12	-
% Grass	54.4	30.5	0.56	5.0	60.0	90.0	12	
% Forb	15.0	24.0	1.60	0.0	2.5	80.0	12	
% Shrub	19.2	22.4	1.17	0.0	10.0	60.0	12	
Clumpiness	2.3	0.6	0.28	1.0	2.0	3.0	12	
Litter Depth (cm)	1.2	1.7	1.48	0.0	0.6	4.6	6	
Patuxent								
Initial Veg. Height (cm)	29.0	9.4	0.32	13.0	27.0	62.6	79	+
Final Veg. Height (cm)	30.3	13.2	0.44	7.2	26.4	83.4	79	+
% Bare	7.2	11.0	1.54	0.0	0.0	50.0	79	-
% Grass	67.7	27.5	0.41	10.0	70.0	100.0	79	+
% Forb	16.0	18.4	1.15	0.0	10.0	70.0	79	
% Shrub	20.9	25.0	1.20	0.0	15.0	90.0	79	
Clumpiness	1.8	0.5	0.27	1.0	2.0	3.0	79	
Litter Depth (cm)	3.0	1.5	0.49	0.6	3.0	6.8	52	+

Table 3. Summary statistics for vegetation characteristics measured in mid-June 2010 & 2012 at random locations throughout nest searching plots on Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD).

Measurement	Mean	Std. Dev.	C.V.	Min	Med	Max	n
Westover							
Veg. Height (cm)	37.6	17.9	0.48	2.2	33.4	150.2	250
Mowed Areas†	28.1	10.2	0.36	4.6	26.6	61.0	120
Non-mowed Areas†	46.4	19.0	0.41	2.2	47.0	150.2	130
% Bare	30.2	22.3	0.74	0.0	30.0	95.0	250
Mowed Areas	29.3	21.0	0.72	0.0	25.0	95.0	120
Non-mowed Areas	31.1	23.4	0.75	0.0	30.0	95.0	130
% Grass	49.9	25.1	0.50	1.0	50.0	100.0	250
Mowed Areas	52.0	26.7	0.51	1.0	55.0	100.0	120
Non-mowed Areas	47.9	23.5	0.49	3.0	50.0	95.0	130
% Forb	17.0	19.0	1.12	0.0	10.0	90.0	250
Mowed Areas	16.5	19.4	1.17	0.0	10.0	70.0	120
Non-mowed Areas	17.4	18.6	1.07	0.0	10.0	90.0	130
% Shrub	5.7	13.4	2.33	0.0	0.0	80.0	250
Mowed Areas	3.8	9.1	2.42	0.0	0.0	60.0	120
Non-mowed Areas	7.6	16.2	2.13	0.0	0.0	80.0	130
Clumpiness	2.0	0.6	0.31	1.0	2.0	3.0	250
Mowed Areas†	1.9	0.7	0.35	1.0	2.0	3.0	120
Non-mowed Areas†	2.2	0.6	0.28	1.0	2.0	3.0	130
Litter Depth (cm)	1.3	1.2	0.93	0.0	1.0	4.8	250
Mowed Areas†	1.1	1.1	1.01	0.0	0.8	4.6	120
Non-mowed Areas†	1.4	1.2	0.86	0.0	1.3	4.8	130

† Indicates significant difference between mowed and non-mowed areas ($P < 0.05$, Wilcoxon rank sum test).

Lakehurst							
Veg. Height (cm)	22.5	18.5	0.82	0.0	21.2	203.4	160
% Bare	41.5	26.4	0.64	0.0	35.0	100.0	160
% Grass	40.4	25.5	0.63	0.0	35.0	100.0	160
% Forb	6.2	9.5	1.55	0.0	1.0	65.0	160
% Shrub	20.3	24.4	1.20	0.0	10.0	95.0	160
Clumpiness	1.9	0.7	0.38	1.0	2.0	3.0	160
Litter Depth (cm)	1.1	1.3	1.14	0.0	0.8	8.8	160
Patuxent							
Veg. Height (cm)	25.0	8.2	0.33	7.8	24.2	56.8	120
% Bare	10.1	13.0	1.28	0.0	5.0	75.0	120
% Grass	56.6	27.6	0.49	0.0	55.0	100.0	120
% Forb	13.8	16.1	1.17	0.0	10.0	80.0	120
% Shrub	22.9	28.9	1.26	0.0	5.0	90.0	120
Clumpiness	1.8	0.5	0.31	1.0	2.0	3.0	120
Litter Depth (cm)	1.6	1.1	0.66	0.0	1.5	5.0	120

Table 4. Nest survival estimates for Grasshopper Sparrow and Eastern Meadowlark nests monitored during the 2009, 2010, and 2012 seasons on Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD). Estimates based on samples of less than 20 nests are shown in gray to indicate lower certainty in these estimates.

Species - Mow History	No. Nests	Overall Nest Survival (%)*	95% C.I.	Apparent Nest Survival (%)**	DSR	95% C.I.
Grasshopper Sparrow						
Westover						
Non-mowed areas	20	53	25 - 75	70	0.97278	0.94074 - 0.98772
Mowed areas	29	28	12 - 47	52	0.94568	0.91035 - 0.96757
Mowed nests	10	30	6 - 61	50	0.94869	0.88258 - 0.97849
Non-mowed nests	19	26	8 - 50	53	0.94384	0.89555 - 0.97054
All nests	49	37	22 - 53	59	0.95818	0.93605 - 0.97286
Lakehurst						
All nests / Non-mowed Areas	49	46	29 - 61	59	0.96656	0.94753 - 0.97883
Patuxent River						
Mowed nests	18	30	10 - 54	50	0.94968	0.90610 - 0.97362
Non-mowed nests	78	27	17 - 39	53	0.94485	0.92477 - 0.95979
All nests / Mowed Areas	96	28	18 - 38	52	0.94586	0.92845 - 0.95922
Eastern Meadowlark						
Westover						
Non-mowed areas	15	40	14 - 67	60	0.96579	0.92593 - 0.98455
Mowed areas	25	15	4 - 32	44	0.92897	0.88360 - 0.95751
Mowed nests	8	20	1 - 55	50	0.93937	0.84928 - 0.97706
Non-mowed nests	17	13	2 - 33	41	0.92374	0.86394 - 0.95852
All nests	40	24	11 - 40	50	0.94631	0.91822 - 0.96511
Lakehurst						
All nests / Non-mowed Areas	10	53	19 - 79	60	0.97604	0.93792 - 0.99098
Patuxent River						
Mowed nests	25	9	2 - 22	24	0.91227	0.86650 - 0.94337
Non-mowed nests	56	16	8 - 26	30	0.93202	0.90826 - 0.94996
All nests / Mowed Areas	81	14	8 - 22	28	0.92661	0.90619 - 0.94285

* estimated survival to fledging based on daily survival rate (DSR), assuming a 23 and 26 day nest cycle for Grasshopper Sparrow and Eastern Meadowlark, respectively

** uncorrected percent survival to fledging (i.e., 100*(Number successful nests / Total number nests))

Table 5. Nest survival estimates for Savannah Sparrow and Upland Sandpiper nests on Westover Air Reserve Base (MA) and Field Sparrow and Common Nighthawk nests on Joint Base McGuire-Dix-Lakehurst (NJ) monitored during the 2009, 2010, and 2012 seasons. Estimates based on samples of less than 20 nests are shown in gray to indicate lower certainty in these estimates.

Species - Mow Type	No. Nests	Overall Nest Survival (%)*	95% C.I.	Apparent Nest Survival (%)**	DSR	95% C.I.
Westover - Savannah Sparrow						
Non-mowed areas	15	20	4 - 45	47	0.93759	0.88007 - 0.96851
Mowed areas	51	24	13 - 36	39	0.94389	0.92129 - 0.96028
Mowed nests	19	42	17 - 65	58	0.96550	0.93254 - 0.98266
Non-mowed nests	32	16	6 - 29	28	0.92820	0.89421 - 0.95187
All nests	66	23	13 - 34	41	0.94270	0.92251 - 0.95788
Westover - Upland Sandpiper						
Non-mowed areas	22	49	24 - 70	64	0.97372	0.94834 - 0.98681
Mowed areas	9	82	26 - 97	89	0.99281	0.95074 - 0.99899
Mowed nests	6	79	19 - 97	83	0.99123	0.9404 - 0.99877
Non-mowed nests	3	100	100-100	100	1.00000	1.00000 - 1.00000
All nests	31	57	35 - 75	71	0.97970	0.96146 - 0.98941
Lakehurst - Field Sparrow						
All nests / Non-mowed Areas	63	35	22-48	54	0.95535	0.93647 - 0.96880
Lakehurst - Common Nighthawk						
All nests / Non-mowed Areas	32	78	55-90	84	0.98706	0.96930 - 0.99461

* estimated survival to fledging based on daily survival rate (DSR), assuming a nest cycle of 26 days for Savannah Sparrow, 27 days for Upland Sandpiper, 23 days for Field Sparrow, and 19 days for Common Nighthawk.
** percent survival to fledging (i.e., 100*(Number successful nests / Total number nests))

Table 6. Model ranking results for Grasshopper Sparrow and Eastern Meadowlark nest survival on Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD) in 2009, 2010, and 2012.

Westover - Grasshopper Sparrow (n = 49) and Eastern Meadowlark (n = 40)					
model	**No. Parameters**	**AICc**	**DeltaAICc**	**weight**	**Deviance**
Species + Dist. To Runway	3	260.83	0.00	0.42	254.80
Species + % Grass	3	262.22	1.38	0.21	256.19
Species + Mowed Area	3	263.04	2.21	0.14	257.01
Species + Nest Mowed	4	264.84	4.01	0.06	256.79
Species + Nest Stage	3	265.68	4.85	0.04	259.65
Species	2	266.09	5.26	0.03	262.08
Species + % Forb	3	266.91	6.07	0.02	260.88
Species + % Shrub	3	266.96	6.13	0.02	260.93
Species + Veg. Height	3	267.40	6.57	0.02	261.37
Species + Year	4	267.60	6.76	0.01	259.55
Species + % Bare	3	267.87	7.03	0.01	261.84
Species + Day of Season	3	268.11	7.27	0.01	262.08
Species + Clumpiness	4	270.11	9.28	0.00	262.06

Lakehurst - Grasshopper Sparrow (n = 49) and Eastern Meadowlark (n = 10)					
model	**No. Parameters**	**AICc**	**DeltaAICc**	**weight**	**Deviance**
Species + Location + % Grass	5	154.49	0.00	0.85	144.41
Species + Location	4	159.73	5.24	0.06	151.68
Species + % Grass	3	161.38	6.88	0.03	155.34
Species + % Bare	3	162.30	7.81	0.02	156.27
Species + Day of Season	3	162.62	8.12	0.01	156.58
Species	2	164.00	9.51	0.01	159.99
Species + Nest Stage	3	164.29	9.80	0.01	158.26
Species + % Forb	3	164.80	10.31	0.00	158.77
Species + Veg. Height	3	165.91	11.41	0.00	159.87
Species + % Shrub	3	165.95	11.45	0.00	159.91
Species + Year	4	167.31	12.82	0.00	159.25
Species + Clumpiness	4	167.90	13.41	0.00	159.85

Patuxent - Grasshopper Sparrow (n = 95) and Eastern Meadowlark (n = 79)					
model	**No. Parameters**	**AICc**	**DeltaAICc**	**weight**	**Deviance**
Species + Year + Veg. Height	5	586.28	0.00	0.85	576.24
Species + Year + % Bare	5	592.03	5.76	0.05	581.99
Species + Year	4	593.63	7.35	0.02	585.60
Species + Year + Day of Season	5	594.53	8.25	0.01	584.49
Species + Year + % Grass	5	594.95	8.67	0.01	584.91
Species + Year + Nest Mowed	5	595.11	8.83	0.01	585.07
Species + Year + Dist. to Runway	5	595.26	8.98	0.01	585.22
Species + Year + % Shrub	5	595.35	9.07	0.01	585.31
Species + Year + Nest Stage	5	595.41	9.14	0.01	585.38
Species + Year + % Forb	5	595.55	9.27	0.01	585.51
Species + Year + Clumpiness	6	596.50	10.22	0.01	584.44
Species	2	600.32	14.04	0.00	596.31
Species + Day of Season	3	601.29	15.01	0.00	595.27
Species + Nest Stage	3	602.32	16.04	0.00	596.30

Table 7. Best-performing nest survival models (see Table 6) for Grasshopper Sparrow and Eastern Meadowlark at Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD) in 2009, 2010, and 2012.

Site	Model - Parameters	*Beta*	*95% C.I.*	*Wald X^2*	*P**
Westover - Grasshopper Sparrow (n = 49) and Eastern Meadowlark (n = 40)					
	Distance to Runway				
	Intercept	2.375	(1.816, 2.933)	69.5	**< 0.001**
	Species (vs. Eastern Meadowlark)			0.8	0.383
	Grasshopper Sparrow	0.284	(-0.354, 0.923)		
	Distance to Runway (m)	0.003	(0.001, 0.006)	5.6	**0.018**
	% Grass Cover				
	Intercept	4.453	(3.042, 5.864)	38.3	**< 0.001**
	Species (vs. Eastern Meadowlark)			0.0	0.940
	Grasshopper Sparrow	0.026	(-0.638, 0.689)		
	% Grass Cover	-1.480	(-2.674, -0.286)	5.9	**0.015**
	Mowed Area				
	Intercept	3.310	(2.656, 3.963)	98.5	**< 0.001**
	Species (vs. Eastern Meadowlark)			0.8	0.361
	Grasshopper Sparrow	0.298	(-0.340, 0.935)		
	Mowed Area (vs. Non-mowed Area)	-0.764	(-1.455, -0.073)	4.7	**0.030**
Lakehurst - Grasshopper Sparrow (n = 49) and Eastern Meadowlark (n = 10)					
	Location and % Grass Cover				
	Intercept	6.120	(3.782, 8.458)	26.3	**< 0.001**
	Species (vs. Eastern Meadowlark)			1.3	0.255
	Grasshopper Sparrow	-0.666	(-1.813, 0.482)		
	Location (vs. Westfield)			10.4	**0.005**
	Jump Circle	-1.019	(-2.099, 0.061)		
	Test Site	0.777	(-0.436, 1.990)		
	% Grass Cover	-2.428	(-4.291, -0.565)	6.5	**0.011**
Patuxent - Grasshopper Sparrow (n = 95) and Eastern Meadowlark (n = 79)					
	Year and % Grass Cover				
	Intercept	1.106	(0.362, 1.85)	8.5	**0.004**
	Species (vs. Eastern Meadowlark)			7.5	**0.006**
	Grasshopper Sparrow	0.626	(0.177, 1.075)		
	Year (vs. 2012)			14.1	**< 0.001**
	2009	0.702	(0.182, 1.222)		
	2010	0.876	(0.387, 1.365)		
	Veg. Height (cm)	0.029	(0.009, 0.049)	8.2	**0.004**

Table 8. Cause-specific failure rate estimates for Grasshopper Sparrow and Eastern Meadowlark nests monitored on Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD) during 2009, 2010, and 2012.

	Cause of Failure	Estimated % Failure Rate (SE)[a]	No. Failures	Apparent Failure Rate (%)[b]	Daily Failure Rate (DFR)	95% C.I.
Grasshopper Sparrow						
Westover						
Non-mowed areas (n = 20)	Predation	47 (19)	6	30	0.02722	0.01228 - 0.05925
	Aband.	0 (0)	0	0	0.00000	0.00000 - 0.00000
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000
Mowed areas (n = 29)	Predation	47 (15)	9	31	0.03531	0.01847 - 0.06646
	Aband.	16 (9)	3	10	0.01191	0.00384 - 0.03625
	Mowing	11 (7)	2	7	0.00794	0.00199 - 0.03116
All nests (*n = 49*)	Predation	47 (12)	15	31	0.03156	0.01911 - 0.05168
	Aband.	10 (5)	3	6	0.00638	0.00206 - 0.01960
	Mowing	6 (4)	2	4	0.00426	0.00106 - 0.01685
Lakehurst						
All nests (*n = 49*)	Predation	45 (11)	15	31	0.02789	0.01688 - 0.04575
(Non-mowed areas)	Aband.	9 (5)	3	6	0.00566	0.00183 - 0.01738
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000
Patuxent River						
All nests (*n = 96*)	Predation	55 (9)	35	36	0.04133	0.02982 - 0.05704
(Mowed areas)	Aband.	10 (4)	6	6	0.00722	0.00325 - 0.01597
	Mowing	8 (3)	5	5	0.00601	0.00250 - 0.01436
Eastern Meadowlark						
Westover						
Non-mowed areas (*n = 15*)	Predation	60 (24)	6	40	0.03421	0.01545 - 0.07407
	Aband.	0 (0)	0	0	0.00000	0.00000 - 0.00000
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000
Mowed areas (*n = 25*)	Predation	56 (19)	9	36	0.04818	0.02525 - 0.09001
	Aband.	13 (8)	2	8	0.01081	0.00271 - 0.04218
	Mowing	19 (10)	3	12	0.01609	0.00520 - 0.04867
All nests (*n = 40*)	Predation	58 (15)	15	38	0.04141	0.02511 - 0.06756
	Aband.	8 (5)	2	5	0.00557	0.00139 - 0.02199
	Mowing	12 (6)	3	8	0.00832	0.00269 - 0.02548
Lakehurst						
All nests (*n = 10*)	Predation	47 (23)	4	40	0.02396	0.00902 - 0.06208
(Non-mowed areas)	Aband.	0 (0)	0	0	0.00000	0.00000 - 0.00000
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000
Patuxent River						
All nests (*n = 81*)	Predation	69 (11)	46	57	0.05854	0.04412 - 0.07730
(Mowed areas)	Aband.	2 (1)	1	1	0.00131	0.00018 - 0.00925
	Mowing	15 (5)	10	12	0.01307	0.02412 - 0.00705

[a]estimated failure rate from each cause based on daily failure rate (see Methods).

[b]percent failure rate (i.e., 100 x [# failed nests / Total # nests])

Table 9. Cause-specific failure rate estimates for Savannah Sparrow and Upland Sandpiper nests at Westover Air Reserve Base (MA), and Field Sparrow and Common Nighthawk nests at Joint Base McGuire-Dix-Lakehurst (NJ) during 2009, 2010, and 2012.

	Cause of Failure	Estimated % Failure Rate (SE)[a]	No. Failures	Apparent Failure Rate (%)[b]	Daily Failure Rate (DFR)	95% C.I.
Westover - Savannah Sparrow						
Non-mowed areas (*n = 15*)	Predation	70 (28)	7	47	0.05480	0.02633 - 0.11056
	Aband.	10 (10)	1	7	0.00803	0.00113 - 0.05477
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000
Mowed areas (*n = 51*)	Predation	54 (12)	22	43	0.03997	0.02645 - 0.05996
	Aband.	13 (5)	5	10	0.00921	0.00384 - 0.02193
	Mowing	10 (5)	4	8	0.00739	0.00278 - 0.01951
All nests (*n = 66*)	Predation	58 (11)	29	44	0.04276	0.02987 - 0.06087
	Aband.	12 (5)	6	9	0.00899	0.00404 - 0.01986
	Mowing	8 (4)	4	6	0.00601	0.00226 - 0.01590
Westover - Upland Sandpiper						
Non-mowed areas (*n = 22*)	Predation	39 (15)	6	27	0.01984	0.00894 - 0.04344
	Aband.	13 (9)	2	9	0.00662	0.00166 - 0.02608
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000
Mowed areas (*n = 9*)	Predation	0 (0)	0	0	0.00000	0.00000 - 0.00000
	Aband.	0 (0)	0	0	0.00000	0.00000 - 0.00000
	Mowing	18 (17)	1	11	0.00720	0.00101 - 0.04926
All nests (*n = 31*)	Predation	28 (11)	6	19	0.01359	0.00612 - 0.02992
	Aband.	10 (6)	2	6	0.00454	0.00113 - 0.01795
	Mowing	5 (5)	1	3	0.00228	0.00032 - 0.01599
Lakehurst - Field Sparrow						
All nests (*n = 63*)	Predation	52 (11)	23	37	0.03554	0.02373 - 0.05292
(Non-mowed areas)	Aband.	14 (5)	6	10	0.00943	0.00424 - 0.02082
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000
Lakehurst - Common Nighthawk						
All nests (*n = 32*)	Predation	18 (8)	4	13	0.01036	0.00389 - 0.02728
(Non-mowed areas)	Aband.	4 (4)	1	3	0.00260	0.00037 - 0.01822
	Mowing	0 (0)	0	0	0.00000	0.00000 - 0.00000

[a]estimated failure rate from each cause based on daily failure rate (see Methods).
[b]percent failure rate (i.e., 100 x [# failed nests / Total # nests])

Table 10. Mean (SE) number and proportion of Grasshopper Sparrows and Eastern Meadowlark fledglings produced per nest at Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD) in 2009, 2010, and 2012.

	Mean Number of Fledglings Produced Per Nest (SE)		Mean Proportion of Fledglings Produced Per Nest (SE)	
	All nests	Successful nests	All nests	Successful nests
Grasshopper Sparrow				
Westover	1.9 (0.3)	3.2 (0.2)	0.46 (0.06)	0.79 (0.05)
Mowed areas	1.5 (0.3)	2.9 (0.2)	0.40 (0.08)	0.78 (0.07)
Non-mowed areas	2.4 (0.4)	3.4 (0.3)	0.55 (0.09)	0.79 (0.06)
Lakehurst	2.3 (0.3)	3.6 (0.2)	0.55 (0.07)	0.86 (0.04)
Patuxent	1.7 (0.2)	3.2 (0.1)	0.43 (0.04)	0.83 (0.03)
Eastern Meadowlark				
Westover	1.7 (0.3)	3.4 (0.3)	0.39 (0.07)	0.78 (0.06)
Mowed areas	1.2 (0.3)	2.6 (0.3)	0.28 (0.07)	0.65 (0.08)
Non-mowed areas	2.6 (0.6)	4.3 (0.2)	0.57 (0.13)	0.95 (0.03)
Lakehurst	2.1 (0.7)	3.5 (0.6)	0.54 (0.15)	0.90 (0.07)
Patuxent	1.0 (0.2)	3.6 (0.2)	0.25 (0.05)	0.89 (0.04)

Table 11. Model ranking results for Grasshopper Sparrow and Eastern Meadowlark productivity (number of young fledged per nest) on Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD) in 2009, 2010, and 2012.

Westover - Grasshopper Sparrow and Eastern Meadowlark

	No. Fledged / Nest (All Nests)				No. Fledged / Successful Nest			
model	**k**	**AICc**	**Δ AICc**	***w***	**k**	**AICc**	**Δ AICc**	**w**
Species + Mowed Area	**4**	**360.68**	**0.00**	**0.45**	**4**	**151.95**	**0.00**	**0.61**
Species + Dist. To Runway	**4**	**361.53**	**0.86**	**0.29**	4	158.72	6.77	0.02
Species + Nest Mowed	5	362.92	2.24	0.15	5	154.16	2.21	0.20
Species + % Grass	4	366.62	5.94	0.02	4	159.80	7.85	0.01
Species + Veg. Height	4	366.63	5.95	0.02	4	156.67	4.71	0.06
Species	3	366.90	6.22	0.02	3	159.39	7.44	0.01
Species + Year	5	367.24	6.57	0.02	5	161.20	9.25	0.01
Species + % Forb	4	368.48	7.80	0.01	4	161.76	9.81	0.00
Species + % Shrub	4	368.80	8.12	0.01	4	161.26	9.31	0.01
Species + Day of Season	4	368.93	8.25	0.01	4	158.58	6.63	0.02
Species + % Bare	4	369.08	8.40	0.01	4	157.33	5.37	0.04
Species + Clumpiness	5	371.34	10.66	0.00	5	162.69	10.74	0.00

Lakehurst - Grasshopper Sparrow and Eastern Meadowlark

	No. Fledged / Nest (All Nests)				No. Fledged / Successful Nest			
model	**k**	**AICc**	**Δ AICc**	***w***	**k**	**AICc**	**Δ AICc**	**w**
Species + Location	**5**	**245.86**	**0.00**	**0.67**	**5**	**112.25**	**0.00**	**0.63**
Species + % Grass	4	249.38	3.52	0.12	4	119.40	7.14	0.02
Species + % Forb	4	250.90	5.04	0.05	4	117.88	5.63	0.04
Species	3	250.98	5.12	0.05	3	117.02	4.77	0.06
Species + % Shrub	4	252.08	6.22	0.03	4	116.48	4.22	0.08
Species + % Bare	4	252.59	6.73	0.02	4	116.73	4.48	0.07
Species + Day of Season	4	252.67	6.81	0.02	4	119.54	7.29	0.02
Species + Veg. Height	4	253.05	7.19	0.02	4	119.52	7.26	0.02
Species + Year	5	255.28	9.42	0.01	5	121.20	8.95	0.01
Species + Clumpiness	5	255.40	9.54	0.01	5	116.74	4.49	0.07

Patuxent - Grasshopper Sparrow and Eastern Meadowlark

	No. Fledged / Nest (All Nests)				No. Fledged / Successful Nest			
model	**k**	**AICc**	**Δ AICc**	***w***	**k**	**AICc**	**Δ AICc**	**w**
Species + % Bare	**4**	**681.66**	**0.00**	**0.57**	**4**	**196.97**	**0.89**	**0.13**
Species + Veg. Height	4	684.26	2.60	0.16	4	198.32	2.24	0.06
Species + Year	5	684.42	2.76	0.14	5	200.28	4.19	0.02
Species + % Shrub	4	687.54	5.87	0.03	**4**	**197.98**	**1.90**	**0.08**
Species	3	688.03	6.37	0.02	**3**	**196.09**	**0.00**	**0.19**
Species + Day of Season	4	688.24	6.58	0.02	4	198.13	2.05	0.07
Species + Dist. To Runway	4	688.34	6.68	0.02	**4**	**197.66**	**1.57**	**0.09**
Species + % Grass	4	689.75	8.09	0.01	**4**	**197.94**	**1.85**	**0.08**
Species + Nest Mowed	4	689.98	8.31	0.01	**4**	**197.86**	**1.77**	**0.08**
Species + % Forb	4	690.12	8.46	0.01	**4**	**197.18**	**1.09**	**0.11**
Species + Clumpiness	5	692.24	10.58	0.00	**5**	**197.66**	**1.57**	**0.09**

Table 12. Best-performing models of productivity (no. young fledged per nest) for Grasshopper Sparrows and Eastern Meadowlarks at Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD) in 2009, 2010, and 2012. See Table 11 for model ranking results.

Site	Model - Parameters	*Beta*	*SE*	*t*	*P**
Westover - Grasshopper Sparrow and Eastern Meadowlark					
	Mowed Area (All Nests)				
	Intercept	2.406	0.371	6.5	**< 0.001**
	Species (vs. Eastern Meadowlark)				
	Grasshopper Sparrow	0.140	0.380	0.1	0.713
	Mowed Area (vs. Non-mowed Area)	-1.129	0.387	8.5	**0.004**
	Distance to Runway (All Nests)				
	Intercept	1.280	0.321	4.0	**< 0.001**
	Species (vs. Eastern Meadowlark)				
	Grasshopper Sparrow	0.037	0.385	0.1	0.924
	Distance to Runway (m)	0.003	0.001	2.8	**0.007**
	Mowed Area (Successful Nests Only)				
	Intercept	3.941	0.294	13.4	**< 0.001**
	Species (vs. Eastern Meadowlark)				
	Grasshopper Sparrow	-0.260	0.313	-0.8	0.410
	Mowed Area (vs. Non-mowed Area)	-0.983	0.308	-3.2	**0.003**
Lakehurst - Grasshopper Sparrow and Eastern Meadowlark					
	Location (All Nests)				
	Intercept	2.773	0.668	4.2	**< 0.001**
	Species (vs. Eastern Meadowlark)				
	Grasshopper Sparrow	0.066	0.652	0.1	0.919
	Site (vs. Westfield)				
	Jump Circle	-1.823	0.638	-2.9	**0.006**
	Test Site	-0.219	0.581	-0.4	**0.708**
	Location (Successful Nests Only)				
	Intercept	4.081	0.482	8.5	**< 0.001**
	Species (vs. Eastern Meadowlark)				
	Grasshopper Sparrow	0.345	0.461	0.7	0.459
	Site (vs. Westfield)				
	Jump Circle	-1.088	0.546	-2.0	**0.054**
	Test Site	-1.155	0.372	-3.1	**0.004**
Patuxent - Grasshopper Sparrow and Eastern Meadowlark*					
	% Bare Ground (All Nests)				
	Intercept	1.308	0.209	6.3	**< 0.001**
	Species (vs. Eastern Meadowlark)				
	Grasshopper Sparrow	0.874	0.269	3.3	**0.001**
	% Bare Ground	-1.560	0.534	-2.9	**0.004**

*No models at Patuxent performed well at predicting the number fledged at successful nests (w < 0.14; Table 11).

Table 13. Nestling morphological measurements taken on days 4-7 (GRSP) or 6-9 (EAME) post-hatch at Westover Air Reserve Base (MA), Joint Base McGuire-Dix-Lakehurst (NJ), and Patuxent River Naval Air Station (MD) in 2009, 2010, and 2012.

		EAME			GRSP		
		n	Mean	SD	n	Mean	SD
Westover	Mass (g)	36	42.6	7.7	48	10.1	1.9
	Wing (mm)	41	49.8	6.6	48	25.6	4.5
	Tail (mm)	36	5.4	2.9	48	3.0	1.6
	Tarsus (mm)	41	30.2	3.3	48	17.6	2.2
	Fat Score*	41	1.6	0.8	48	1.9	0.9
	Keel Score*	41	1.4	0.5	48	1.7	0.7
Lakehurst	Mass (g)	22	39.4	7.4	98	10.0	2.1
	Wing (mm)	22	48.4	7.5	98	24.6	5.5
	Tail (mm)	22	2.0	2.9	98	2.5	1.6
	Tarsus (mm)	22	29.9	3.0	98	16.4	2.0
	Fat Score*	22	0.5	0.7	98	1.3	0.9
	Keel Score*	22	1.5	0.5	98	2.2	0.7
Patuxent	Mass (g)	50	41.4	7.2	68	10.8	2.5
	Wing (mm)	54	52.0	7.8	70	30.6	6.5
	Tail (mm)	54	5.4	2.5	70	3.0	1.9
	Tarsus (mm)	54	32.4	4.1	70	18.3	2.0
	Fat Score*	54	0.5	0.8	70	1.1	1.0
	Keel Score*	54	1.9	0.4	70	2.1	0.4

* See Appendix B

Appendix A. Nest location maps.

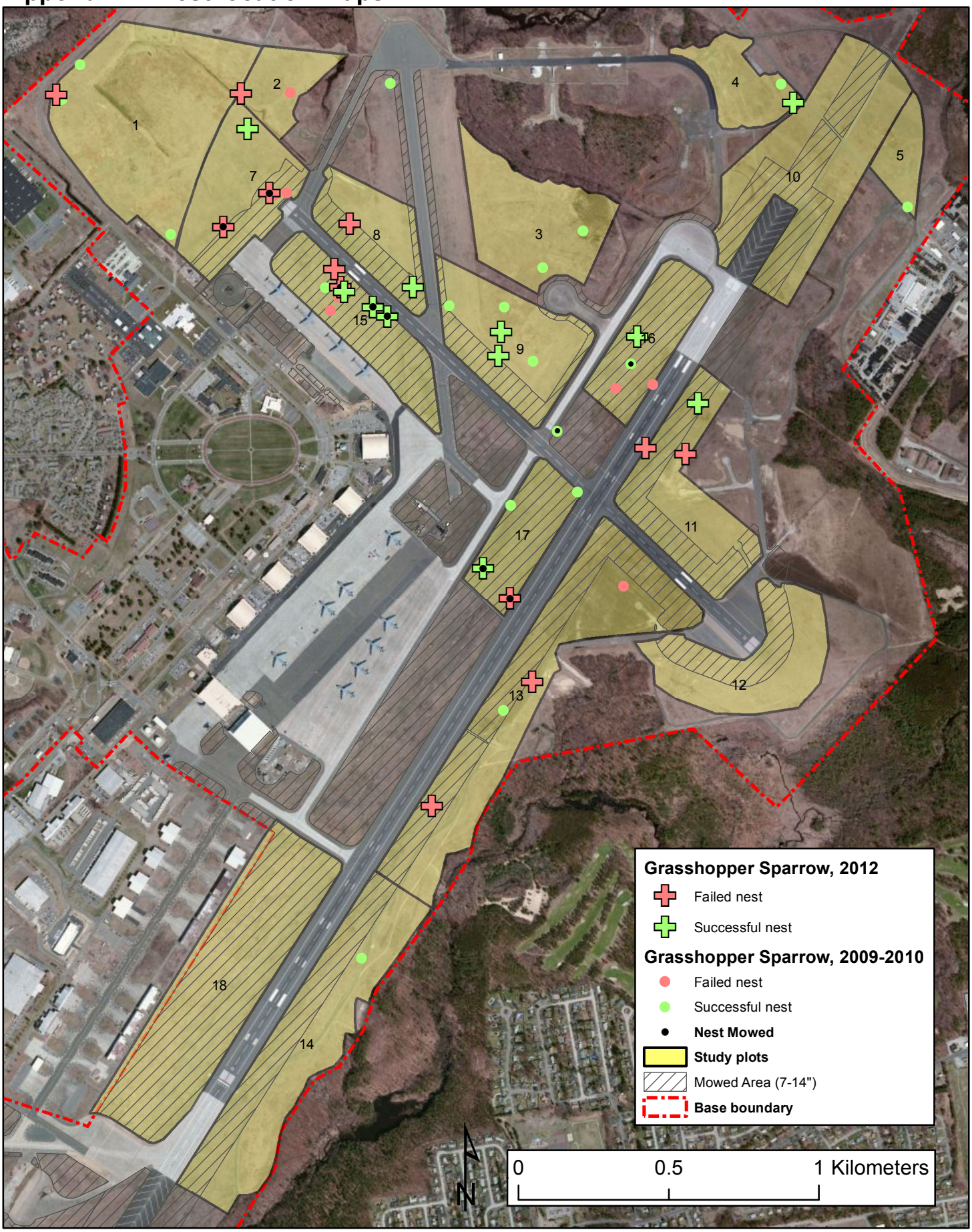


Figure A1. Locations of Grasshopper Sparrow nests monitored on Westover Air Reserve Base, Massachusetts in 2009, 2010, and 2012.

Appendix A. Nest location maps.

Figure A2. Locations of Eastern Meadowlark nests monitored on Westover Air Reserve Base, Massachusetts in 2009, 2010, and 2012.

Appendix A. Nest location maps.

Figure A3. Locations of Savannah Sparrow nests monitored on Westover Air Reserve Base, Massachusetts in 2009, 2010, and 2012.

Appendix A. Nest location maps.

Figure A4. Locations of Upland Sandpiper nests monitored on Westover Air Reserve Base, Massachusetts in 2009, 2010, and 2012.

Appendix A. Nest location maps.

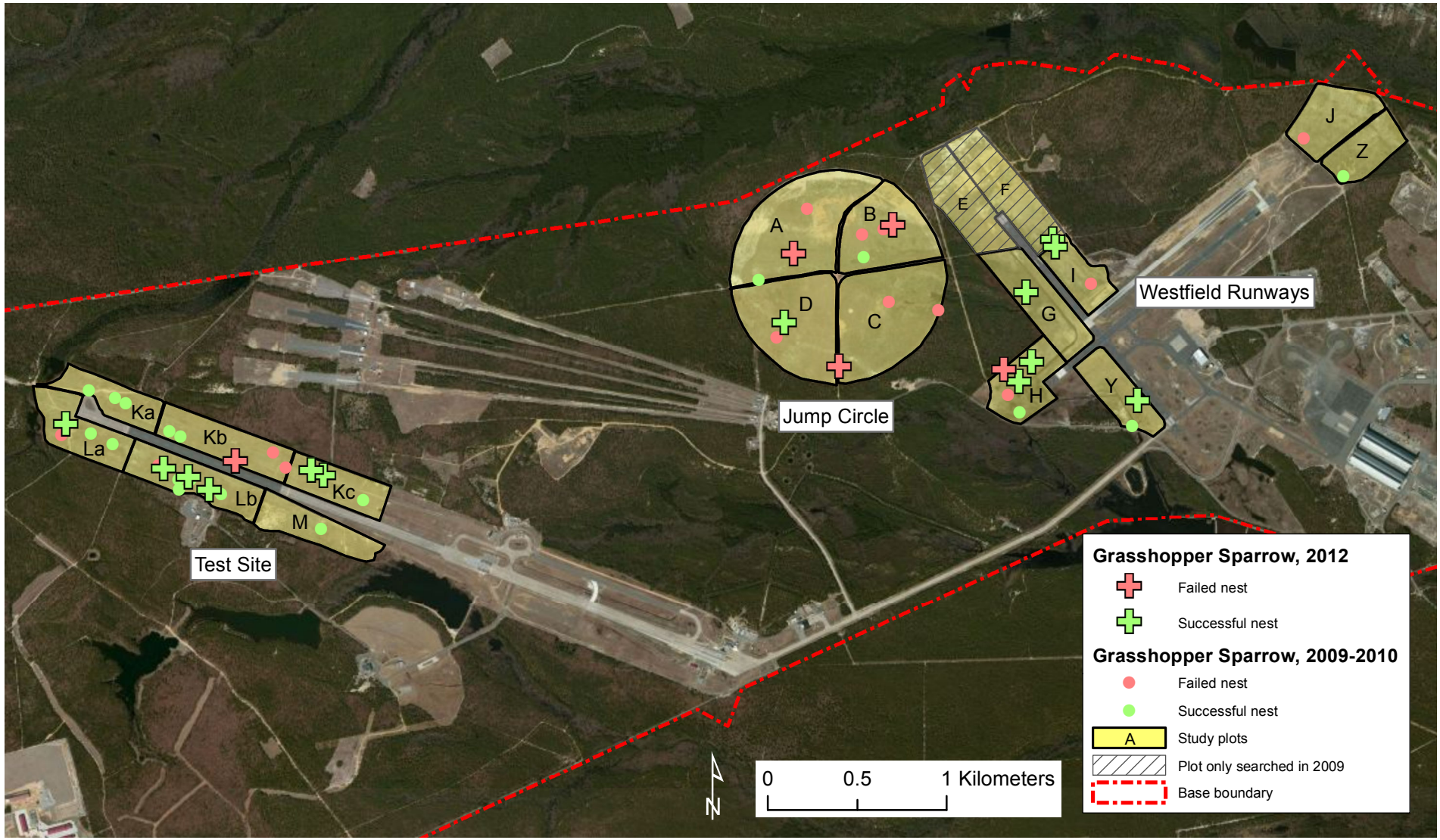


Figure A5. Locations of Grasshopper Sparrow nests monitored on the Lakehurst section of Joint Base McGuire-Dix-Lakehurst, New Jersey in 2009, 2010, and 2012.

Appendix A. Nest location maps.

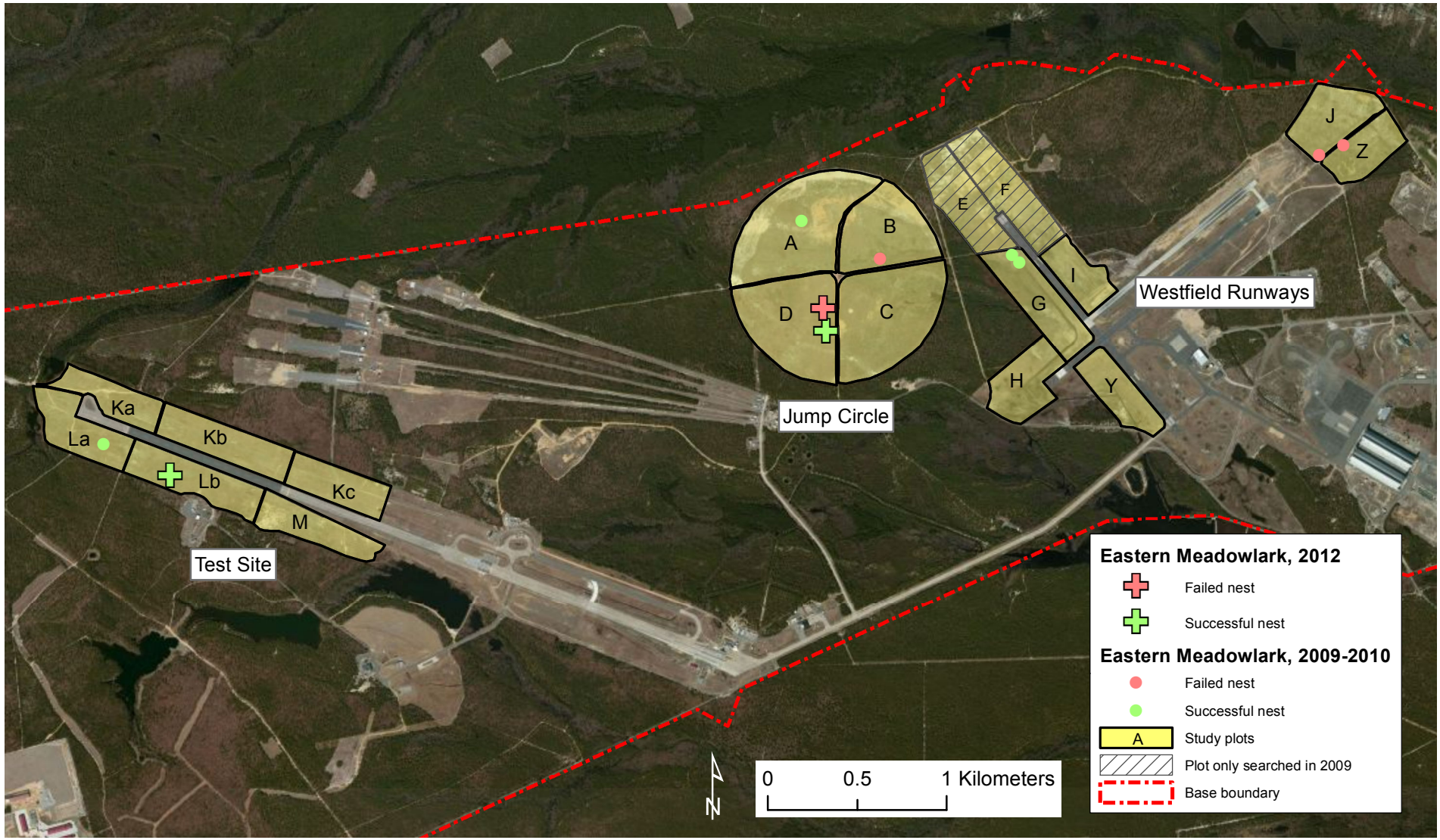


Figure A6. Locations of Eastern Meadowlark nests monitored on the Lakehurst section of Joint Base McGuire-Dix-Lakehurst, New Jersey in 2009, 2010, and 2012.

Appendix A. Nest location maps.

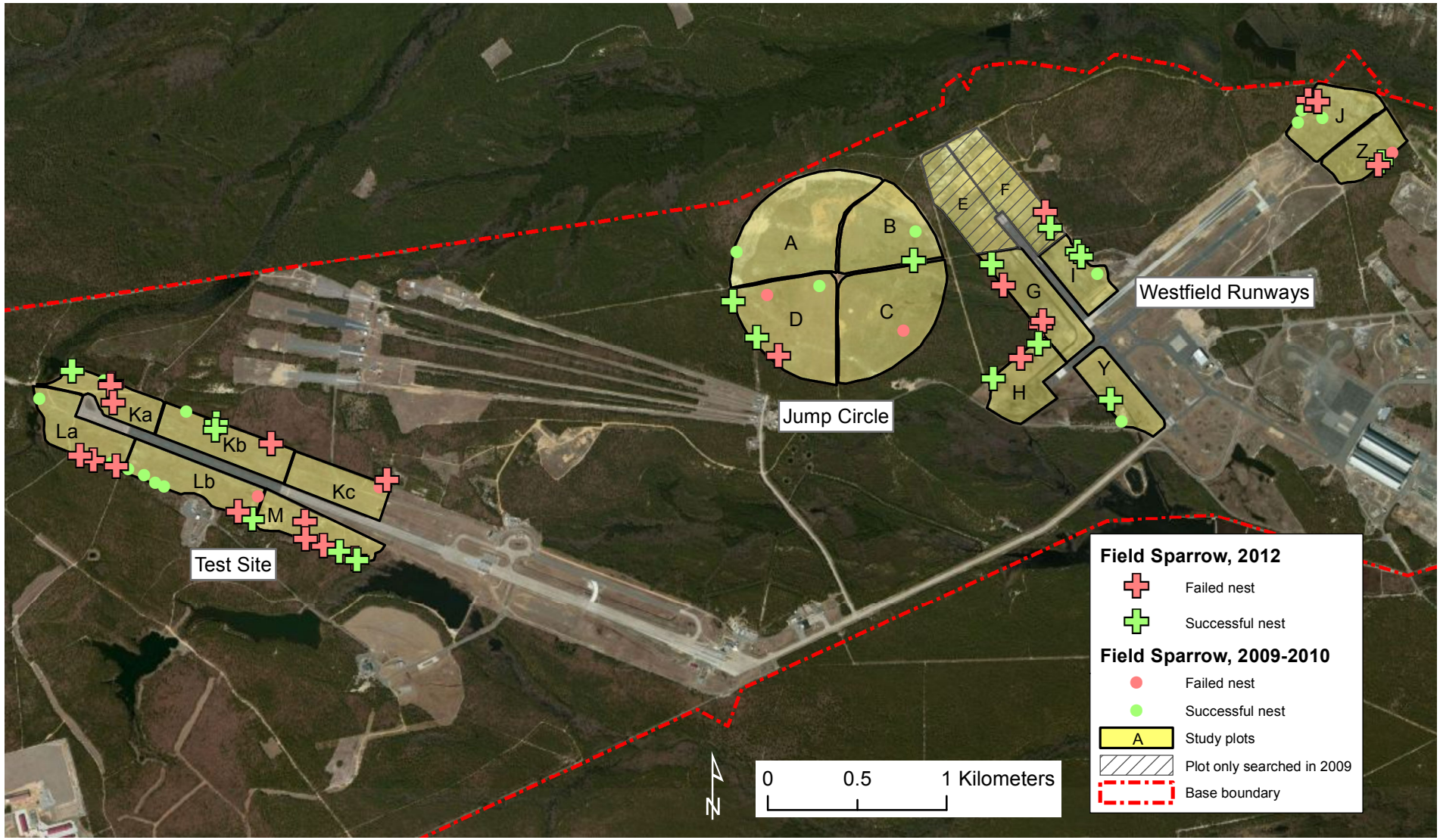


Figure A7. Locations of Field Sparrow nests monitored on the Lakehurst section of Joint Base McGuire-Dix-Lakehurst, New Jersey in 2009, 2010, and 2012.

Appendix A. Nest location maps.

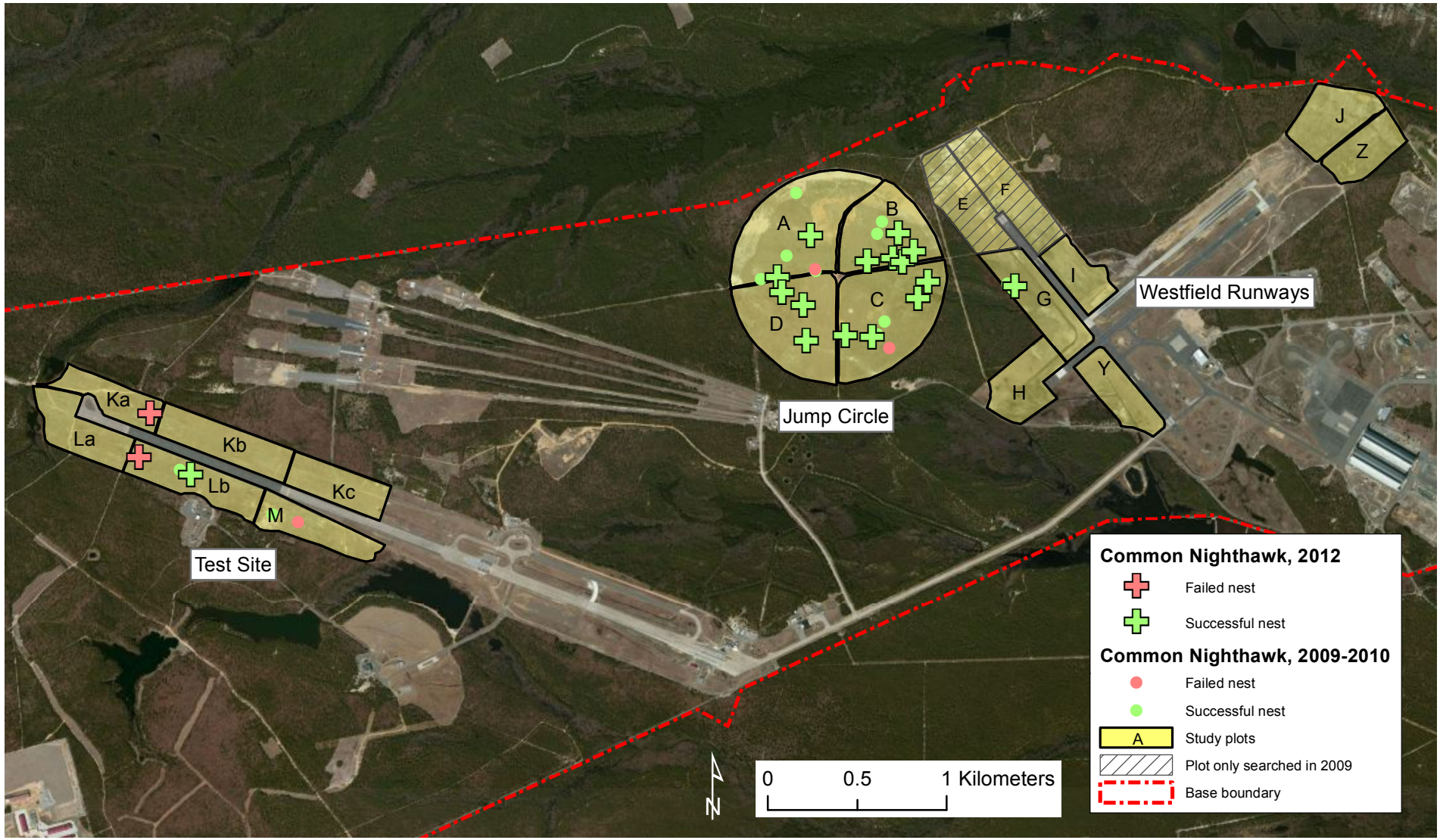


Figure A8. Locations of Common Nighthawk nests monitored on the Lakehurst section of Joint Base McGuire-Dix-Lakehurst, New Jersey in 2009, 2010, and 2012.

Appendix A. Nest location maps.

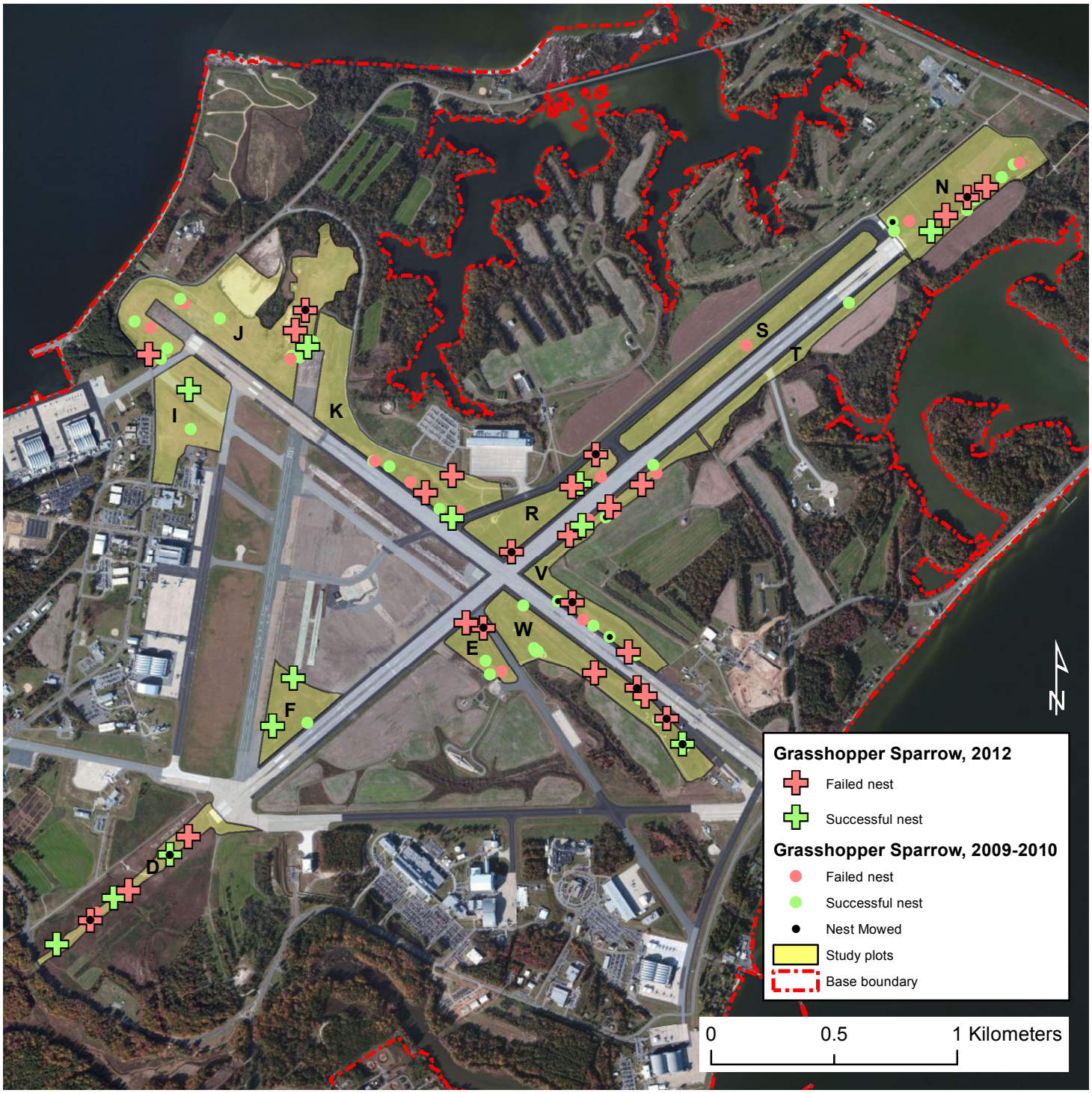


Figure A9. Locations of Grasshopper Sparrow nests monitored on Patuxent Rvier Naval Air Station, Maryland in 2009, 2010, and 2012.

Appendix A. Nest location maps.

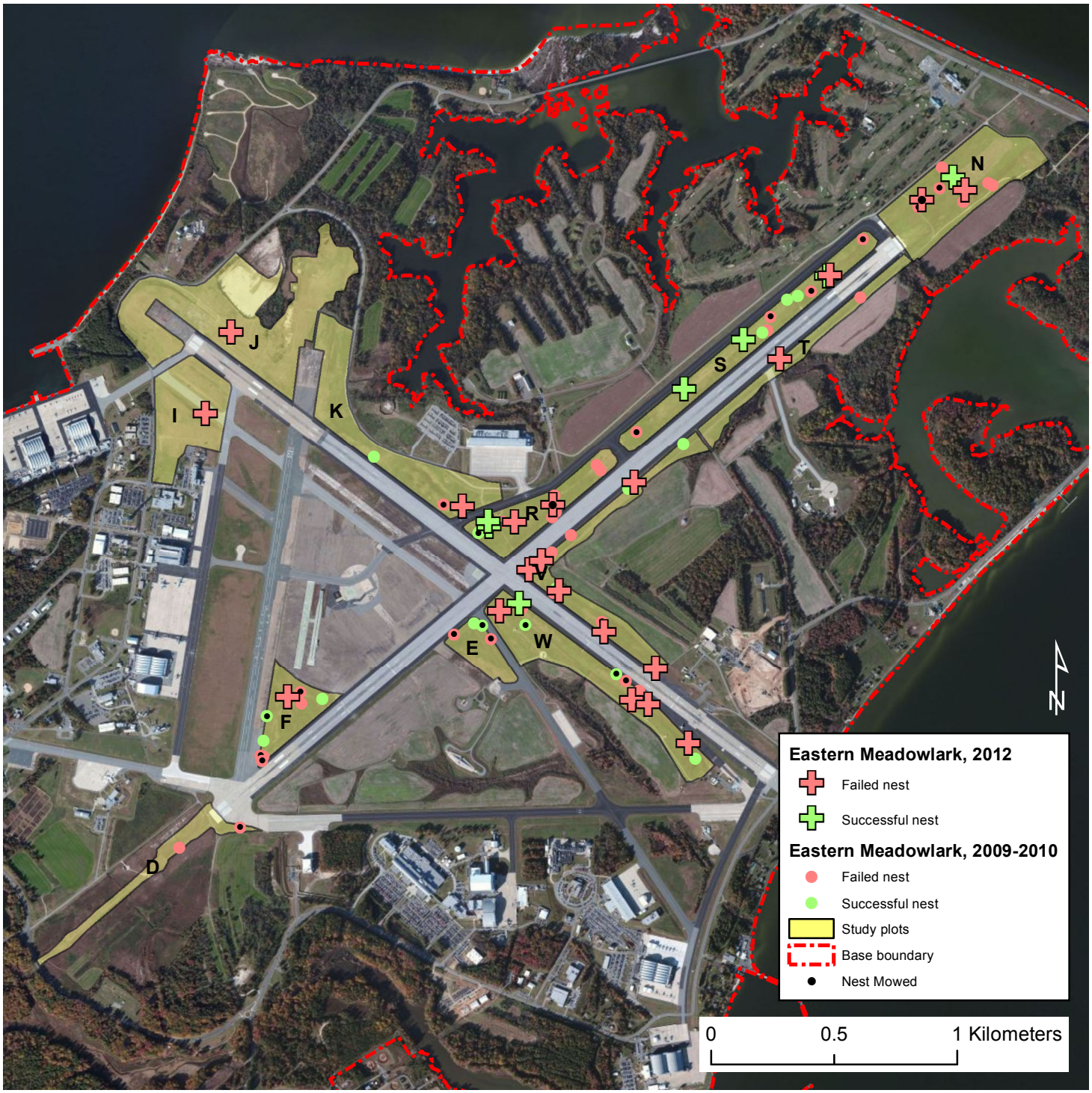


Figure A10. Locations of Eastern Meadowlark nests monitored on Patuxent Rvier Naval Air Station, Maryland in 2009, 2010, and 2012.

APPENDIX B. Codes used for morphological measurements.

Fat-
(MAPS categories; examine furcular hollow, wingpits, abdomen)
0 = no fat in furcular hollow or anywhere on the body
1 = furcular hollow less than 5% full; none or just a trace elsewhere
2 = furcular hollow 5% to 33% full; bottom completely covered
3 = furcular hollow 34% to 66% full; fat covering wingpit and/or abdomen
4 = furcular hollow 67% to 100% full; fat thick under wings and on abdomen
5 = fat bulging above furcular hollow; fat well mounded elsewhere
6 = fat bulging greatly above furcular hollow; huge mounds under wings and on abdomen
7 = extremely fat; fat nearly joined in all areas

Keel-
(Bairlein 1995)
0 = sternum sharp; muscles depressed
1 = sternum easy to distinguish, but not sharp; muscles neither depressed or rounded
2 = sternum yet distinguishable; muscles slightly rounded
3 = sternum difficult to distinguish due to rounded muscles