BREEDING PHENOLOGY, NESTING SUCCESS, HABITAT SELECTION, AND CENSUS METHODS FOR THE STREAKED HORNED LARK IN THE PUGET LOWLANDS OF WASHINGTON

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INTRODUCTION

The Streaked Horned Lark (*Eremophila alpestris strigata*) is a recognized subspecies of the Horned Lark (Beason 1995, AOU 1957, Behle 1942). The historic breeding range of the Streaked Horned Lark extended from southern British Columbia (Campbell et al. 1997) south through the Puget lowlands and outer coast of Washington (Jewett et al. 1953) and south through the Willamette Valley of Oregon (Gilligan et al. 1994, Gabrielson and Jewett 1940). It was historically considered to be a common to abundant breeder in appropriate habitats (Bowles 1900, Dawson and Bowles 1909, Gabrielson and Jewett 1940, Jewett et. al. 1953, Browning 1975, Campbell et al. 1997).

Today, this subspecies is extirpated as a breeding species from British Columbia, the northern Puget Sound of Washington and the Rogue Valley in Oregon (Rogers 2000, Altman 1999). The total breeding population has apparently declined; surveys conducted in the late 1990s indicate that there may be fewer than 100 birds in Washington (49 singing males; Rogers 1999) and 300 birds in Oregon (< 150 singing males; Altman 1999). This population estimate assumes that all males are paired. However, the actual population size is likely to be lower than 300 because breeding sex ratios (tertiary sex ratios) are often male biased (Lack 1954, Promislow et al. 1992). Preliminary data indicating low nest success (Altman 1999) raises concerns about the viability of these small populations.

The Streaked Horned Lark was historically described as a common breeder in the glacial outwash or Puget prairies of the south Puget Sound area (Dawson and Bowles 1909, Bowles 1900, Bowles 1898, Suckley and Cooper 1860). Crawford and Hall (1997) estimated the historic distribution of grasslands in the southern Puget Sound region by mapping grassland soils (Puget prairies only occur on gravelly, well drained soils or on soils derived from materials with low water holding capacity). They estimated that grasslands currently occupy about 22% of their historic distribution and that prairies dominated by native species occupy approximately 3% of the historic grassland distribution. The loss of these grasslands has been attributed to urban development (33%), forest invasion or conversion (32%) and agriculture conversion (30%; Crawford and Hall 1997). Currently, there are only five known Streaked Horned Lark populations in the southern Puget Sound region and four of these are associated with airports (Rogers 1999 & 2000, MacLaren and Cummins 2000).

Because of its precarious status, the Streaked Horned Lark is: 1) a priority species for conservation by Oregon-Washington Partners in Flight (Altman 2000) and British Columbia Partners in Flight (Fraser et al. 1999); 2) listed as State Sensitive by the Oregon Department of Fish and Wildlife (Critical Status; Oregon Sensitive Species List, 1997); 3) listed as a candidate for listing under the Washington Endangered Species Act (Washington Department of Fish and Wildlife, 28 October 1998); 4) considered a Red list species in British Columbia; 5) listed as a federal Candidate species under the Endangered Species Act, U.S. Fish and Wildlife Service.

In the spring and summer of 2002 three field assistants and I conducted research on this species at four research sites in the south Puget Sound. The specific objectives of this research were five-fold:

1) Describe Streaked Horned Lark breeding phenology and life history.

2) Assess reproductive success in four of the populations where males have been reported singing and performing flight displays.

3) Identify habitat features important to successful breeding at the nest site and territory scales.

4) Assess the impacts of human activities on Streaked Horned Larks at the 13th Division Prairie.

5) Develop a Streaked Horned Lark survey protocol that could be used by Washington Department of Transportation biologists to determine species presence or absence.

METHODS

Research Sites

Field work was conducted from late February to mid-August, 2002 in the Puget lowlands at four sites: (1) Olympia Airport (46° 97' N, 122° 90'W), (2) 13th Division Prairie on Ft. Lewis (47° 02'N 122° 44'W), (3) Gray Army Airfield on Ft. Lewis (47° 08'N 122° 58'W), (4) McChord Airforce Base (47° 12'N 122° 45'W). All four sites are dominated by grasses, occur on glacial outwash soils and were formally or are currently composed of native Puget prairie species. The three airport sites are mowed regularly to keep the grasses short as required by the Federal Aviation Administration (shorter vegetation provides better visibility for pilots). These sites were selected because males and, in some cases, females were reported at all sites (Rogers 1999, 2000, MacLaren and Cummins 2000).

Arrival Dates, Territory Establishment and Pairing

I surveyed each of the four research sites for new arrivals once a week from mid-February through early May. I restricted my search to locations where males and/or females had been reported previously (Rogers 1999, 2000, MacLaren and Cummins 2000). Because sites were only visited once a week, I recorded the number of birds observed, each bird's behavior (territorial behavior, foraging, pairing, and flocking) and its sex for each 7-day period rather than attempt to identify specific arrival dates. I stopped recording arrival date information shortly after females started arriving.

Territory Mapping

Throughout the breeding season, locations and behaviors of all birds observed were plotted on an orthographic photograph or detailed map of each research site during a relatively quick tour of the site (approximately 1-2 hrs) weekly. This work focused on specific areas within each research site (see Appendix I) and did not necessarily include the entire Lark population at a given site. Along with location information, the following information was included on the map: sex and age (adult/fledgling) and behaviors such as agonistic interactions, singing, flight displays, courtship behaviors, etc. These maps represent a snapshot picture of bird locations and behaviors at a given research site.

Field biologists also delineated territories by visiting fixed observation posts within each research site approximately weekly. From these observation points, they recorded the azimuth and distance to each bird detected along with information on age, sex and behavior. At the end of the breeding season, they entered each observation into a hand-held Geoexplorer III GIS unit using the offset option. This approach to recording location and behavioral information has been used successfully to predict the reproductive state of breeding birds (Christoferson and Morrison 2001). The information from all of the territory mapping and observation points were combined on to a single composite map for each site. For each site, locations of territorial behaviors such as agonistic interactions, singing, and flight displays were used to delineate territories following Robbins (1970).

Locating Nests and Determining Reproductive Success

Field biologists searched for and monitored Streaked Horned Lark nests from April until mid- August. Nests were located and monitored using standardized methodology (Martin and Geupel 1993). Nests were located by observing adults with nesting materials or carrying food, by flushing brooding adults, or by simply searching the vegetation. Date and status (presence of parents, eggs, nestlings) of each nest was recorded approximately every 3-5 days. Nest success and mortality was calculated using the Mayfield method (Mayfield 1961, 1975) as modified by Johnson (1979) and Hensler and Nichols (1981). Nest outcome was reported as the proportion of successful nests, nests that failed, nests lost to predation, nests abandoned and nests lost to human activities (mowing and construction activities).

Clutch Initiation Dates

Unless observed directly, I calculated clutch initiation date by backdating from known dates (hatching dates, estimated age of nestlings, or fledging dates). Backdating using known dates requires information on the time intervals associated with egg laying, incubation and/or nestling stages. Because our sample size was too small to compute these time intervals directly, I used the following time intervals from Beason (1995) to calculate clutch initiation dates: egg laying = 1 egg laid per day (thus, the number of eggs = the length of the egg laying stage), incubation = 12 days, nestling = 9 days. Although not reported here, the intervals quantified for these nest stages during this study match closely the time intervals reported by Beason (1995).

When a nest found during incubation failed before hatching, I used the following formula to estimate the first date of incubation (Martin et al. 1997):

First date of incubation = date found - ((incubation period - number of days observed) ÷ 2)

I then subtracted the number of eggs in the clutch from this value to determine clutch initiation date.

Clutch Size

The average, median, and modal clutch size was calculated for all four research sites combined. I only included clutch sizes from nests that were seen with the same number of eggs at least twice during the incubation period.

Habitat Sampling

Habitat variables were measured at the territory and nest site scale. At the territory scale, habitat variables were measured within territories delineated through territory mapping. Within territories, high use areas were identified (areas with high concentrations of bird locations). Within high use areas, I randomly located two 25 m perpendicular transects that crossed at their midpoints. I used the point intercept method (Bonham 1989) at each meter along these axes and recorded species that intercepted the rod, maximum height of the vegetation, and whether or not the rod hit bare ground, rock or thatch. For all analyses total hits were averaged per territory or non-use site and plant species were put into the following functional groupings before analysis: ferns, annual forbs (non-native), perennial forbs (native), perennial forb (non-native), annual grass (native & non-native), perennial grass (caespitose), perennial grass (rhizomatous), perennial grass (tuft), and shrubs (native and non-native). Transects were also randomly located in grassland areas adjacent to those used by Larks but that were not used or rarely used (non-use sites). I used the same sampling protocol for nonuse sites as I did for use sites.

At the nest site scale, a 1m wooden frame and dowel was used to measure habitat variables following Barbour et al. 1980. Vegetation was measured within a 0.5 m radius of the nest center by centering the 1m long frame on the nest so that the axis was oriented north-south. Field biologists recorded every plant hit by a vertical dowel dropped through the frame at 10 cm intervals. They recorded the number of hits by species, maximum vegetation height and, when the dowel hit the ground, whether the dowel hit bare ground, thatch or rock. The frame was then oriented east-west and the same protocol was followed. For all analyses plant species were put into the following functional groupings before analysis: annual forbs (native and non), perennial forbs (native), perennial forbs (non-native), annual grasses (non-native), perennial grasses (caespitose), perennial grasses (rhizomatous), perennial grasses (tuft), and perennial shrubs (native and non-native). Differences in these species groupings from those measured at the territory scale reflect differences in the species present. For example, no ferns were recorded at the nest scale and the annual forbs consisted of both native and non-native species at the nest site scale but only non-native species were reported at the territory scale. Nonuse nest sites were located using a random distance (within 10 m of the nest) and random azimuth from the nest. These random nest sites were located within the same vegetation type (grassland) and likely fell within the same male's territory as the nest site. The same sampling protocol was used for nonuse nest sites as was used for nest sites. Females usually build their nests on the north side of a plant (Beason 1995). We recorded the species of the base plant to examine potential preferences.

Logistic regression was used to compare habitat variables between nest/territory plots and random plots (Hosmer and Lemeshow 1989). I used the following strategy to develop our multivariable models. As suggested by Hosmer and Lemeshow (1989), I made univariate comparisons of habitat variables between nest and random transects and between territory and random transects. All variables with $P < 0.25$ were included in an initial multivariate model. I controlled for multicollinearity by computing a correlation matrix among the remaining variables. No variables were significantly correlated ($r > 0.60$). The most parsimonious model was developed using a manual "step-down" method, minimizing Akaike's Information Criterion (AIC; Lebreton et al. 1992). Predictors were eliminated from the full model if their removal reduced the value of AIC. The final models were evaluated using the likelihood-ratio test comparing the full model with a constant only model, and the coefficient, t-ratio, p-value, and model log likelihood, chi-square, and Rho-squared values were reported.

<u>Human Disturbance</u>
I evaluated the effects of human activities on Lark behavior using two different approaches. First, field biologists quantified behaviors of individual birds at all research

sites throughout the breeding season using a 10-minute focal animal approach. All behaviors were either counted or the duration of the behavior was recorded during the 10-minute period. Behaviors were put into five groups, (1) territorial (e.g., songs, calls, flight displays, male-male interactions), (2) foraging (e.g., pecks, and time spent actively foraging), (3) maintenance (e.g., preening, feather ruffles, dust bathing, resting), (4) reproductive (e.g., copulations, courtship displays, nest building), and (5) alert/fleeing (e.g., head up alert position while standing, walking, or running and flights). I do not present a comprehensive analysis of these data here. However, several disturbance events occurred during these observation periods. I used an ANOVA to compare bird behaviors during disturbance events to behaviors without them.

The second approach examined the frequency of human activities by activity type. During 18 7-hour days, field biologists recorded the number of human activities by activity type (dog walking, horseback riding, off road vehicle use, military training, etc.) at the 13th Division Prairie research site. Visits to the site were evenly spaced throughout the breeding season.

<u>Survey Protocol</u>

To evaluate the relative effectiveness of point counts and belt transects for determining presence/ absence of Horned Larks, field biologists established four point count stations and two transects within areas occupied by Horned Larks at each of the four research sites. Each point count and transect was visited at least 8 times between mid-April to late-June. Field biologists rotated among sites to control for observer bias. Reference flags were placed at 25m and 50m on either side of transects and point count stations to facilitate accurate distance estimates. Censuses were started within 1 hr of dawn and were completed within 2 hrs. The surveys were evenly spaced throughout the breeding season. Upon arriving at a site, observers first conducted a point count followed by two transects and finally the second point count. Upon arriving at a point count station/transect, observers remained stationary and quiet for a minimum of 1 minute to allow birds to settle. At point count stations, observers recorded each bird detected within concentric bands (0-25m, 25-50m, 50-75m, & >75m) and during two time intervals (0-3 min, 3-6 min). At the last point count station of the day, observers conducted a 6 minute point count as described and then conducted a second 6 minute point count using these same methods but this time playing a recording of a Horned Lark song. A song playback was used to compare the effectiveness of taped song recordings in eliciting responses from Horned Larks within hearing distance of the cassette player that might not be detected without a song playback. For transects, observers walked the 200m transects slowly and recorded the distance and azimuth to each bird detected. The direction in which transects were walked was alternated among visits. No survey was conducted during heavy precipitation or high winds. Every attempt was made to avoid counting individual birds more than once. To compare differences in observer's ability to detect Larks, field biologists conducted double observer point counts and transects on 11 occasions.

I used a paired t-test to compare the number of birds detected in a 3-min interval with the number detected in a 6-min interval, to compare point counts with playbacks with those without, and to compare detection differences among observers.

RESULTS & DISCUSSION

Phenology & Clutch Size

Information about the timing of Streaked Horned Lark breeding is poorly understood and is important for determining when certain land management activities might impact Streaked Horned Lark reproduction and survival. Consequently, we documented Horned Lark spring arrival dates, pairing dates and clutch initiation dates.

Males were first observed on February 20th and apparently arrived that day or the day before (Figure 1). Females were first observed on March 8th but didn't start arriving in numbers until March 22nd (Figure 1). Upon arrival, males were often found in flocks and spent most of their time foraging but occasionally spent time singing and performing flight displays. Coincident with female arrival (March 8th) males were no longer found in flocks and were actively singing, performing flight displays and agonistic interactions were observed. The first pairing of the season was initiated around the 22nd of March.

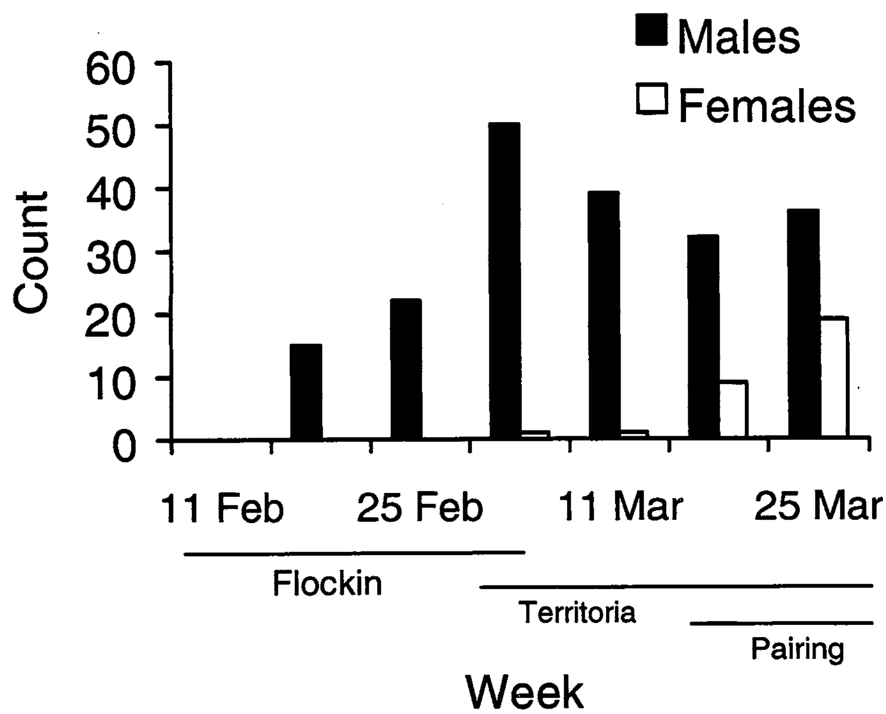

Figure 1. Males first arrived on the breeding grounds during the week of February 18th and females first arrived in numbers during the week of March 18th. Upon arrival males spent most of their time in flocks and actively foraging. Males initiated territorial behavior when females were first observed on the research sites (March 8th). Pairing was initiated around the 22nd of March.

Nest building activity was first observed on April 18th, the first eggs in a nest were observed on April 30th and the last active nest failed on August 8th with three eggs. The graph of clutch initiation dates (Figure 2) suggests that there are likely three periods of clutch initiation. The first period begins in late April and extends into mid-May. This period is likely followed by what I believe is a period of renesting after failed attempts (late May to mid-June) and finally by a period of second clutches (mid-June to late July). I base this description of clutch initiation periods on the relationship between nest failures and clutch initiation and on the relationship between fledging from first nests and apparent initiation of second nests.

Nesting dates reported here are similar to those reported by Bowles (1900). According to Bowles (1900), nesting begins in late April and nesting extends through the first week in July, with the height of the season about the middle of May.

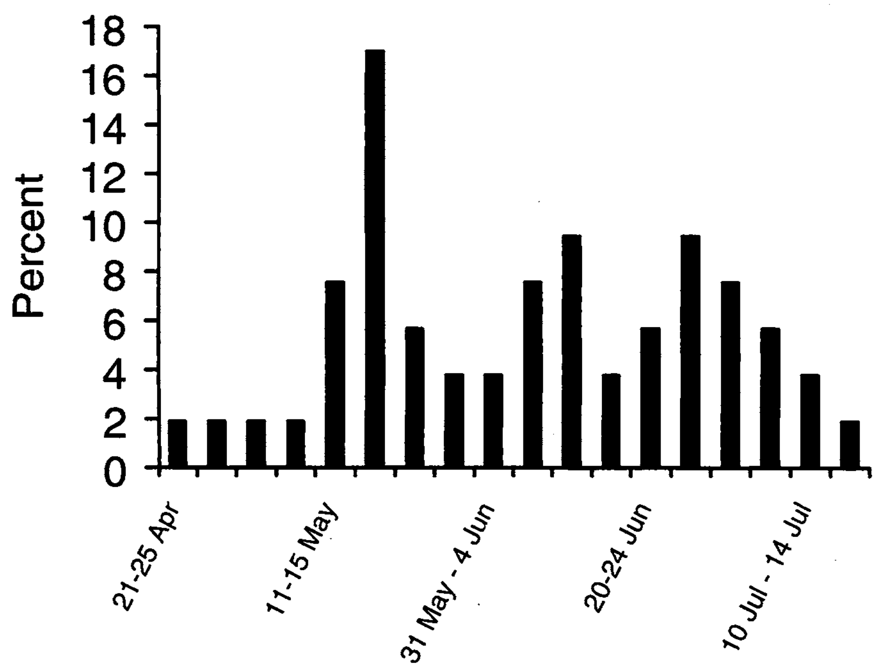

Figure 2. Clutch initiation dates (in five day intervals) for Streaked Horned Larks at four breeding locations in the south Puget Sound.

<u>Clutch Size</u>

Clutch size ranged from 2 to 5 eggs (n = 44 nests) with a mode of 3 and a mean of 3.1 ± 0.1 (SE). Beason (1995) summarized what is known about Horned Lark clutch sizes throughout North America and reports a clutch-size range from 2 to 5 eggs; mean clutch size varies geographically [British Columbia and Washington = 2.4 (n = 15), Colorado = 3.0 (n = 9), Illinois = 3.3 (n = 26), and Northwest Territories = 3.5]. The average clutch size reported in this study is similar to those reported elsewhere for this species but larger than that reported previously for the Northwest. These differences in clutch sizes may be the result differences in sample size (n = 44 for this study and n = 15 for other studies combined). In addition, our clutch size data is based on clutches produced throughout the breeding season. Work on a number of other passerine species suggests that clutch size decreases in replacement and second clutches.

Territory Mapping

Using the composite maps and locations of agonistic behaviors, singing, flight displays and male-female interactions we delineated 45 territories on the four research sites (Table 1). The composite maps for each research site in Appendix I show locations of Larks throughout the breeding season.

Table 1. Estimated number of Streaked Horned Lark territories in June, 2002 by location.

Location	Number of Territories
McChord	13
Olympia	18
Gray Army Airfield	6
13TH Division	8
Total	45

Nesting Success

Nesting success associated with different nesting stages (egg laying, incubation, and nestling) varies from nest stage to nest stage. Nests are usually found at different stages of the nestling cycle. Consequently, biases associated with the relative number of nests found by nesting stage can influence overall estimates of nesting success. The Mayfield method accounts for potential biases associated with date of nest discovery by calculating a daily nest success rate for each one of the three nest stages independently. I did not report Mayfield estimates for egg laying because too few nests were discovered before eggs were layed and thus could not be monitored throughout the egg laying period. I did not statistically compare nesting success among locations or between successful and depredated nests because of small sample sizes (Hensler & Nichols 1981, Nur et al. 1999)

Table 2. Streaked Horned Lark nest survivorship: Mayfield method and proportion of successful nests during the 2002 field season (n = 55 active nests).

Site	Egg laying	Incubation	Nestling	Overall	Proportion successful[1]
Olympia	-	0.55	0.81	0.35	0.43
Gray	-	0.59	0.62	0.32	0.42
McChord	-	0.55	0.63	0.30	0.43
13th Div.	-	0.31	0.09	0.07	0.00
Overall	1.0	0.49	0.58	0.25	0.36

[1]The proportion of successful is the number o f nests that fledged at least one young divided by the total number of active nests found.

Overall Mayfield nest success for all four research sites combined was 25% with more nests lost during the incubation period than the nestling and egg laying periods (Table 2). Mayfield nesting success was lowest in 13th Division Prairie, where no young fledged, and highest at the Olympia Airport. Other than 13th Division, nesting success was similar among sites (Table 2). Nest failure was greater during the incubation stage than the nestling stage for all sites except 13th Division.

The primary source of nest failure at all sites was nest predation (Table 3), which appears to be the primary source of nest failure in most North American grassland systems (Best 1978, Johnson and Temple 1990). We only observed one predator in the act of depredating a nest - a garter snake (*Thamnophis sp.*) with one nestling already consumed (evidenced by the large lump) and the second nestling in its mouth. The relative importance of garter snake predation is unknown. Potential nest predators include: American crow (*Corvus brachyrhynchos*), domestic cat (*Felis cattus*) & dog (*Canis familiaris*), coyote (*Canis latrans*), common raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), long-tailed weasel (*Mustela frenata*), and Virginia opossum (*Didelphis virginiana*). Potential predators observed at our research sites include domestic dog (several sites), coyote, and American crow.

On the three airport sites, American crows may be a significant nest predator. On these sites, crows were observed walking side-by-side (approx. 10 m apart) in a systematic fashion and were observed successfully finding killdeer nests and killing the young. Crows were not observed walking in the grasslands in 13th Division Prairie - probably because the grass was taller and difficult to walk through. Other sources of nest failure in our study include abandonment (9%) and human caused failure (11%; mowing activities and construction activities). Three of the four research sites were actively mowed throughout all or part of the breeding season. Although brown-headed cowbirds (*Molothrus ater*) were noted in the area, no nests were parasitized.

Table 3. Streaked Horned Lark nest outcomes for four research sites in the south Puget Sound region.

Location	Nest activity[1]	Number of Nests[2]	Active Nests[3]	Successful[4]	Fledged[5]	Failed	Depredated	Abandoned	Human Caused Failure[6]
McChord	8 May -6 Aug	16	14	6	15	8	5	2	1
Olympia	23 Apr - 8 Aug	23	21	9	20	12	6	2	4
Gray Army Airfield	18 Apr - 17 Jul	12	12	5	11	7	5	1	1
13TH Division	2 May - 23 Jul	8	8	0	0	8	8	0	0
Total (%)[7]		59	55	20 (36)	46	35 (64)	24 (44)	5 (9)	6(11)

[1]Period of time when birds were actively nesting (i.e., nest building, egg laying, incubation, and nestling periods)
[2]Total number of nests discovered
[3]Of the total number of nests discovered, some nests were discovered after nesting occurred and were no longer being actively used.
[4]Number of nests that fledged at least one young
[5]Number of young that successfully fledged
[6]Mowing and construction activities
[7]Percent is expressed as a proportion of the number of active nests

Habitat Selection

I compared habitat variables surrounding each nest and within male territories with habitat variables associated with areas not used for nests or territories. This type of comparison is critical for identifying the habitat variables selected by breeding Horned Larks (Martin and Roper 1988). At the territorial scale, males are avoiding areas dominated by shrubs, perennial bunch grasses (caespitose), sod forming perennial grasses (rhizomatous), non-native perennial forbs, perennial grasses that grow in clumps (Table 4, Figure 3). They appear to be selecting areas with annual grasses that are sparsely vegetated with relatively short plants and that have a relatively high percent rock cover (Table 4, Figure 3). The McFadden's Rho-squared, similar to r^2, is relatively high indicating that the model accounts for a considerable amount of variability in the data. Horned Larks walk through the grass rather than hopping (Beason 1995), consequently dense, tall grass can be very difficult to move through. Other research indicates that Horned Larks are associated with areas composed of short, sparse vegetation (Dubois 1935, Stewart and Kantrud 1972, Owens and Myres 1973, Weins 1973, Davis and Duncan 1999).

Table 4. Results of the multivariate logistic regression comparing habitat variables associated with territories to those associated with areas not used for territories (n = 70 used and 67 sites that were not used for territories). All variables were averaged per territory and non-use site. The model with the smallest AIC value is presented.

Vegetation variable	Coefficient ± SE	t-ratio	P value
Shrubs	-0.17 ± 0.06	-2.81	0.001
Moss	-0.06 ± 0.02	-2.56	0.010
Perennial grass (caespitose)	-0.10 ± 0.04	-2.38	0.017
Perennial forb (non-native)	-0.09 ± 0.04	-2.16	0.031
Perennial grass (rhizomatous)	-0.02 ± 0.01	-2.10	0.036
Annual grass	0.02 ± 0.01	2.08	0.037
Perennial grass (tuft)	-0.07 ± 0.04	-1.85	0.064
Non vegetated	0.12 ± 0.07	1.62	0.105
Avge. vegetation height	0.06 ± 0.04	1.41	0.159
Rock	0.18 ± 0.13	1.39	0.165
Model log likelihood = -46.08			
Model Chi-square P value < 0.001			
Model McFadden's Rho-Squared = 0.52			

The regression comparing habitat variables associated with nest sites to those associated with nearby random locations suggests that females are selecting areas with native perennial forbs for nest sites. However, this model is not significant at the $P < 0.05$ level (model $P < 0.06$) and it explained little of the variability in the data. However, many nests were placed at the base of a lupine or other native forb suggesting that the presence of native forbs may be important.

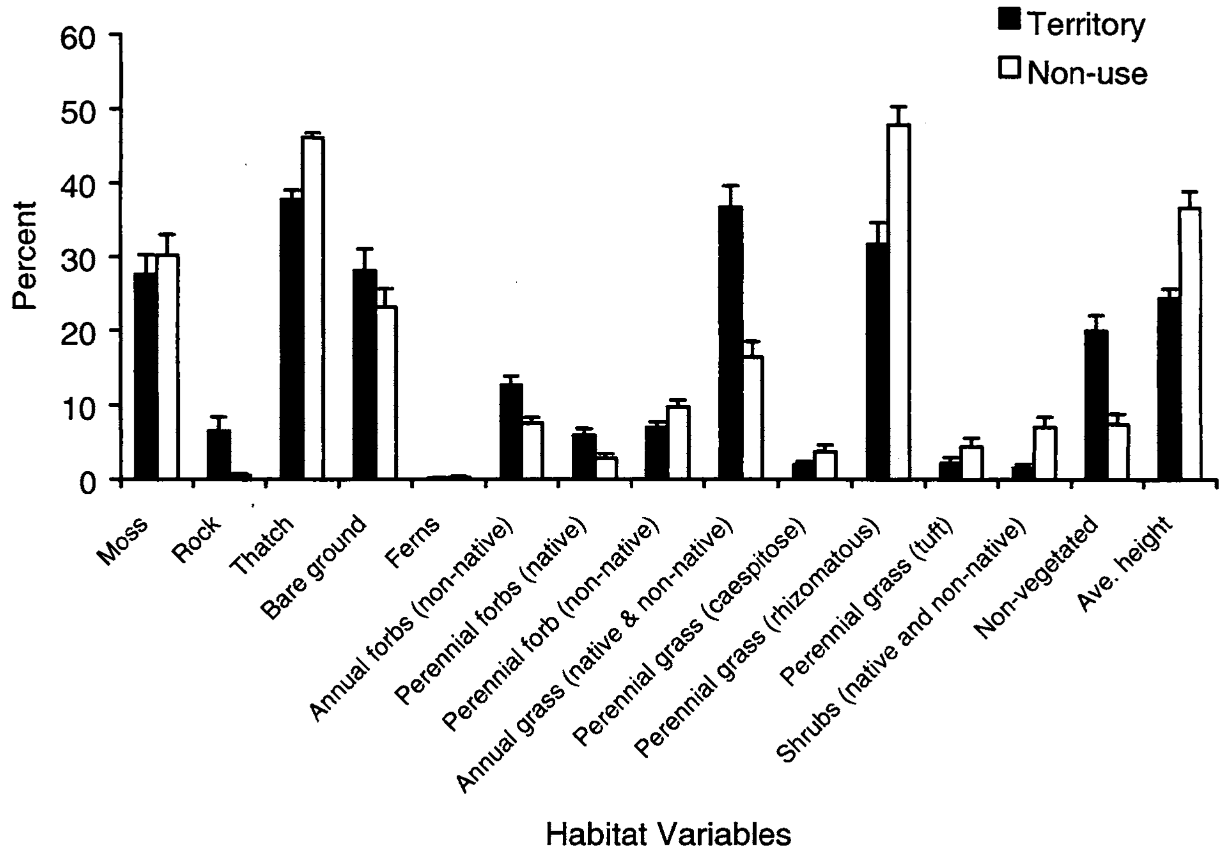

Figure 3. Percent cover of ground cover variables (percent of the total ground intercepts per territory or non-use site), vegetation variables (percent of total vegetation intercepts per territory or non-use site), percent non-vegetated (percent of total points sampled per territory or non-use site) and average vegetation height (cm) for Streaked Horned Lark territories and non-use areas located within adjacent grasslands.

Table 5. Results of the multivariate logistic regression comparing habitat variables associated with Streaked Horned Lark nest sites to nearby random locations. All variables were averaged per nest site and random locations (n = 57 nests and 57 random locations). The model with the smallest AIC value is presented.

Vegetation variable	Coefficient ± SE	t-ratio	P value
Perennial forb (native)	0.075 ± 0.043	1.722	0.085
Model log likelihood = -77.29			
Model Chi-square P value < 0.06			
Model McFadden's Rho-Squared = 0.02			

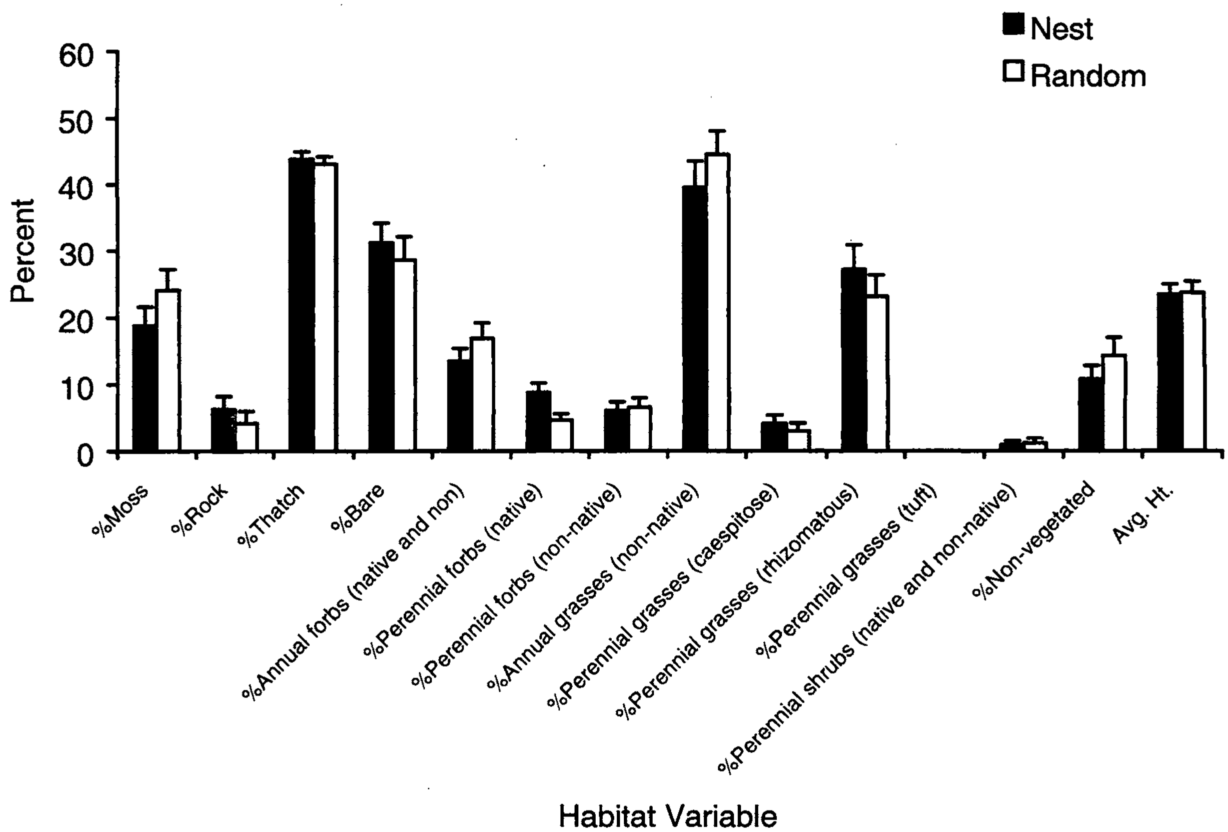

Figure 4. Percent cover of ground cover variables (percent of the total ground intercepts per nest or random site), vegetation variables (percent of total vegetation intercepts per nest or random site), percent non-vegetated (percent of total points sampled per nest or random site) and average vegetation height (cm) for Streaked Horned Lark nest sites and random sites located within adjacent grasslands.

Of the nests located, 57% were located along the northern base of a lupine. Interestingly, lupine was only found on 3% of the territory points suggesting that Larks are selecting lupines over other potential base plants. Larks appear to place their nests along the northern edge of a plant because of the shade provided (Nelson and Martin 1999, Hartman et al. 2003). Lupine may provide thermal advantages over other plant species.

<u>Human Disturbance</u>

When comparing behaviors of birds during a low helicopter flyover to bird behavior in the absence of a such an activity, I found no effect on Lark behavior ($F = 0.39$, $df = 5, 177$, $P = 0.85$). However, field biologists only witnessed 8 potential disturbance events by the military (low helicopter flights) during 182, 10-minute observations. The very small sample size makes it very difficult to draw any conclusions about the potential impacts of military activities on Lark behavior. At Gray Army Airfield, helicopters flew over the main breeding location at the north end of the airstrip near the Compass Rose almost daily. We observed the Larks during these very low (< 10m) flights and were surprised to find that the Larks rarely fled the area but instead walked or ran away from the activity and kept their body very close to the ground. At all three airports, Larks appeared to become accustomed to helicopter and airplane traffic.

At 13th Division prairie, we quantified recreational and military activities within and immediately adjacent to Lark breeding areas on 18 different days (approximately 7 hours of observation per day) throughout the breeding season. During our observations, we found recreational activities to be common and military activities to be relatively rare (Figure 5). Recreational activities were not predictable and Larks did not appear to become accustomed to the myriad of activities. Civilians regularly used the area for training and walking dogs and fore horseback riding. Civilians also regularly used the area for flying model airplanes (both rubber band and engine powered). We know of four occasions when an airplane club held events. During three of these events, there were approximately 30 vehicles parked on the dirt roads where Larks foraged and nested, planes were being flown across the prairie, and mopeds were driven across the prairie to retrieve the planes. On two occasions we observed birds fly off in response to model airplanes. The location of these events, the number of people and the amount of area disturbed by these activities likely resulted in considerable disturbance to all grassland breeding birds in the area. We also observed civilians driving across the prairie while spinning their cars in circles. This activity was extremely destructive to the prairie vegetation. Human activities appear to have negative effects on grassland birds throughout the world. Van der Zande et al. (1980) and Reijnen et al. (1996) found depressed densities of grassland birds adjacent to roadways in the Netherlands, with disturbance impacts increasing with traffic volume and noise levels. In Colorado, Miller et al. (1998) examined the influence of recreational trails on breeding bird communities and found that bird species composition was altered adjacent to trails, birds were less likely to nest near trails, and nest predation near trails was greater.

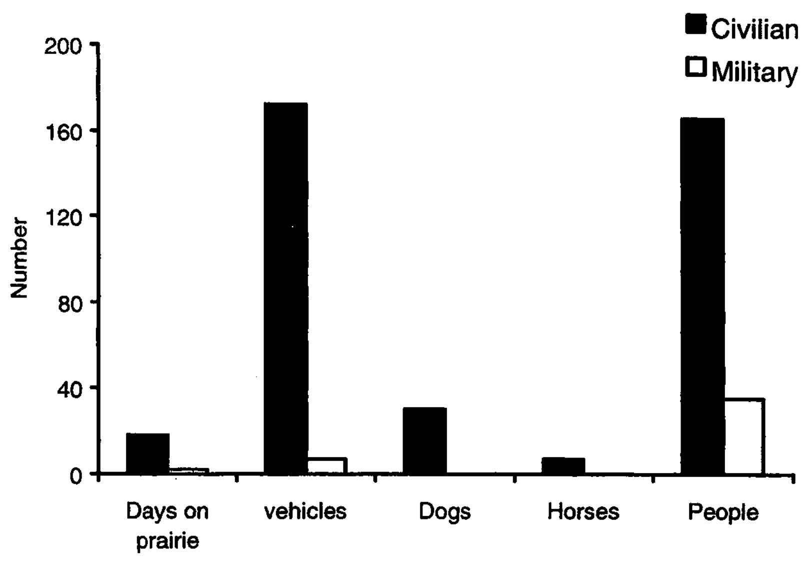

Figure 5. Counts of vehicles, dogs, horses, people and days on 13th Division Prairie by the military and civilians.

Military training also occurred during our visits to 13th prairie when we were not quantifying human activities. Training activities that we observed included large gatherings of troops on Pacemaker Field, striker, humvee and other vehicle activity (mostly confined to the roads), low elevation helicopter flights that including picking up and dropping concrete blocks, troop movement across the prairie on foot, etc. It is unclear what affect these activities had on Lark behavior. However, any activity in the vicinity of active nests has the potential to directly damage or destroy eggs or nestlings.

Survey Protocol

Below I examine the effect of point count duration, song playbacks, and observers on Lark detection rate. I also provide an estimate of Streaked Horned Lark detection distance. This information is critical to the development of a reliable survey protocol.

Point counts.-- A 6 minute counting period resulted in more detections than a 3 minute period ($t = 1.97$, $df = 168$, $P < 0.001$; Figure 6) and with a higher percentage of the point counts resulting in the detection of at least one Lark (3 minute = 49% with at least one detection, 6 minute = 64% with at least one detection) indicating that a 6 minute period is more effective. It is important to note that all transects and point counts were placed in areas where Larks were known to occur and at least one Lark was detected at every point count and transect.

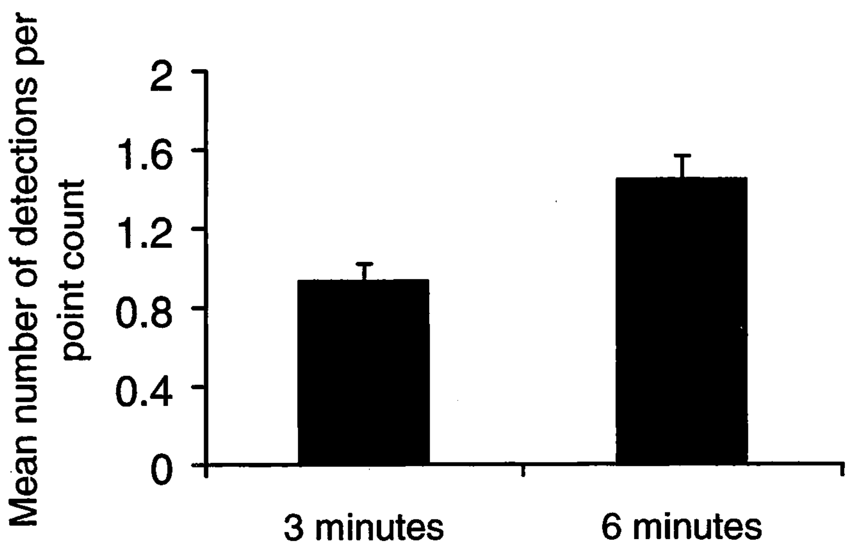

Figure 6. On average, more Streaked Horned Larks were detected during a 6-minute counting interval than a 3-minute interval.

I found no difference in the number of Horned Lark detections between detection periods with and without a taped song recording ($t = 1.99$, $df = 81$, $P = 0.86$; Fig. 7) suggesting that playbacks do not increase the number of Lark detections.

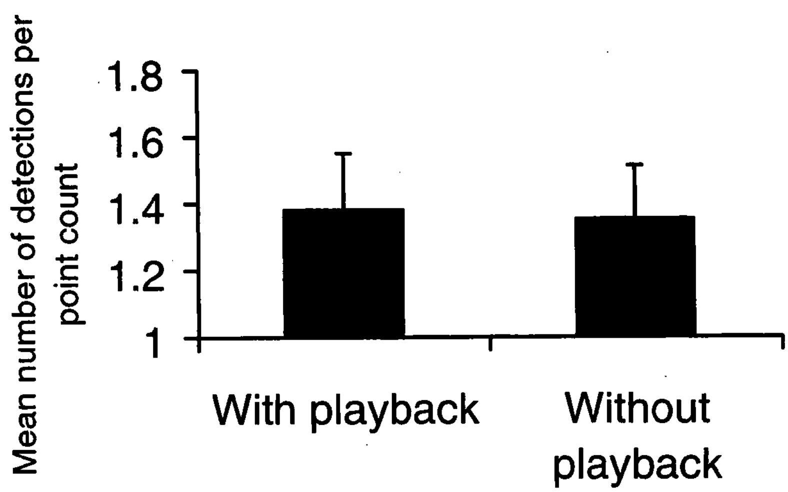

Figure 7. The playing of a tape-recorded Streaked Horned Lark song did not improve the average number of detections per point count.

In paired comparisons of the number of detections recorded by observers standing at the same point count station at the same time, I found no difference between observers ($t = 2.20$, $df = 11$, $P = 0.24$). I found 83% agreement between observers in ability to detect presence/absence of Horned Larks. This result indicates that the method is repeatable and that field biologists with good bird identification skills can use it reliably.

Transects.--In paired comparisons of the number of detections of Larks by observers along the same transect while walking side-by-side, I found no difference between observers ($t = 2.23$, $df = 10$, $P = 0.14$). I found 100% agreement between observers in ability to detect presence/absence of Horned Larks. This result indicates that the method is repeatable and that field biologists with good bird identification skills can use it reliably.

Detection distance.-- Detection distance is the distance over which an observer can effectively detect (hear or see) a given bird and is critical for determining how far apart transects should be or how large to make a point count radius. To determine detection distances for Horned Larks, I used the transect distance information and plotted the number of detections vs. distance from the observer to the detected birds (Figure 8). Number of detections should increase with increasing distance. However, there becomes a point beyond which an observer has difficulty seeing or hearing birds and, at this point, the number of detections declines. For Larks, the number of detections decreases between 61 and 80m, suggesting a maximum detection distance of approximately 70m. The very low detection rate within 20m suggests that Larks avoid observers within 20 m.

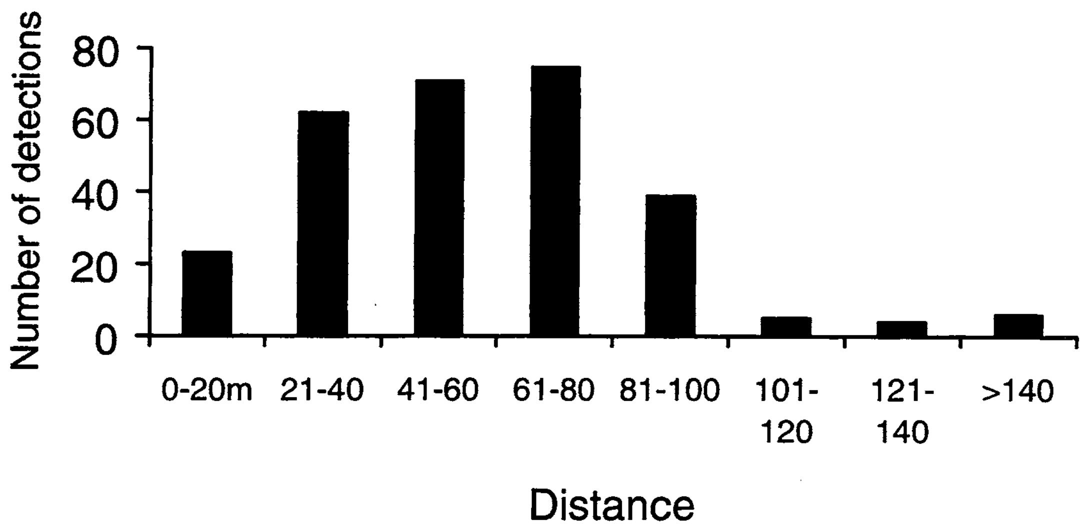

Figure 8. The number of Streaked Horned Larks detected decreased beyond the 61-80 m interval.

Comparing point counts and transects.-- Evaluating bird sampling techniques has been the focus of many recent studies (Bart and Earnst 2002, Thompson 2002, Thompson et al. 2002, Rosenstock et al. 2002). The goal of this study is not to provide a comprehensive evaluation of survey techniques but to evaluate the effectiveness of two commonly used techniques for detecting the presence/absence of Streaked Horned Larks.

On average, observers were more likely to detect Streaked Horned Lark presence during a single transect visit (79%; Figure 9) than during a single point count visit (64%; Figure 9). The amount of area covered by a 200m x 150m transect is larger (30,000m^2) than the area covered by a 75m radius point count (17,662.5m^2). In addition, the amount of time required to conduct a 200m x 150m transect is considerably greater (30 minutes vs. 6 minutes). However, to achieve the same detection reliability with point counts as occurs with transects requires conducting two point counts (12 minutes) plus the time spent walking the minimum distance between points of 200 m (this distance accounts for point count radii plus a recommended 50 m buffer between point count circles).

The three airport research sites support a higher density of Larks than that found at 13th Division Prairie. At low densities, detecting presence/absence can be difficult and requires more surveys and more visits. Consequently, I compared the relative percent of transects and point counts with detections at the 13th Division Prairie (Figure 10). At 13th Division Prairie, 16% of the point counts and 48% of the transects detected at least one Lark. This result suggests that it would take three point counts to achieve the same number of detections as occurred with transects. In this case, the additional point counts required to achieve the same level of reliability as transects would more than offset any efficiencies gained. I believe that the density and distribution of birds found at 13th Division Prairie is more representative of the types of grasslands and the Lark abundance/distribution that field biologists are likely to experience in the Puget lowlands.

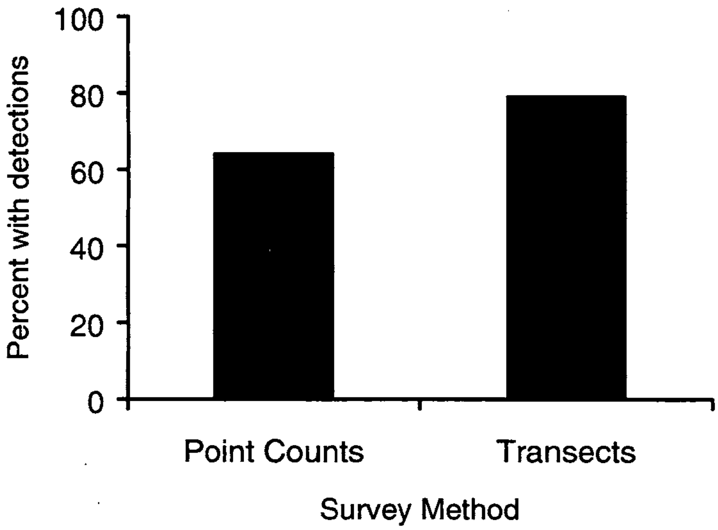

Figure 9. Percent of transects and point counts that detected the presence of at least one Streaked Horned Lark.

Streaked Horned Lark populations are aggregated or clumped in their distribution (Bowles 1900, Dawson and Bowles 1909, Rogers 2000, this study). When populations are aggregated, rectangular sampling units yield more precise estimates of abundance or density than square or circular sampling units of the same size. This is true because rectangular sampling units are more likely to include some portion of the clumped population, thereby reducing the number of zero counts and reducing the number of very high counts. Consequently, the rectangular shape of transects should provide more precise estimates of Horned Lark abundance and fewer zero detections than circular point counts.

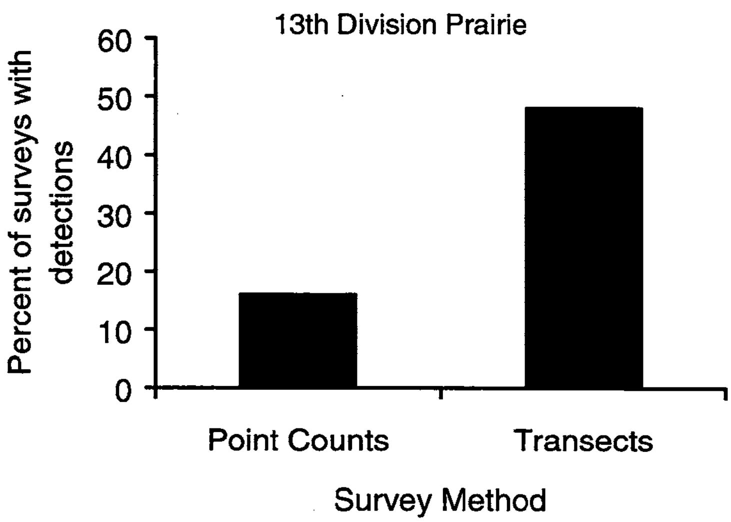

Figure 10. Percent of transects and point counts that detected the presence of at least one Streaked Horned Lark at 13th Division Prairie

MANAGEMENT RECOMMENDATIONS

Timing of Activities

Streaked Horned Larks are actively establishing territories and breeding from early March until early August. Consequently, human activities that are likely to disrupt Lark breeding should be minimized during this time period in areas being used by breeding Larks. The following activities appear to influence Lark behavior by causing them to become alert or fly or the activities directly destroy nests: mowing, vehicle traffic (including ORVs), model airplane flying, dog walking, and gatherings of people and/or vehicles. If possible, the timing or location of these activities should be adjusted to avoid areas of Lark use, especially during the breeding season.

Nesting Success

Nesting success was extremely low at 13th Division prairie and relatively low on all study sites. Altman (1999) reported 14% nesting success for Streaked Horned Larks in the Willamette Valley in Oregon; a number of these nests were associated with roads and sources of nest failure included predation, human disturbance and abandonment. It is difficult to determine why a female abandons her nest (human or predator activity, physiological condition, weather, or death). We can however, attempt to limit the potential human sources of failure and abandonment as described above. Because predation was the primary source of nest failure, I recommend efforts to identify the primary nest predators. Additional information on habitat variables associated with successful and depredated nest may help identify habitat features associated with successful nesting.

Habitat Management

On the sites studied, Streaked Horned Larks selected habitats that were sparsely vegetated by relatively short annual grasses, with a relatively high percent of bare ground (particularly associated with dirt, gravel and cobbles) and avoided areas dominated by shrubs, perennial bunch grasses (caespitose), sod forming perennial grasses (rhizomatous), and non-native perennial forbs (this study, Altman 1999). Consequently, efforts to remove non-native and invasive shrubs such as Scotch broom (*Cytisus scoparius*) and sod forming perennial grasses such as *Agrostis spp.* are recommended. Other specific recommendations for improving habitat conditions associated with territories include: maintaining relatively short grasses and forbs [0-6 inches (Altman 1999); 7.9-10.4 inches (95% confidence interval from this study)] and a relatively high percent of bare ground [17% (Altman 1999); 7-15% (95% confidence interval from this study)]. This study did not reveal differences between habitat variables associated with nest sites and that associated with territories. Altman (1999) recommended a higher percent cover of bare ground (31%) for Streaked Horned Lark nest sites. For foraging, Larks select sites with low vegetation (mean = 4.2 inches), and with low vegetation density (Rogers 2000).

Today, Larks are found on accreted soils along the coast and Columbia River, dredge spoils, gravel or dirt roads adjacent to grasslands (natural or human created) or agriculture fields, recently planted Christmas tree farms with bare soils, wetland mudflats, and airports (Altman 1999, Rogers 2000, this study). It is unclear what habitat conditions were historically selected by Streaked Horned Larks in the Puget lowlands because they no longer occupy high quality native prairie sites. However, three factors may have worked either independently or in concert to create appropriate habitat conditions. Short, sparsely vegetated conditions may have existed in areas (1) burned frequently, (2) with an A soil horizon that is extremely high in gravels and cobble content, and (3) with a poorly developed A horizon. Typically, Spanaway soils have a well developed A horizon (Pringle 1990). However, the amount of gravel in the upper soil layer varies dramatically across the Puget prairie landscape (pers. obs.). Areas that are extremely gravelly/cobblely do exist on the landscape and are likely to have a higher component of bare ground. Plants growing under such harsh conditions are likely to be less vigorous. Poor plant growth would, in turn, result in a less well developed A soil horizon. Very frequent fire intervals could also create areas that are sparsely vegetated. Frequent intervals would prevent the accumulation of thatch and if the fire burns hot, it can volatilize soil nutrients leading to poor plant vigor. A frequent fire interval seems plausible given what is currently know about historic fire frequency. Areas subject to frequent fires were likely dominated by native Roemer's fescue (*Festuca roemeri*) and forbs with plenty of open space between plants. Consequently, I recommend focusing Lark restoration activities on degraded prairies that contain high gravel/cobble content in the upper soil horizon and that can be burned frequently. I don't recommend conducting restoration activities for the Lark in areas where such activities are likely to negatively influence high quality native prairies; high quality native prairies are extremely rare. If attempts are made to increase the amount of gravels/cobbles in restoration areas, I recommend the use of native Spanaway gravels and cobbles over other materials such as crushed asphalt or concrete. Other materials may increase ground temperature (darker materials) or may make walking and running difficult (highly angled materials). In the Puget lowlands, I recommend that restoration activities focus on large open prairies (100s of acres in size). Although this species has not been found to be area sensitive, it is not currently found on very small grassland remnants. Finally, I recommend that restoration activities be treated as experiments so that the effectiveness of treatments can be evaluated.

<u>Human Disturbance</u>
I recommend that Ft. Lewis attempt to reduce the amount of recreational and military activity in the areas occupied by breeding Larks. In particular, I recommend that the Fort prohibit model airplane flying, dog walking and vehicle traffic in the area occupied by breeding Larks at 13th Division Prairie. Pedestrians can have a number of negative effects on breeding bird communities (Fernandez-Juricic 2000, Lafferty 2001, Thomas et al. 2003) and these negative effects are increased if pedestrians bring dogs (Thomas et al. 2003).

If land managers are interested in a more comprehensive evaluation of the effects of human disturbances on Lark behavior, then I recommend an experimental approach that would quantify Lark behavior before and after a potential disturbance event.

Surveys

- I recommend the use of transects over point counts because they resulted in higher repeatability among observers, they result in fewer non-detections, and because they provide more precise estimates of Streaked Horned Lark abundance or density.
- To obtain estimates of Streaked Horned Lark abundance or density, I strongly recommend the use of distance sampling methods (Burnham et al. 1980, Buckland et al. 1993). Distance sampling is an integrated approach that includes study design, data collection, and statistical analysis that avoids many pitfalls of index counts. Distance sampling provides direct estimates of bird density that are not confounded by detectability.
- Playbacks do not increase the number of detections and therefore should not be used.
- Individuals conducting surveys should walk transects slowly (approx. 20-30 min per 200 m transect) and they should record all birds within 70 m of the transect. In appropriate habitat, transects should be placed 150 m apart.
- I recommend recording location of the transects (GPS locations are preferred) and assigning a unique identifier to each transect. In addition, I recommend recording the azimuth of the transect, and the azimuth and distance to each bird detected by an observer walking the transect.
- Surveys should only be conducted by individuals with good bird identification skills (sight and sound) and by individuals that can identify Horned Larks. When looking for Larks, it is important to search the ground, perches and the air; Larks often sing and call from perches but will also sing during flight displays and from the ground (pers. obs.).
- I did not examine potential effects of time of day on Lark detection rate. However, most passerines are very active within the first few hours of dawn and then activity declines. Consequently, I recommend that surveys be conducted within 4 hours of dawn.
- If Larks are spotted, surveyors should describe plumage characteristics (extent of yellow on breast and flanks, extent of reddish brown on nape and back, presence or absence of flank streaks, and amount of yellow/white surrounding the black face patch). I noted the alpine subspecies (*E. a. alpina*) on the prairies during migration and early pairing. Consequently, recording information on plumage characteristics is critical information for separating these two subspecies.
- Based on a less than 50% detection rate at 13th Division prairie, I recommend at least three visits in a season to determine presence/absence. The three surveys should be evenly spaced across the primary breeding season (mid-April to early July).
- Finally, the following habitat types should be surveyed for Larks within the historic breeding range of the Streaked Horned Lark: accreted soils along the coast and Columbia River, dredge spoil deposits, gravel or dirt roads adjacent to grasslands (natural or human created) or agriculture fields that are sparsely vegetated, planted Christmas tree farms with bare soils and recently planted trees, wetland mudflats, and airports. For a detailed description of the historic breeding

range see Rogers (2000). Forested and shrubby habitats (> 25% shrub/tree cover) do not need to be surveyed.

Scope and limitations

There are several limitations to my study that should be considered before applying these results to management prescriptions, and that highlight the need for additional research:

- I describe breeding phenology, nesting success and habitat selection for one breeding season. There is likely to be temporal variation in all of these variables. Consequently, the results described may or may not be typical and additional years of study are required to document the temporal variability.
- This study was not an inventory. No effort was made to inventory all of the birds on the research sites. Instead we focused on areas within the research sites where most of the birds were located. I feel fairly confident that we accounted for all of the birds in the immediate vicinity of Pacemaker airstrip on the 13th Division prairie and nearly all if not all of the birds at the Olympia Airport. I observed territorial males and associated females along the runways at both McChord and Gray Army Airfield that we did not monitor and are not included in the maps in Appendix I. A comprehensive inventory is required before we can determine population boundaries.
- Comparing reproductive success among locations or developing a model that identifies habitat features associated with successful breeding requires locating at least 70 nests (Hensler & Nichols 1981, Nur et al. 1999) indicating the need for nest outcome and habitat information from additional nests.
- This work describes habitat features for four Puget Sound sites and the habitat variables associated with these sites are likely to differ from those associated with populations along the coast or on islands in the Columbia River. I recommend habitat and reproductive success research on coastal and island populations.

UNEXPECTED, POSITIVE OUTCOMES

- I delivered dead nestlings, unhatched eggs, and one adult bird found dead to the Burke Museum in Seattle because I knew that Sergei Drovetski, Sievert Rohwer, and Bob Zink were developing a phylogeny of Holarctic Larks. The results of genetic analysis show that the seven Streaked Horned Lark samples contained the same haplotype even though they came from multiple nests. This haplotype differed significantly from the subspecies breeding in eastern Washington (*E. a. merrilli*) and the subspecies that breeds in the alpine areas of Washington (*E. a. alpina*). The haplotype data indicate that the closest relative to the Streaked Horned Lark is one of the California subspecies (*E. a. rubea*). This result is interesting because there were no significant genetic differences between other subspecies that are very different from each other in size and coloration (e.g. *E. a. merrilli* and *E. a. alpina*). In short, this genetic analysis reveals that the

Streaked Horned Lark is genetically distinct and we will be submitting a short note to a journal shortly that presents this result.

- Gray Army Airfield modified their mowing regimes to avoid disturbing or destroy nests.
- Ft. Lewis did not renew a permit that allowed a model airplane club to use the area where Larks breed on 13th Division Prairie. This group sponsored at least three gatherings last year that resulted in 30 vehicles parked on the roads where the Larks breed and forage, mopeds and mini-bikes driving across the prairie where Larks forage and breed in order to retrieve planes and planes flying directly over Larks causing the Larks to flee. In addition, Ft. Lewis put signs on 13th Division Prairie that prohibit recreational activities near the nesting Larks.
- Information from this research is helping to minimize potential impacts of Airport development on breeding Larks at the Olympia Airport.

ACKNOWLEDGMENTS

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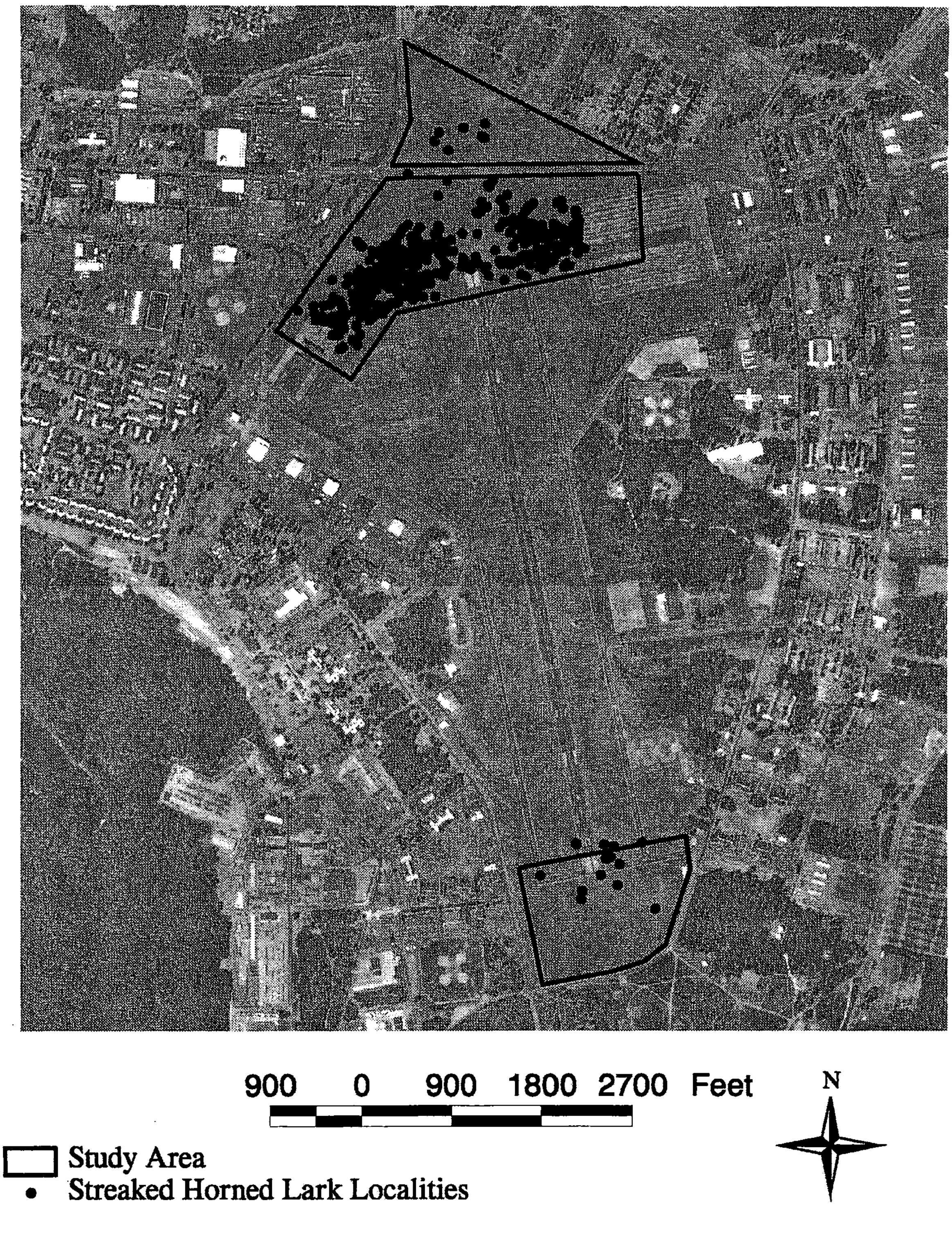
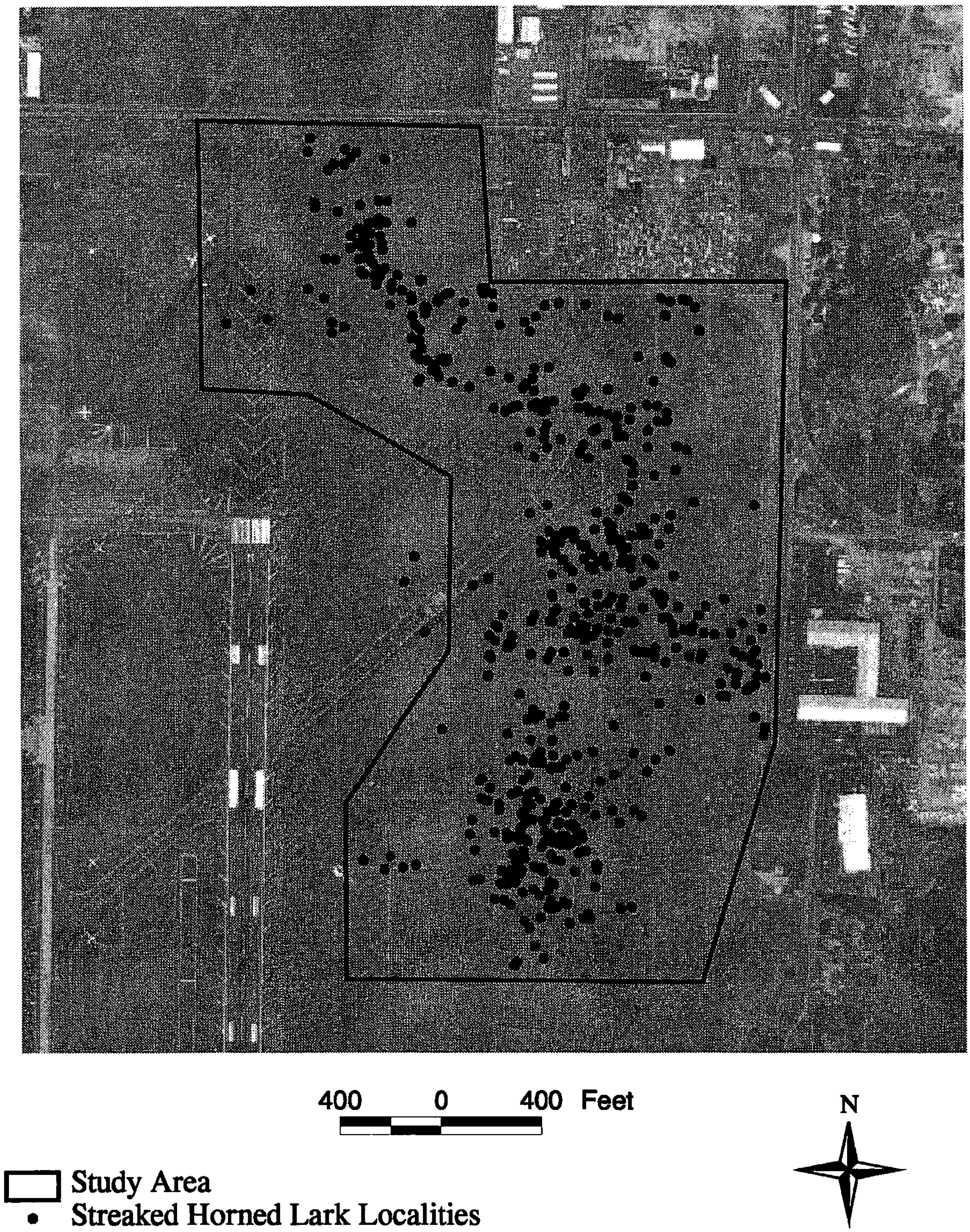
APPENDIX I

The following four figures identify Streaked Horned Lark research sites and bird locations. Bird locations were mapped throughout the breeding season at each research site. Consequently, many of the localities undoubtedly represent the same birds detected numerous times and should not be used to infer bird abundance or density. Birds were noted outside the research sites (delineated in black) at Gray Army Airfield and McChord Air Force Base during the breeding season and no attempt was made to map the locations of birds outside the research.

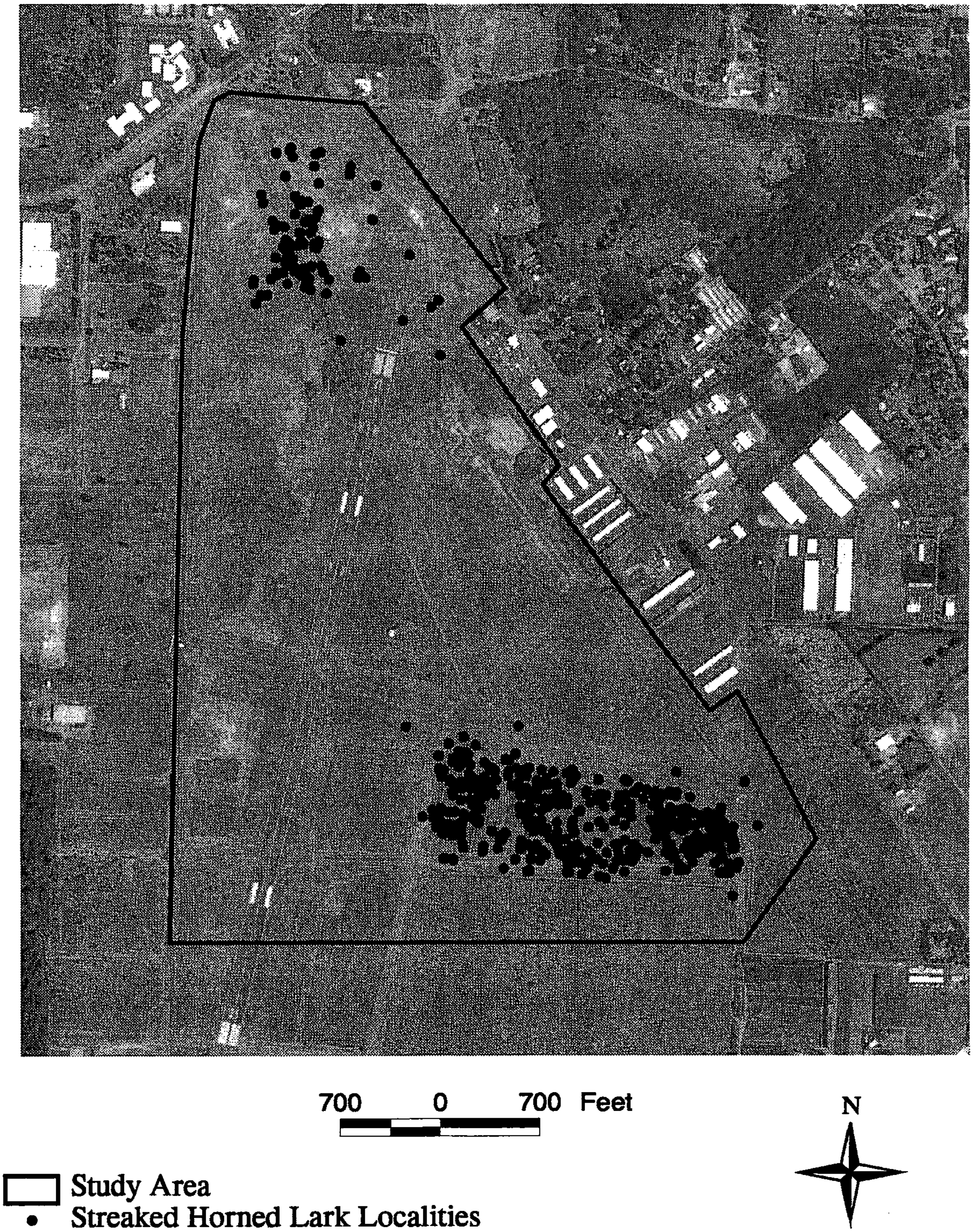
Gray Army Airfield



McChord Air Force Base



Olympia Airport



13th Division Prairie