

**Streaked Horned Lark Nest Success, Habitat Selection, and
Habitat Enhancement Experiments for the Puget Lowlands,
Coastal Washington and Columbia River Islands**

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SUMMARY

The Streaked Horned Lark (*Eremophila alpestris strigata*) is a recognized subspecies of the Horned Lark (American Ornithologists' Union 1957) and is a federal and state candidate for listing under the state and federal Endangered Species Acts. Identifying the habitat features important to successful breeding, understanding the factors that influence reproductive success and identifying methods for enhancing habitat are critical steps to recovering rare species. Consequently, the objectives of this research are:

- 1) Describe breeding phenology and clutch size for birds in the Puget Lowlands, Coastal Washington and Columbia Islands
- 2) Map locations of all larks during breeding censuses at Damon Point, Midway Beach, Whites Island, Gray Army Airfield, 13th Division Prairie, and McChord Air Force Base.
- 3) Assess reproductive success of all horned larks at Damon Point, Midway Beach, Whites Island, Gray Army Airfield, 13th Division Prairie, and birds within a selected study area at McChord Air Force Base.
- 4) Survey all known and potential breeding locations along the Washington coast and Columbia River islands for breeding larks.
- 5) Identify habitat features important to breeding at the nest site and territory scales at Damon Point, Midway Beach, and Whites Island.
- 6) Compare habitat variables associated with breeding at coastal/island sites with Puget lowland sites.
- 7) Assess the effects of the herbicide Poast Plus[®] on lark breeding habitat and lark abundance.
- 8) Assess the effects of prescribed fire on lark post-fledgling and breeding habitat and lark abundance.

Field work was conducted on Puget lowland breeding sites during the 2002, 2003 and 2004 seasons, and on coastal Washington and Columbia River island breeding sites during the 2004 field season. In 2004, nest building activity was first observed at Puget lowland sites May 5th and at coastal sites April 30th. Breeding activity completed July 30th and August 12th respectively. Combining clutch size data from 2002, 2003 and 2004 we observed clutch size to range from 1 to 5 eggs ($n = 107$ clutches) with a mode of 3 and a mean of 3.03 ± 0.07 (SE).

On six study sites, combined nest success was 32% in 2004. Nesting success was 33% on the coast and Columbia River sites and was 28% on the three Puget lowland sites. Nest success was 28% in 2002 and 21% in 2003 on the Puget lowland sites.

Predation was the primary (70%) source of nest failure at Puget lowland sites in 2004 for the previous two years. Predation and nest abandonment contributed equally to nest failures (46%) on coastal and river sites.

Territorial Streaked Horned Larks selected habitats that were sparsely vegetated by relatively short annual grasses and with a relatively high percent of bare ground (particularly associated with gravel, cobbles, or sand on the coast), and avoided areas dominated by shrubs and perennial grasses.

We examined the effects of the herbicide Poast Plus[®] on grassland habitat at Gray Army Airfield. Poast Plus[®] is a grass specific herbicide that apparently kills non-native pasture grasses but does not kill the native bunch grass (*Festuca roemerii*) or sedge (*Carex inops*). Applying the herbicide to areas with a high cover of non-native grasses should result in a more sparsely vegetated habitat preferred by larks. The 2003 herbicide application occurred late in the season and there were no changes to lark abundance or vegetation. The 2004 herbicide application occurred earlier in the season and, if funding is available, we will measure bird and vegetation response in 2005.

Lark abundance increased and vegetation changed dramatically in response to September experimental burns on 13th Division Prairie, Ft. Lewis. If funding is available, we will measure vegetation and breeding bird response to burn treatments in 2005.

Specific management recommendations include:

- Human activities that are likely to disrupt Lark breeding should be minimized in areas being used by breeding Larks from late March until early August.
- Streaked Horned Lark habitat restoration should focus on creating habitats consisting of sparsely vegetated areas composed of short annual grasses and with a relatively high percent of bare ground (particularly associated with gravel, cobble, and sand). Specifically, managers should maintain relatively short grasses and forbs [0-6 inches (Altman 1999); 3.9 – 13.3 inches (95% confidence interval from this study)] and a relatively high percent of bare ground [17% (Altman 1999); 16% (mean from this study)]. 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).
- In the Puget lowlands, we recommend that habitat restoration activities for the lark focus on large open grasslands (100s of acres in size) and away from suburban and forested edges.
- We recommend that restoration activities be treated as experiments so that the effectiveness of treatments can be evaluated.
- Streaked Horned Larks are not found in portions of grasslands with > 15 % scotch broom cover and efforts should be focused on reducing the percent cover of scotch broom. Larks also appear to avoid areas where broom has been mowed resulting in a dense cover of short shrubs.

- The colonization of Puget prairies by rhizomatous grasses (turf forming grasses) has resulted in densely vegetated grasslands. Control of these grasses should be a priority if the objective is to create native grasslands that might support Streaked Horned Larks.
- To maintain and deepen the Columbia River shipping channel, the Army Corps of Engineers deposits dredge spoils on many of the islands used by breeding larks. The timing, location and the amount of deposited materials can have dramatic impacts on the lark. To benefit the larks, we recommend that spoils not be deposited on active territories and nesting sites. To avoid disturbing breeding larks, we recommend that spoils not be deposited immediately adjacent to active territories during the breeding season. Maintaining an adequate amount of habitat in appropriate successional stages is critical to maintaining Columbia River lark populations which can be achieved by coordinating the timing and spatial distribution of spoils. Dredge spoils can be used to convert unsuitable habitats into suitable habitats. For example, if spoils are colonized by Scotch broom or equisetum (habitats not used by larks) they can be converted to appropriate habitats by depositing additional spoils.
- To minimize the negative impacts of mowing on larks, we recommend that mowing occur during non-peak breeding times: before breeding starts in mid-April, the first week of June, and at the end of the breeding season (late July). We also recommend that mowing very low before and after the breeding season and higher (6-8 inches or higher) during the breeding season.
- Predator numbers (especially corvids) increase in response to increased food supplies. We recommend that all human sources of food in proximity to breeding locations be eliminated including uncovered garbage and littered food scraps. We recommend posting signs that encouraging people to properly dispose food waste, and to not feed wild animals near restaurants and high-use areas near breeding areas.
- We recommend that most human activities within 30 m of breeding larks be limited.

Positive outcomes and management activities:

- Gray Army Airfield again modified their mowing regimes to avoid disturbing or destroy nests.
- Ft. Lewis limited recreational and military uses of the area where Larks breed on 13th Division Prairie including the exclusion of motorized model airplanes, horses, dog training and private vehicles. In addition, Ft. Lewis put signs on 13th Division Prairie that prohibit recreational activities during much of the breeding season.
- Ft. Lewis in cooperation with The Nature Conservancy continued to control Scotch broom at 13th Division Prairie.
- Ft. Lewis continues to control Scotch broom on other prairies, which may increase the amount of suitable habitat in the long-term.

New Findings:

- Completed the first comprehensive inventory of breeding larks on the lower Columbia River resulting in the discovery of additional breeding locations and more breeding birds than recorded previously.
- First assessment of lark reproductive success for the Washington coast sites and lower Columbia River site.
- First comparison of reproductive success between the Puget lowland populations and coastal/island populations.
- Developed a habitat selection model using both Puget lowland and coastal/island sites.
- Evidence that late summer fire creates habitat conditions selected by post-breeding adult and hatch-year larks.

INTRODUCTION

The Streaked Horned Lark (*Eremophila alpestris strigata*) is a recognized subspecies of the Horned Lark (AOU 1957). In British Columbia and Washington, the historic breeding range of the Streaked Horned Lark extended from the Georgia Basin in southern British Columbia (Campbell et al. 1997) south through the Puget lowlands to just south of Olympia. Along the outer coast of Washington it extended from Grays Harbor to the Columbia River and in Oregon its range extended from the Columbia River south through the Willamette Valley with a disjunct population in the Rogue River Valley (Gilligan et al. 1994, Gabrielson and Jewett 1940, Jewett et al. 1953). 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).

The Streaked Horned Lark was historically described as a common breeder in the glacial outwash or Puget prairies of the south Puget lowlands (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 lowlands 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).

This Streaked Horned Lark is apparently extirpated from British Columbia, the northern Puget lowlands of Washington and the Rogue Valley in Oregon (Rogers 2000, Altman 1999). Currently, there are only six known Streaked Horned Lark populations in the southern Puget lowlands and four of these are associated with airports (Rogers 1999 & 2000, MacLaren and Cummins 2000, Pearson 2003, Pearson and Hopey 2004, this study).

Because there are few populations of this subspecies and because larks have disappeared from several historic breeding locations, 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 2005 we conducted research and collected breeding phenology data on this subspecies at three research sites in the Puget lowlands, two sites

on the outer coast of Washington and one site on a Columbia River island. In addition, we surveyed a number of locations for breeding larks along the outer Washington coast and on Columbia River islands. The specific objectives of this research were:

- 1) Describe breeding phenology and clutch size for birds in the Puget Lowlands, Coastal Washington and Columbia River islands.
- 2) Map locations of all larks during breeding censuses at Damon Point, Midway Beach, Whites Island, Gray Army Airfield, 13th Division Prairie, and McChord Air Force Base.
- 3) Assess reproductive success at Damon Point, Midway Beach, Whites Island, Gray Army Airfield, 13th Division Prairie, and birds within a selected study area at McChord Air Force Base.
- 4) Survey all known and potential breeding locations along the Washington coast and Columbia River islands for breeding larks.
- 5) Identify habitat features important to breeding at the nest site and territory scales at Damon Point, Midway Beach, and Whites Island.
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- 7) Assess the effects of the herbicide Poast Plus[®] on lark breeding habitat and lark abundance.
- 8) Assess the effects of prescribed fire on lark post-fledgling habitat, breeding habitat and lark abundance.

METHODS

Research Sites

In 2002, fieldwork was conducted from late February to mid-August, in four Puget lowland 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), and (4) McChord Air Force Base (47° 12' N 122° 45' W). In 2003, fieldwork was conducted from early April to mid-August on 13th Division Prairie and Gray Army Airfield. From March to mid-August 2004, we mapped territories and assessed reproductive success at three Puget lowland sites (Gray Army Airfield, 13th Division Prairie and McChord Air Force Base), two sites on the outer coast [Midway Beach (46° 46' N, 124° 06' W) and Damon Point (46° 57' N, 124° 09' W)] and one Columbia River island site [east end of Puget Island known as Whites Island (46° 09' N, 123° 20' W)]. At Gray Army Airfield and 13th Division Prairie, all potential lark habitat was surveyed and territories were mapped. We mapped territories only on the northeast portion of McChord Air Force Base. The following sites were surveyed at least once to determine the presence of larks and to estimate numbers of breeding birds: Olympia Airport, the entire McChord airfield, and Graveyard Spit (46° 03' N, 124° 01' W) and Ledbetter Point (46° 38' N, 124° 03' W) on the coast. We also surveyed five Columbia River island sites: Rice Island (46° 15' N, 123° 43' W), Miller Sands (46° 15' N, 123° 39' W), Pillar Rock Island (46° 15' N, 123° 37' W), Coffeepot Island (46° 10' N, 123° 24' W), Tenasillahe Island (46° 13' N, 123° 26' W), and West Wallace Island.

The Puget lowland sites are dominated by grasses, occur on glacial outwash soils and were formally or are currently composed of native Puget prairie species. The airport sites are mowed to keep the grasses short. These sites were selected because males and, in some cases, females were reported at all sites (Rogers 1999, 2000, MacLaren and Cummins 2000). On the outer coast, the study sites consisted of accreted lands or erosional features along sandy shorelines with sparse to dense beach grass cover. The Columbia River island sites consisted of accreted sandy soils and sites created by the deposition of dredge spoils.

Inventory

Along the coast and Columbia River, we identified potential sites to inventory by locating grassland habitat on aerial photographs, by visiting sites previously recorded as occupied (Rogers 2000) and by learning of sites from local birders and USFWS personnel. Surveys were conducted by hiking through appropriate habitat from sunrise through mid-afternoon. Birds were located visually or by detecting songs or flight displays. The duration of each survey varied depending on the amount of appropriate habitat to cover at each site. We recorded the age (adult or hatch year), sex and behaviors of each lark observed.

Territory Mapping

In 2004, locations of breeding birds were mapped on an orthographic photograph or detailed map of each research site when walking transects that covered most of the study sites. Individual birds were also mapped during relatively quick tours of the site. Along

with the location of each bird, we recorded the following information 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. All locations were entered into GIS. The information from all of the territory mapping activities was combined on 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

We 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 searching appropriate habitat. 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, construction and recreational).

Clutch Initiation Dates

Unless observed directly, we 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, we 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, we used the following formula to estimate the first date of incubation (Martin et al. 1997):

$$\text{First date of incubation} = \text{date found} - ((\text{incubation period} - \text{number of days observed}) \div 2)$$

Because one egg is laid per day, we 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 research sites and all years combined. We 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 detections). Within high use areas, we randomly located two 25 m perpendicular transects that crossed at their midpoints and that were oriented north-south and east-west. We used the point intercept method (Bonham 1989) at each meter along these axes and recorded the plant species that intercepted the rod, maximum height of the vegetation, and whether or not the rod hit bare ground, moss (on the Puget lowland sites)/algae

(coastal sites), rock/wood 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: annual forbs, perennial forbs, annual grass, perennial grass, and shrubs and small trees. Transects were also randomly located in adjacent low use areas where we used the same sampling protocol for nonuse sites as we 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. We recorded every plant hit by a vertical dowel dropped through the frame at 10 cm intervals. We 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. The same functional groupings used for territories were also used for nests. 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). We used the following strategy to develop our multivariable models. As suggested by Hosmer and Lemeshow (1989), we 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. We 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.

Habitat Enhancement Experiments

Herbicide

We experimentally examined the effects of the herbicide Poast Plus[®] on grassland habitat in 2003 and 2004. Poast Plus[®] is a grass specific herbicide that apparently kills non-native pasture grasses but does not kill the native bunch grass (*Festuca roemerii*) or sedge (*Carex inops*). Applying the herbicide to areas with a high cover of non-native grasses should result in a more sparsely vegetated habitat preferred by larks (Dinkins et al. 2003, Rogers 2000). Horned Lark densities increased in herbicide treated grassland in Maine (Vickery et al. 1999). Six treatment and control plots (50 m x 50 m) were established at Gray Army Airfield in 2003 and two additional treatment and control plots were added in

2004. Vegetation within treatments and controls were measured in May of 2003 just prior to the herbicide application in early June using the point intercept method as described for territories above. Vegetation was measured again in May of 2004 prior to a second application of herbicide in May of 2004. Birds were monitored on control and treatment plots throughout the breeding season by walking transects through the control and treatment plots.

Fire

We examined the effects of fire on lark habitat and abundance at 13th Division Prairie, Fort Lewis, WA. The use of prescribed burns in Oklahoma tallgrass prairie created a mosaic of successional habitats that increased relative abundance of Eastern Meadowlark (*Sturnella magna*) (Rohrbaugh et al. 1999) and Grasshopper Sparrow (*Ammodramus savannarum*) (Heckert 1994). Johnson and Temple (1990) noted higher probability of nesting success for Grasshopper Sparrows and Western Meadowlarks (*Sturnella neglecta*) in recently burned prairie. On 13th Division prairie, bird habitat use is focused on light-duty dirt roads in the interior portions of the prairie and adjacent to Pacemaker runway, which suggests that birds prefer appropriate habitat adjacent to roads (Pearson 2003). We established replicated treatment and control macroplots (50 x 50 m squares) along roads (n = 6 treatments and n = 6 controls) and interior prairie not adjacent to roads (n = 6 treatments and n = 6 controls) at 13th Division Prairie. Burns were conducted in early September 2004. Vegetation was measured before and after burns using the methods described for territories above. Bird abundance was measured before and after burns in the summer and autumn of 2004 by walking transects through the center of each macroplot. The initial results are presented as mean number of bird observations/visit for both control and treatment plots pre- and post-burn. Only 6 treatment plots were burned in September of 2004 and on two of the burn plots, the area burned was considerably larger than the plot size. We took advantage of these larger burns by randomly establishing three additional treatment plots within the burns and unburned controls in adjacent habitat. If funding is available, we will also measure use of treatment and control plots during the breeding season of 2005.

RESULTS & DISCUSSION

Clutch Initiation

Information about the timing of Streaked Horned Lark breeding is important for determining when certain land management activities might impact Horned Lark reproduction. Consequently, we documented Horned Lark clutch initiation dates at Puget lowland sites in 2002 and 2003 (Pearson 2003, Pearson and Hopey 2004) and coastal and Puget lowland sites in 2004.

In 2004, nest building activity was first observed at Puget lowland sites on May 5th with breeding activity completed by July 30th. These dates are similar to the dates we recorded in 2002 (April 18 and August 8th) and 2003 (April 25th and August 9th). The graph of Puget lowland clutch initiation dates (Figure 1) suggests that there are at least two periods of clutch initiation. The first period of clutch initiation begins in late April/early May and extends into late May/early June. This period appears to be followed by a period of re-nesting after failed attempts and second clutches (early June to late July). We base this description of clutch initiation periods on the relationship between nest failures and clutch initiation and on the relationship between first fledglings and apparent initiation of second nests. In the Puget lowlands, the duration of breeding activity is similar among years (Figure 1).

Adult larks were observed feeding fledglings at Columbia River island sites on May 15th, indicating that the first clutch was initiated approximately April 22nd. On Midway Beach, the final nest under observation was abandoned on August 12th.

Nesting dates reported here are similar to those reported for the Streaked Horned Lark by Bowles (1900). According to Bowles (1900), lark nesting near Tacoma begins in late April and nesting extends through the first week in July, with the height of the season about the middle of May. Data for 2004 suggest that more clutches are initiated both earlier and later in the season at coastal sites when compared to Puget lowland sites (Figure 2). In addition, there appear to be three peaks in clutch initiation at coastal and Columbia River islands sites, suggesting that individual birds may attempt to initiate three clutches while the inland birds appear to have two distinct peaks of clutch initiation. Reasons for this difference may be related to climatic differences, food availability or other reasons. Larks on the coast and Columbia River islands are found on these sites year round while larks in the Puget lowlands are mostly migratory (Pearson and Hopey unpublished). This difference in winter habitat use suggests differences in climatic conditions or food availability and may influence breeding condition.

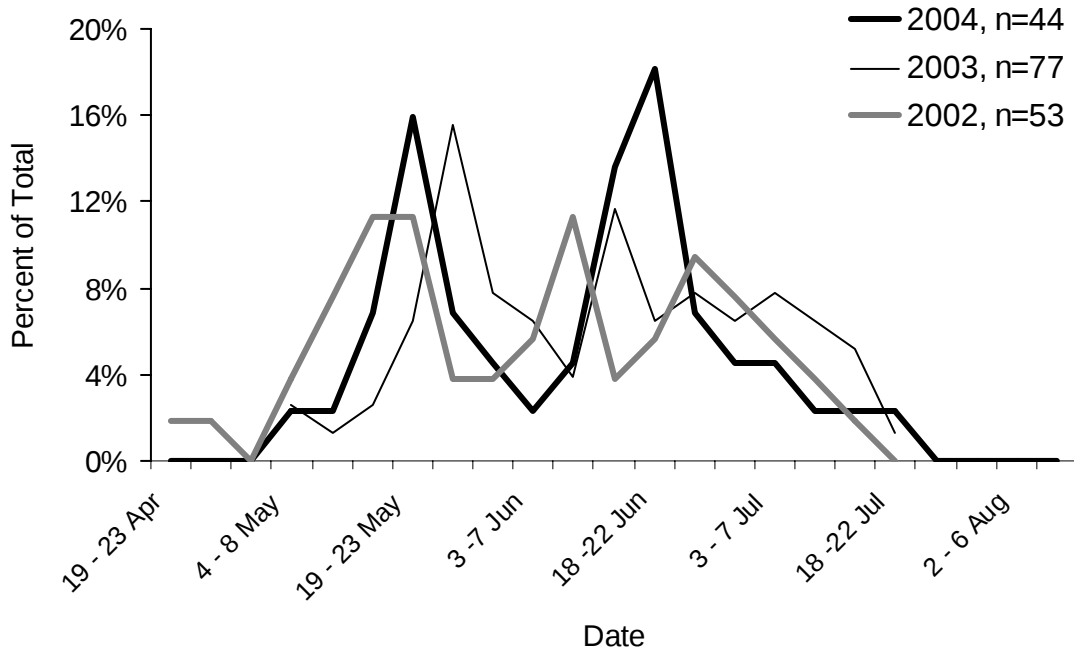


Figure 1. South Puget lowland Streaked horned lark clutch initiation dates (in five day intervals) for the 2002, 2003 and 2004 breeding seasons.

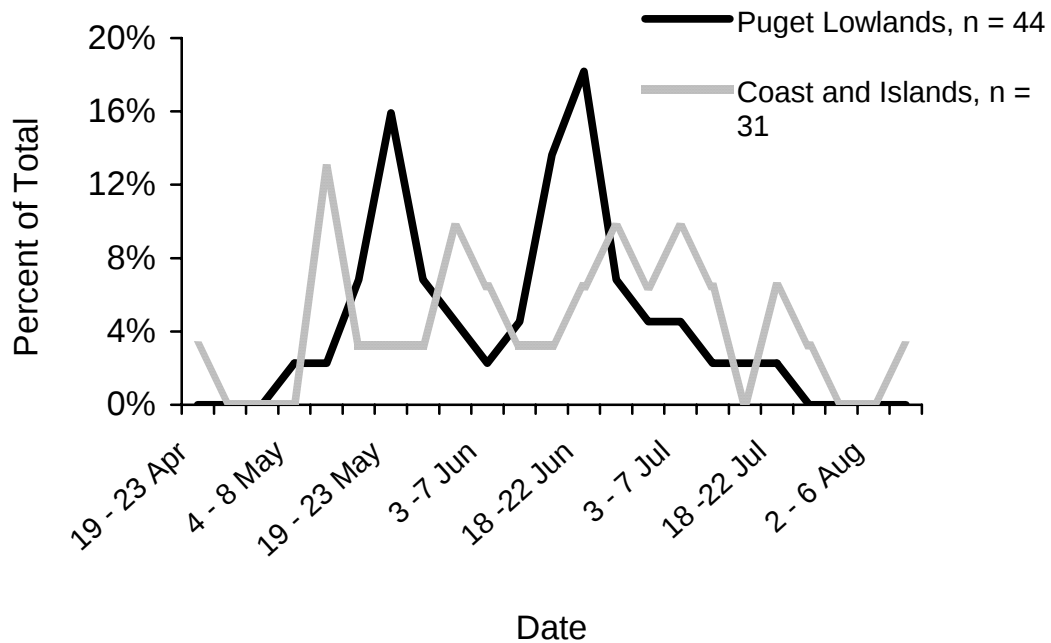


Figure 2. South Puget lowlands and Washington coast/Columbia River islands Streaked Horned Lark clutch initiation dates (in five day intervals) during the 2004 breeding season.

Clutch Size

For all seasons (2002, 2003, 2004) and all sites combined, clutch size ranged from 1 to 5 eggs ($n = 107$ clutches) with a mode of 3 and a mean of 3.03 ± 0.07 (SE) (Table 1). 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 of differences in sample size ($n = 107$ 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.

Table 1. Mean clutch size, standard error, range and number of clutches from the Puget lowlands and coastal regions of western Washington.

Location	Year	Mean	SE	Range	Number Clutches
Puget Lowlands	2004	3.35	± 0.13	2 – 4	20
Coastal	2004	3.14	± 0.23	2 – 5	14
All sites	2004	3.26	± 0.12	2 – 5	34
All sites	2003	2.89	± 0.12	1 - 4	39
All sites	2002	2.97	± 0.12	1 – 4	34
All sites	2002-04	3.03	± 0.07	1 – 5	107

Coastal Washington and Columbia River Island Inventory

In 2004, we visited five Columbia River island sites [Lark Island, Coffeepot Island, Pillar Rock Island (Jim Crow Island), Miller Sands, West Wallace Island, and Rice Island] on at least one occasion during the breeding season and counted the number of birds and estimated the number of territories at each site (Table 2).

Table 2. Estimated numbers of territories and numbers of birds from the Washington coast and lower Columbia River island sites during the 2004 breeding season.

Location	# Territories ¹	# birds ²	# visits ³	Dates visited
Graveyard Spit	3	5	2	10-Mar, 1-June
Ledbetter Point	2	2	3	13- June, 16-June, 13-July
Rice Island	8-12	15	2	13-May, 1-Jul
Miller Sands	3	7	2	13-May, 1-Jul
Pillar Rock Is. (Jim Crow Is.)	6	10	2	13-May, 1-Jul
West Wallace Is.	1	2	1	27 April
Coffeepot Island	2	4	1	12-May
Lark Island ⁴	0	0	1	12-May

¹ Number of territories based on number of singing males

² Highest total number of birds observed during a site visit

³ Visit duration varied from 1-6 hours depending on extent of habitat

⁴Lark island is our nickname for this un-named island that is located just upstream of Tenasillahe Island

Evidence of nesting was discovered at several of these sites: 1) an active nest with eggs was discovered at Miller Sands on July 1st, and 2) recent fledglings or young of the year were observed at Rice Island, Pillar Rock Island, and Graveyard Spit.

Territory Mapping

We used composite maps of the locations of agonistic behaviors, singing, flight displays and male-female interactions to delineate 110 territories on the six research sites in 2004 (Table 3). For this work, we defined a territory as the area actively defended by a single male. For all of the territories observed, it appears that each male successfully attracted at least one mate. Consequently, doubling the count of territories gives an approximate count of the number of birds at each location when the entire population at a site was observed. The entire population was observed at Olympia Airport and 13th Division Prairie in 2002 and the entire population was observed at Gray Army Airfield, and 13th Division Prairie in 2003. At McChord Air Force Base, we used the northeastern portion of the airfield for our study of breeding larks in 2002. In 2004, we continued our intensive study of breeding birds in the northeastern corner of the airfield where we delineated 15 territories. In addition, we conducted a nearly complete survey of the McChord airfield that allowed us to estimate an additional 16 territories outside our intensive study area for a total of 31 territories on the entire site.

Table 3. Estimated number of Streaked Horned Lark territories by location, in the month of June 2002 - 2004.

Location	Territories 2002	Territories 2003	Territories 2004
Gray Army Airfield	6 ^a	30	31
Olympia Airport	18	-	-
McChord AFB	13 ^a	-	31
13 th Division Prairie	8	10	18
Artillery Impact Area	-	10 ^a	-
Midway Beach	-	-	21
Damon Point	-	-	17
Puget Island	-	-	8
Total	45	50	126

^a Partial survey of territory area

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 of the three nest stages independently. In Table 4, we report Mayfield nest success estimates for the 2002-04 breeding seasons.

Table 4. Mayfield estimates of Streaked Horned Lark nest success for the 2002, 2003 and 2004 breeding seasons at four Puget Lowland sites (n = 55 active nests in 2002, n = 72 active nests in 2003, and n = 39 active nests in 2004).

Site	Egg laying			Incubation			Nestling			Overall		
	2002	2003	2004	2002	2003	2004	2002	2003	2004	2002	2003	2004
Gray	-	0.85	1.00	0.59	0.38	0.48	0.63	0.80	0.71	0.31	0.23	0.30
13 th Div.	1.00	1.00	-	0.31	0.31	0.26	0.09	1.00	1.00	0.07	0.15	0.07
Olympia	-	-	-	0.56	-	-	0.81	-	-	0.37	-	-
McChord	-	-	1.00	0.55	-	0.60	0.63	-	0.70	0.29	-	0.46
Overall	1.00	0.88	0.72	0.51	0.36	0.47	0.63	0.82	0.76	0.28	0.21	0.28

At three Puget lowland sites observed in 2004, overall nest success was 28%, the same percentage as the 2002 season and higher than the 21% observed during the 2003 breeding season (Table 4). We did not statistically compare nesting success among locations because of small sample sizes (Hensler & Nichols 1981, Nur et al. 1999). The Two coastal and one Columbia River island site studied in 2004 had a nesting success of 33% (Table 5). In all years, more nests were lost during the incubation period than the nestling and egg laying periods except 13th Division in 2002. Mayfield nesting success was lowest in 13th Division Prairie, where no young fledged in 2002, only five fledged in 2003 and 12 in 2004. Highest nesting success observed was 66% at Damon Point coastal site and a 46% at McChord AFB Puget lowland site.

Table 5. Mayfield estimates of Streaked Horned Lark nest survivorship at two coastal and one Columbia River island site for the 2004 breeding season (n = 31 nests).

Site	Egg	Incubation	Nestling	Overall
Midway	1.00	0.34	0.82	0.21
Damon	-	0.64	1.00	0.66
Whites	-	0.44	0.60	0.21
Overall	1.00	0.43	0.86	0.33

The primary source of nest failure in all sites and years was nest predation (Tables 6 and 7), which appears to be the primary source of nest failure in most North American grassland systems (Best 1978, Johnson and Temple 1990). We observed two predators depredating nests, a garter snake (*Thamnophis sp.*) eating the nestlings from one nest in 2002 and an American crow depredating one nest in 2003 (*Corvus brachyrhynchos*) and again in 2004 when an American Crow was observed depredating a flightless fledgling at Gray Army Airfield. We also suspect that a killdeer may have pecked a hole in a lark egg in 2003. The relative contribution of these two nest predators to overall lark nest predation is unknown. American Crow are more frequently observed on transects conducted at Gray Army Airfield than at any other breeding site (Pearson and Hopey unpublished).

Table 6. Streaked Horned Lark nest outcomes for three research sites in the south Puget lowlands in 2004.

Location	Nest Activity ¹	Number of Nests ²	Active Nests ³	Successful ⁴	Fledglings ⁵	Failed ⁶	Depredated	Abandoned	Human Caused Failure ⁷
Gray Army Airfield	5 May – 30 July	29	22	9	15	13	11	2	0
13 th Division Prairie	19 May – 27 July	10	7	3	10	4	1	3	0
McChord Air Force Base	13 May – 31 July	11	10	7	16	3	2	1	0
Total (%)⁸		50	39	19 (49)	41	20 (51)	14 (70)	6 (30)	0

¹ Period of time when birds were actively nesting (i.e., nest building, egg laying, incubating, and caring for nestlings)

² Total number of nests discovered

³ Of the total number of nests discovered, those that progressed at least to the egg-laying stage with known outcomes

⁴ Number of active nests that fledged at least one young

⁵ Number of young that successfully fledged from active nests

⁶ Number of active nests that failed to fledge nestlings

⁷ Mowing, construction or recreational activities

⁸ Percent of active nests that fail or are successful or the percent of the failed nests that were depredated, abandoned or lost to human activities.

Based on studies of nest predators in grassland systems (Pietz and Granfors 2000, Renfrew and Ribic 2003) other potential nest predators that are found in and around our study sites are: domestic cat (*Felis catus*) & dog (*Canis familiaris*), coyote (*Canis latrans*), northern raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), red fox (*Vulpes vulpes*), long-tailed weasel (*Mustela frenata*), Virginia opossum (*Didelphis virginiana*), black-tailed deer (*Odocoileus*), Northern Harrier (*Circus cyaneus*) and other hawks, various small mammals and song birds. Brown-headed cowbirds (*Molothrus ater*) were noted on all lark breeding sites, and fledgling cowbirds have also been observed begging food from adult streaked horned larks at river island sites. No cowbird young or eggs have been observed in the 198 lark nests located to date. Cowbirds could depredate lark nests because they have been observed depredating a nest without parasitizing the nest (Pietz and Granfors 2000).

Other sources of nest failure are abandonment, (22% at Puget lowland sites and 46% at coastal sites, Table 7) and human caused failure, including mowing, construction projects and recreational activities (8% at both Puget lowland and coastal sites, Table 7 and 8). Human activities may be responsible for some of the observed nest abandonment. Activities that prevent females from returning to their nests for extended periods of time may cause them to abandon their nest. For example, during 2004 extensive renovation of the paved areas at Gray Army Airfield occurred during the peak of breeding activity. Birds use the pavement as a display area, and most nests are located within 25 m of runways, taxiways and aircraft ramps.

Table 7. Streaked Horned Lark nest outcomes for five research sites in the south Puget lowlands for the 2002, 2003 and 2004 nesting seasons combined.

Location	Nest Activity ¹	Number of Nests ²	Active Nests ³	Successful ⁴	Fledglings ⁵	Failed ⁶	Depredated	Abandoned	Human Caused Failure ⁷
Gray Army Airfield 13th Division Prairie	4 May – 9 Aug	113	90	35	71	58	44	9	3
	17 May – 27 Jul	40	31	6	15	25	16	9	0
Artillery Impact Area Olympia Airport	24 May – 10 Jul	2	1	-	-	-	-	-	-
		23	21	9	20	12	6	2	4
McChord		27	24	13	31	11	7	3	1
Total (%)⁸		205	167	63 (37)	137	106 (63)	73 (69)	23 (22)	8 (8)

¹ Period of time when birds were actively nesting (i.e., nest building, egg laying, incubating, and caring for nestlings)

² Total number of nests discovered

³ Of the total number of nests discovered, those that progressed at least to the egg-laying stage with known outcomes

⁴ Number of active nests that fledged at least one young

⁵ Number of young that successfully fledged from active nests

⁶ Number of active nests that failed to fledge nestlings

⁷ Mowing activities

⁸ Percent of active nests that fail or are successful or the percent of the failed nests that were depredated, abandoned or lost to human activities

Table 8. Streaked Horned Lark nest outcomes for two coastal research sites and one river island research site in Washington in 2004.

Location	Nest Activity ¹	Number of Nests ²	Active Nests ³	Successful ⁴	Fledglings ⁵	Failed ⁶	Depredated	Abandoned	Human Caused Failure ⁷
Midway Beach	22 May - 21 August	16	14	5	6	9	3	5	1
Damon Point	14 May – 30 July	11	9	7	13	2	1	1	0
Puget Island (East)	22 April – 29 July	8	8	6	10	2	2	0	0
Total (%)⁸		35	31	18 (58)	29	13 (42)	6 (46)	6 (46)	1 (8)

¹ Period of time when birds were actively nesting (i.e., nest building, egg laying, incubating, and caring for nestlings)

² Total number of nests discovered

³ Of the total number of nests discovered, those that progressed at least to the egg-laying stage with known outcomes

⁴ Number of active nests that fledged at least one young

⁵ Number of young that successfully fledged from active nests

⁶ Number of active nests that failed to fledge nestlings

⁷ Recreational activities

⁸ Percent of active nests that fail or are successful or the percent of the failed nests that were depredated, abandoned or lost to human activities.

Airfield mowing caused nest failures in both 2002 and 2003. In 2002, three of the four research sites in the Puget lowlands (airfields) were actively mowed throughout all or part of the breeding season. In 2003 and 2004, Gray Army Airfield modified its mowing schedule, mowing only once during the breeding season in order to minimize impacts on larks. In 2004 at Midway Beach, recreational horse back riding was the cause of one nest being crushed during the incubation stage. Recreational activities such as dog walking, beachcombing, driving vehicles and horseback riding in lark coastal habitat may indirectly increase predation, nest abandonment and decrease overall nesting success.

Habitat Selection

We compared habitat variables within male territories to adjacent non-used grassland habitat. We also compared habitat variables associated with nest sits (within 0.5 m of a nest) and random locations within the same territory. This type of comparison is critical for identifying the habitat variables selected by breeding Horned Larks (Martin and Roper 1988).

Territory

On Puget lowland sites, larks used territories with less vegetation (more bare ground and fewer vegetated hits), more annual grasses, more rocks, less moss/lichen, fewer shrubs, and less cover of perennial grasses than occurs on adjacent non-use sites (Tables 9 & 10).

Table 9. Habitat variables associated with lark territories and adjacent non-use areas at all study sites combined and compared between Puget lowland sites and coastal sites (Washington coast and Columbia River islands). The first ten habitat variables are expressed as mean (SE) percent cover. Vegetated hits are the mean (SE) number of times the pin hit plant vegetation (multiple hits per drop were counted) at each site, non-vegetated hits are the mean (SE) number of pin drops where the pin did not touch any vascular plant vegetation on a site, and height is the mean (SE) vegetation height (cm) at each site.

Habitat variable	All Sites		Puget		Coast	
	Use (n = 116)	Non-use (n = 111)	Use (n = 86)	Non-use (n = 83)	Use (n = 30)	Non-use (n = 28)
Moss lichen	38.5 (3.5)	43.7 (3.8)	50.5 (4.0)	52.6 (4.4)	4.3 (1.6)	17.4 (4.9)
Rock/Wood	8.6 (1.6)	1.2 (0.4)	8.3 (1.8)	1.0 (0.5)	9.4 (3.1)	1.6 (0.6)
Thatch	49.0 (2.9)	74.9 (2.4)	59.3 (3.0)	84.7 (1.9)	19.4 (4.0)	46.1 (4.6)
Bare ground	29.4 (3.0)	15.7 (2.4)	15.9 (2.1)	8.3 (2.0)	68.1 (5.4)	37.5 (5.3)
Annual forb	17.4 (1.9)	16.2 (1.5)	22.4 (2.3)	20.4 (1.7)	2.8 (1.4)	3.7 (1.3)
Perennial forb	16.7 (1.3)	29.2 (2.3)	19.1 (1.4)	26.8 (2.1)	9.7 (2.2)	36.4 (6.6)
Annual grass	42.3 (3.4)	26.9 (2.9)	51.3 (4.1)	31.4 (3.6)	16.7 (3.2)	13.3 (2.8)
Perennial grass	36.2 (2.8)	76.0 (3.3)	41.1 (3.4)	81.0 (3.5)	22.2 (3.9)	61.1 (7.2)
Shrub	1.2 (0.3)	8.8 (1.7)	1.4 (0.4)	11.2 (2.2)	0.7 (0.3)	1.6 (0.8)
Unknown	3.1 (1.0)	3.1 (1.0)	0.2 (0.1)	0.1 (0.1)	11.6 (3.5)	11.8 (3.4)
Vegetated hits	71.8 (4.3)	104.5 (5.4)	85.3 (5.0)	117.4 (6.3)	33.2 (2.8)	66.5 (5.5)
Non-veg. hits	0.3 (0.0)	0.1 (0.0)	0.2 (0.0)	0.1 (0.0)	0.5 (0.0)	0.2 (0.0)
Height	18.2 (1.1)	30.0 (1.8)	20.6 (1.2)	31.1 (2.0)	11.2 (1.8)	26.9 (3.6)

On the coast and the Columbia River island site, larks used areas that were sparsely vegetated, with more wood and cover of annual grasses with less algae (indicator of areas effected by very high tides) than adjacent areas in the same habitat type (Tables 9 & 11).

The McFadden's Rho-squared, similar to r^2 , is relatively high (Tables 10 & 11) for both coast and Puget site models indicating that the models account 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, Dinkins et al. 2003).

Table 10. Results of the multivariate logistic regression comparing habitat variables associated with territories to adjacent areas rarely used by larks (n = 86 used and n = 83 sites that were not used for territories) from the Puget lowland only. All variables were averaged per territory and non-use site.

Vegetation variable	Coefficient $\pm$ SE	t-ratio	P value
Non-vegetated hits	0.19 $\pm$ 0.05	3.95	0.000
Annual grass	0.06 $\pm$ 0.01	4.65	0.000
Moss/lichen	-0.04 $\pm$ 0.01	-2.90	0.004
Rock/wood	0.27 $\pm$ 0.10	2.67	0.008
Shrub	-0.21 $\pm$ 0.08	-2.59	0.009
Vegetated hits	-0.03 $\pm$ 0.01	-2.54	0.011
Perennial grass	-0.01 $\pm$ 0.01	-1.43	0.152
Model log likelihood = -66.587			
Model Chi-square P value < 0.001			
Model McFadden's Rho-Squared = 0.43			

Table 11. Results of the multivariate logistic regression comparing habitat variables associated with territories to adjacent areas rarely used by larks (n = 30 used and n = 28 sites that were not used for territories) from the Coastal and Columbia River island sites only. All variables were averaged per territory and non-use site.

Vegetation variable	Coefficient $\pm$ SE	t-ratio	P value
Non-vegetated hits	0.27 $\pm$ 0.09	3.12	0.002
Moss/lichen/Algae	-0.16 $\pm$ 0.06	-2.56	0.010
Rock/wood	0.67 $\pm$ 0.29	2.33	0.020
Annual grass	0.19 $\pm$ 0.09	2.23	0.026
Model log likelihood = -14.752			
Model Chi-square P value < 0.001			
Model McFadden's Rho-Squared = 0.63			

Nests

Females in the Puget lowlands are selecting areas that have fewer non-vegetated areas and less cover of annual and perennial grass than nearby non-use sites (Table 12 & 15). On the coast sites and Columbia River island, females are selecting nest sites with fewer non-vegetated areas, more thatch and perennial forbs, shorter vegetation than nearby non-

use sites (Tables 13 & 15). Successful nest sites contained more annual grasses, perennial forbs, and unknown species and they contained less rock and the vegetation was shorter than on unsuccessful nests (Tables 14 & 15). Even though these models were significant, they explained little of the variability in the data.

Table 12. Results of the multivariate logistic regression comparing habitat variables associated with Streaked Horned Lark nest sites to those associated with nearby random locations in the Puget lowlands. All variables were averaged per nest site and random locations (n = 189 nests and 187 random locations).

Vegetation variable	Coefficient $\pm$ SE	t-ratio	P value
Non-vegetated hits	-0.19 $\pm$ 0.05	-3.57	0.000
Annual grass	-0.10 $\pm$ 0.03	-3.41	0.001
Perennial grass	-0.09 $\pm$ 0.04	-2.45	0.016
Model log likelihood = -252.79			
Model Chi-square P value = 0.001			
Model McFadden's Rho-Squared = 0.03			

Table 13. Results of the multivariate logistic regression comparing habitat variables associated with Streaked Horned Lark nest sites to those associated with nearby random locations on the Washington coast and Columbia River island sites. All variables were averaged per nest site and random locations (n = 30 nests and 30 random locations).

Vegetation variable	Coefficient $\pm$ SE	t-ratio	P value
Non-vegetated hits	-0.31 $\pm$ 0.13	-2.31	0.021
Thatch	0.28 $\pm$ 0.12	2.28	0.023
Vegetation height	-0.07 $\pm$ 0.03	-2.11	0.035
Perennial forbs	-0.34 $\pm$ 0.19	-1.76	0.079
Model log likelihood = -35.785			
Model Chi-square P value < 0.02			
Model McFadden's Rho-Squared = 0.14			

Table 14. Results of the multivariate logistic regression comparing habitat variables associated with successful Streaked Horned Lark nest sites to those associated with depredated nest sites on Puget lowland sites. All variables were averaged per nest site (n = 57 successful nests and n = 74 depredated nests).

Vegetation variable	Coefficient $\pm$ SE	t-ratio	P value
Annual grass	1.29 $\pm$ 0.53	2.47	0.013
Unknown	27.73 $\pm$ 15.21	1.82	0.068
Rock	-1.29 $\pm$ 0.92	-1.41	0.159
Vegetation height	-0.03 $\pm$ 0.02	-1.40	0.163
Perennial forbs	1.10 $\pm$ 0.83	1.33	0.183
Model log likelihood = -79.368			
Model Chi-square P value = 0.0001			
Model McFadden's Rho-Squared = 0.12			

Table 15. Habitat variables associated with nest sites and randomly located nearby non-use sites and habitat variables associated with successful (fledged at least one young) and depredated nests at all study sites combined and compared between Puget lowland sites and Washington coast and Columbia River island sites. The first ten habitat variables expressed as mean (SE) percent cover, vegetated hits are the mean (SE) number of times the pin hit plant vegetation (multiple hits per drop were counted), non-vegetated hits are the mean (SE) number of pin drops per site where the pin did not touch any vascular plant vegetation, height is the mean (SE) vegetation height (cm) at each site, and cover above is the mean (SE) percent nest concealment when viewed from directly overhead.

Habitat Variable	All sites		Puget		Coast		All sites	
	Nest (n = 219)	Random (n = 217)	Nest (n = 189)	Random (n = 187)	Nest (n = 30)	Random (n = 30)	Successful (n = 70)	Depredated (n = 79)
Moss lichen	38.5 (2.7)	44.9 (2.9)	44.6 (3.0)	51.8 (3.1)	0.3 (0.3)	1.7 (1.2)	32.9 (4.5)	44.8 (4.8)
Rock/Wood	14.2 (1.7)	13.8 (2.0)	15.0 (1.9)	14.6 (2.2)	8.9 (3.5)	8.6 (3.8)	11.0 (2.6)	15.5 (3.0)
Thatch	47.8 (2.3)	41.9 (2.5)	50.6 (2.5)	45.9 (2.8)	30.0 (5.3)	16.7 (4.1)	53.3 (4.2)	48.6 (3.9)
Bare ground	24.2 (2.2)	22.5 (2.3)	17.5 (2.0)	14.0 (1.9)	66.7 (6.0)	75.6 (6.7)	25.2 (4.1)	18.9 (3.3)
Annual forb	17.5 (1.4)	16.3 (1.5)	19.7 (1.6)	18.6 (1.6)	3.9 (1.9)	2.0 (1.2)	17.4 (2.4)	20.0 (2.5)
Perennial forb	19.4 (1.5)	16.3 (1.4)	20.6 (1.7)	17.4 (1.5)	11.7 (3.0)	9.7 (3.7)	24.2 (2.9)	18.5 (2.7)
Annual grass	41.1 (2.7)	46.1 (2.9)	44.1 (2.9)	50.3 (3.2)	22.2 (5.0)	20.3 (4.6)	49.3 (5.2)	36.1 (4.0)
Perennial grass	35.5 (2.0)	35.4 (2.1)	34.6 (2.1)	34.7 (2.3)	40.8 (6.6)	40.3 (5.8)	30.8 (3.6)	37.1 (3.5)
Shrub	3.2 (0.7)	2.5 (0.8)	3.3 (0.8)	2.8 (1.0)	2.8 (1.8)	0.6 (0.4)	3.5 (1.3)	2.8 (0.9)
Unknown	2.5 (0.8)	2.0 (0.7)	1.0 (0.4)	0.8 (0.3)	12.5 (5.2)	9.4 (4.7)	5.8 (2.3)	0.8 (0.7)
Vegetated hits	34.0 (1.3)	32.5 (1.6)	35.5 (1.5)	33.3 (1.7)	24.6 (2.3)	26.9 (3.5)	37.1 (2.3)	31.2 (1.9)
Non-veg. hits	2.7 (0.2)	3.3 (0.2)	2.5 (0.2)	3.1 (0.2)	3.8 (0.5)	4.8 (0.6)	2.4 (0.4)	2.7 (0.3)
Height	15.2 (0.7)	14.7 (0.8)	15.3 (0.7)	14.3 (0.8)	14.6 (1.8)	17.2 (2.6)	15.3 (1.2)	16.6 (1.2)
Cover above	-	-	-	-	-	-	45.4 (3.3)	41.3 (3.6)

Nearly all nests were located at the base of a grass or forb plant. We recoded the aspect of the nest (in degrees relative the center of the base plant) and found that 89% of the nests were located on the northerly side of a base plant (between NE and NW) similar results have been recorded elsewhere (Nelson and Martin 1999, Hartman and Oring 2003). Birds appear to place their nests on the north side of plants because the plants shade to the nest (Nelson and Martin 1999, Hartman and Oring 2003). Larks placed their nests primarily at the base of perennial grasses, perennial forbs and annual forbs (Table 16). Based on the percent cover of these plant functional groups on territories, it appears that larks are preferentially selecting perennial forbs and avoiding annual grasses for nest base plants (Table 16).

Table 16. Percent nest placed at the base of various plant functional groups and the percent cover of these functional groups on lark territories.

Functional Group	Percent used as base plant	Percent cover on territories
Perennial Grass	43	36
Perennial forbs	27	17
Annual forbs	19	17
Shrubs	9	1
Annual grass	3	42

Habitat Enhancement Experiments

Herbicide treatment

We conducted an experimental study (n = 6 treatments and n = 6 controls at Gray Army Airfield) to examine the effects of the herbicide Poast Plus[®] on grassland habitat. Poast Plus[®] is a grass specific herbicide that apparently kills non-native pasture grasses but does not kill the native bunch grass (e.g., *Festuca roemerii*), native sedge (*Carex inops*), or native forbs. Consequently, applying the herbicide to areas with a high cover of non-native grasses should result in a more sparsely vegetated habitat preferred by larks. The herbicide was applied in early June of 2003 and we measured bird and vegetation response pre- and post-treatment. We found no effect of the treatment on the vegetation or birds (Table 17, Fig. 3). We believe that the herbicide was applied too late in the season and, as a result, was not effective. Consequently, the treatment was repeated in May of 2004 and we will measure bird and vegetation response in 2005 if funding is available.

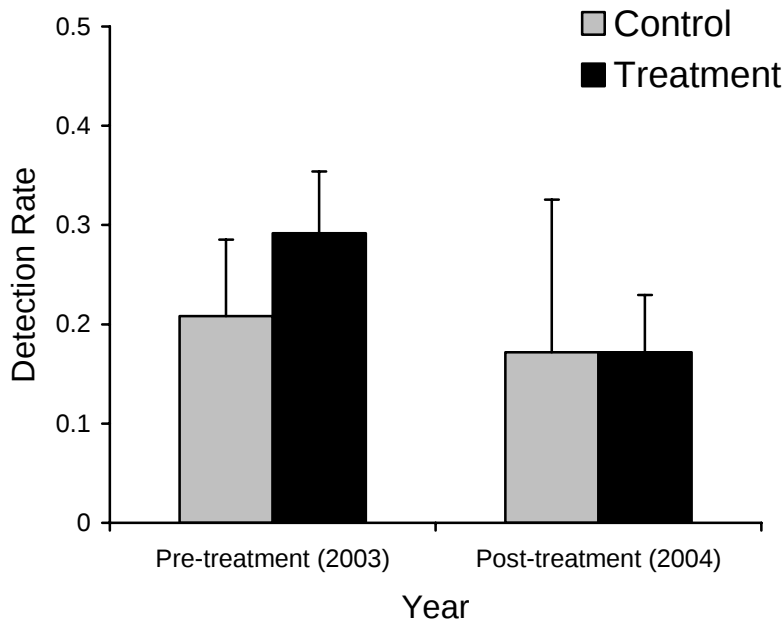


Figure 3. Mean bird abundance on herbicide treatments and controls before and after treatment with the herbicide Poast Plus® on Gray Army Airfield, WA.

Table 17. Habitat variables associated with herbicide treatment and control plots pre- and post-treatment on Gray Army Airfield. The first ten habitat variables expressed as mean (SE) percent cover, vegetated hits are the mean (SE) number of times the pin hit plant vegetation (multiple hits per drop were counted), non-vegetated hits are the mean (SE) number of pin drops per plot where the pin did not touch any vascular plant vegetation, and height is the mean (SE) vegetation height (cm) on each plot.

Habitat Variables	Pre-treatment		Post-treatment	
	Control (n = 6)	Treatment (n = 6)	Control (n = 6)	Treatment (n = 6)
Thatch	66.7 (5.3)	70.5 (5.2)	17.3 (2.9)	19.6 (7.9)
Moss lichen	92.6 (4.8)	95.8 (2.2)	84.0 (3.5)	80.1 (8.6)
Bare ground	2.6 (1.8)	2.9 (1.8)	1.6 (1.6)	2.9 (1.8)
Rock/Wood	3.2 (3.2)	1.0 (1.0)	1.0 (1.0)	0.3 (0.3)
Annual forb	37.2 (7.4)	30.4 (8.7)	46.5 (6.1)	48.4 (9.1)
Perennial forb	7.4 (2.3)	10.9 (3.8)	14.4 (3.5)	19.9 (3.2)
Annual grass	31.7 (10.7)	19.9 (9.5)	26.0 (7.2)	8.0 (5.0)
Perennial grass	34.9 (6.8)	38.8 (5.9)	36.5 (5.0)	26.0 (3.4)
Shrub	0.0	1.0 (0.4)	0.0	1.6 (1.6)
Unknown	4.2 (1.9)	0.0	0.3 (0.3)	1.9 (0.9)
Vegetated hits	61.0 (2.3)	56.0 (3.6)	67.2 (7.1)	58.7 (1.6)
Non-veg. hits	10.3 (1.7)	12.2 (1.7)	10.7 (1.7)	13.7 (0.7)
Height	-	-	3.5 (0.4)	4.1 (0.2)

Controlled burn

After fire, lark abundance was greater on treatment plots than control plots (Figure 5) and there was a considerable change in the vegetation (Table 18). In fact, larks were only observed on treatment plots after the fire. These initial results indicate that post-breeding lark populations responding favorably to fire. We will measure breeding bird response to these treatments in 2005 if funding is available.

Table 18. Habitat variables associated with fire treatment and control plots pre- and post-treatment on 13th Division Prairie. The first ten habitat variables expressed as mean (SE) percent cover, vegetated hits are the mean (SE) number of times the pin hit plant vegetation (multiple hits per drop were counted), non-vegetated hits are the mean (SE) number of pin drops per plot where the pin did not touch any vascular plant vegetation, and height is the mean (SE) vegetation height (cm) on each plot.

Habitat Variables	Pre-burn		Post-burn	
	Control (n = 6)	Treatment (n = 6)	Control (n = 9)	Treatment (n = 9)
Thatch	36.2 (1.5)	37.5 (5.0)	54.5 (4.4)	29.1 (2.4)
Moss lichen	10.3 (3.9)	15.4 (4.0)	32.7 (5.2)	51.3 (3.5)
Bare ground	59.0 (5.7)	51.0 (6.8)	10.5 (3.1)	19.2 (2.5)
Rock/Wood	1.3 (0.6)	1.9 (1.2)	1.5 (1.0)	0.2 (0.2)
Annual forb	29.5 (5.5)	23.7 (3.9)	25.0 (7.2)	10.5 (2.1)
Perennial forb	56.4 (4.8)	54.8 (1.6)	66.7 (7.1)	19.9 (3.0)
Annual grass	70.8 (6.7)	63.1 (4.2)	94.0 (10.3)	25.4 (4.2)
Perennial grass	48.4 (5.2)	43.6 (9.8)	76.5 (5.5)	50.9 (6.7)
Shrub	0.0	0.0	0.9 (0.9)	0.6 (0.5)
Unknown	5.1 (3.0)	2.6 (1.0)	18.6 (4.1)	29.9 (5.3)
Vegetated hits	119.8 (5.7)	109.7 (2.6)	154.0 (5.3)	74.4 (3.0)
Non-veg. hits	2.0 (0.4)	2.0 (0.4)	0.3 (0.2)	7.3 (1.1)
Height	15.7 (0.8)	16.4 (1.4)	13.4 (0.8)	4.9 (0.7)

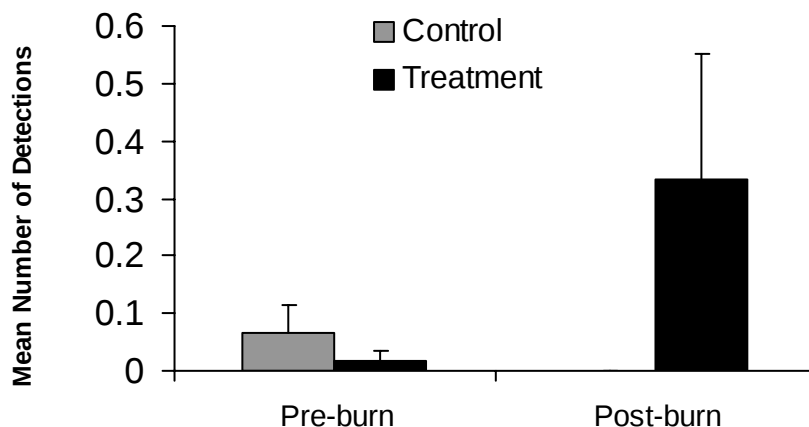


Figure 4. Mean (SE) number of Streaked Horned Lark detections per visit to treatment and control sites before and after a September 2004 prescribed fire on Thirteenth Division Prairie.

MANAGEMENT RECOMMENDATIONS

Timing of Activities

Streaked Horned Larks are actively establishing territories and breeding from late March to 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. Activities that keep larks away from nests for extended periods of time are particularly disruptive and may result in nest abandonment.

Disturbance

Flush distances depend on breeding stage and type of disturbance. In general, activities that occur within 30 m (mean + 1 SD of the mean flushing distance) are more likely to cause flush events than more distant activities (Pearson and Hopey 2004). When possible, we recommend that most activities within 30 m of breeding larks be restricted. Our observations suggest that birds are more likely to flee in response to pedestrian activity than vehicle activity.

Nesting Success

Nesting success was extremely low at 13th Division prairie in all years and relatively low on nearly all study sites. Altman (1999) reported 14% nesting success for Streaked Horned Larks in the Willamette Valley in Oregon. Most of his 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 nest failure and abandonment as described above. Because predation was the primary source of nest failure, we recommend efforts to identify the primary nest predators.

On airport sites, we recommend that construction vehicles, personnel and construction related activity be limited to the pavement areas when possible. We recommend the use of Pin flags rather than ‘construction fencing’ be used to prevent personnel and vehicles from driving over vegetated and gravel areas immediately adjacent to pavement are heavy bird use areas. Fencing may influence lark use of these habitats.

Predators

Predator numbers (especially corvids) increase in response to increased food supplies. We recommend that all human sources of food in proximity to breeding locations be eliminated including uncovered garbage and littered food scraps. We recommend posting signs that encourage people to properly dispose food waste, and to not feed wild animals near restaurants and high-use areas near breeding areas.

Habitat Management

On the Puget lowland 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 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); 3.9 – 13.3 inches (95% confidence interval from this study)] and a relatively high percent of bare ground [17% (Altman 1999); 16% (mean from this study)]. 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). A review of the effects of management practices on the horned lark (Dinkins et al. 2003) also indicates that larks prefer areas with short, sparse herbaceous vegetation with little or no woody vegetation.

On the coast and islands in the Columbia River, larks are selecting sparsely vegetated areas with more wood and cover of annual grasses with less algae (indicator of areas effected by very high tides) than adjacent areas in the same habitat type. Specific recommendations for maintaining habitat conditions appropriate for larks include maintaining areas with a high percent of bare ground (primarily sand – approx. 68%) that are sparsely vegetated (approximately 35% of the area with no vegetation) and the vegetation is dominated by relatively short annual grasses (0.6 – 8.7 inches; 95% confidence interval from this study). Maintaining this habitat type either means managing for processes that create accreted habitats and/or controlling beachgrasses (*Ammophila spp.*) that colonizes these habitats creating unsuitable lark habitat. Larks are found breeding adjacent to Snowy Plovers (*Charadrius alexandrinus*) at several sites and many management activities that benefit the plover will likely benefit the lark.

Today, Streaked Horned Larks are found on accreted soils along the coast, on dredge spoil islands in the Columbia River, 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, Pearson 2003, Pearson and Hopey 2004, 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. On Puget lowland sites, 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 a poorly developed A horizon, and (3) with a high content of gravels and cobble content. Typically, Spanaway soils have a well developed A horizon (Pringle 1990). However, the width of the A horizon and the amount of gravel in the upper soil layer varies dramatically across the Puget prairie landscape (pers. obs.). Areas that are extremely gravelly/cobbly 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 and poor plant growth would result in a less well developed A soil horizon.

Very frequent fire intervals could create areas that are sparsely vegetated. Frequent intervals would prevent the accumulation of thatch and if the fire burns hot (summer burns), it can volatilize soil nutrients leading to poor plant vigor. A frequent fire interval seems plausible given what is currently known about historic fire frequency. Areas subject to frequent fires were likely dominated by native Roemer's fescue (*Festuca roemerii*) and forbs with plenty of open space between plants.

In Puget prairie habitats, we 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. We do not 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) or other rare prairie dependent species (e.g., Taylor's checkerspot). If attempts are made to increase the amount of gravels/cobbles in restoration areas, we 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, we recommend that restoration activities focus on large open prairies (100s of acres in size). We know of no studies that have investigated the relationship between habitat patch size and nest success for the horned lark. Bock et al. (1999) compared lark abundance between interior and edge locations and found lark abundance to be greater on interior plots. This result was not significant due to high variation in numbers of larks among plots.

There are opportunities to create additional lark habitat on islands in the Columbia River through the deposition of dredge spoils. To maintain and deepen the Columbia River shipping channel, the Army Corps of Engineers deposits dredge spoils on many of the islands used by breeding larks. A number of these islands were created through the deposition of dredge spoils. The timing, location and the amount of deposited materials can have dramatic impacts on the lark. To benefit the larks we recommend that spoils not be deposited on active territories and nesting sites. To avoid disturbing breeding larks, we recommend that they not be deposited immediately adjacent to active territories during the breeding season. The un-vegetated landscape created by depositing dredge spoils is not used by larks for the first year or two after deposition. Spoils that are sparsely vegetated with annual grasses and a mixture of forbs are successfully used by larks for breeding. Consequently, keeping an adequate amount of habitat in appropriate successional stages is critical to maintaining Columbia River lark populations. Larks move among islands and appear to colonize suitable habitat (Pearson and Hopey unpubl.) Dredge spoils can also be used to convert unsuitable habitats into suitable habitats. For example, if spoils are colonized by Scotch broom or equisetum (habitats not used by larks) they can be converted to appropriate habitats by depositing additional spoils.

We recommend that restoration activities be treated as experiments so that the effectiveness of treatments can be evaluated.

Human Disturbance

In 2002, we recommend that Ft. Lewis attempt to reduce the amount of recreational activity in the areas occupied by breeding Larks. In response to this recommendation, Fort Lewis prohibited 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). In response, Ft. Lewis restricted recreational activities on 13th Division Prairie during the 2003 and 2004 breeding seasons.

Streaked Horned Larks breed in the triangularly shaped grassland just north of Gray Army Airfield (see Appendix I). This habitat can be improved for lark breeding by limiting access to this area and by mowing outside the primary breeding season, and by either conducting prescribed fires or controlling pasture and sod forming grasses in this area.

Recreational activities such as dog walking, beachcombing, driving vehicles and horseback riding in coastal lark habitat may indirectly increase predation, nest abandonment and decrease overall nesting success. We recommend the continued closure of Midway Beach road access gate, especially during the breeding months of late March thru August to reduce use of the dune habitat by recreational activities. We also recommend that public access to the primary breeding sites at Damon Point be limited, that dogs only be permitted on a leash if at all. To prevent vehicle access, we recommend that the washed out road to the point not be repaired.

Mowing

Mowing may be both a blessing and curse for the streaked horned lark. All of the airport sites are mowed and the mowing may be partially responsible for creating suitable habitat at these sites. At the same time, mowing results in direct mortality of nests and may cause some nest abandonment. To minimize the negative impacts of mowing on larks, we recommend that mowing occur during non-peak breeding times: before breeding starts in mid-April, the first week of June, and at the end of the breeding season (mid to late July). The curve of clutch initiation dates suggests that there is a break in clutch initiations between the first and second clutches, which occurs in the first week of June. We also recommend mowing very low before and/or after the breeding season and higher (6-8 inches) during the breeding season. We have noted that mowing with the mowing deck very close to the ground results in more nests being destroyed.

Future Planning and Research

In 2003, we initiated a study examining the effects of the herbicide Poast Plus[®] on grassland habitat and habitat use by larks. Because the initial herbicide treatment occurred too late in the season, we recommend measuring lark and vegetation response to the second treatment in the 2005 field season if funding is available.

We recommend continuing to measure the response of larks and vegetation to the fire treatments on 13th Division Prairie during the 2005 field season if funding is available.

We recommend initiating a study that attempts to identify nest predators. For three years and on nearly all sites, predators have been the primary source of nest failure. Unfortunately, we do not know which predators are primarily responsible for this predation.

Scope and limitations

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

- This study provides information on breeding phenology, nesting success and habitat selection for three breeding seasons in the Puget lowlands and one season in the coastal and river island populations. 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, habitat and population variability.

Positive outcomes and management activities:

- Gray Army Airfield again modified their mowing regimes to avoid disturbing or destroy nests.
- Ft. Lewis limited recreational and military uses of the area where Larks breed on 13th Division Prairie including the exclusion of motorized model airplanes, horses, dog training and private vehicles. In addition, Ft. Lewis put signs on 13th Division Prairie that prohibit recreational activities during much of the breeding season.
- Ft. Lewis in cooperation with The Nature Conservancy continued to control Scotch broom at 13th Division Prairie.
- Ft. Lewis continues to control Scotch broom on other prairies, which may increase the amount of suitable habitat in the long-term.

New Findings:

- Completed the first comprehensive inventory of breeding larks on the lower Columbia River resulting in the discovery of additional breeding locations and more breeding birds than recorded previously.
- First assessment of lark reproductive success for the Washington coast sites and lower Columbia River site.
- First comparison of reproductive success between the Puget lowland populations and coastal/island populations.
- Developed a habitat selection model using both Puget lowland and coastal/island sites.
- Evidence that late summer fire creates habitat conditions selected by post-breeding adult and hatch-year larks.

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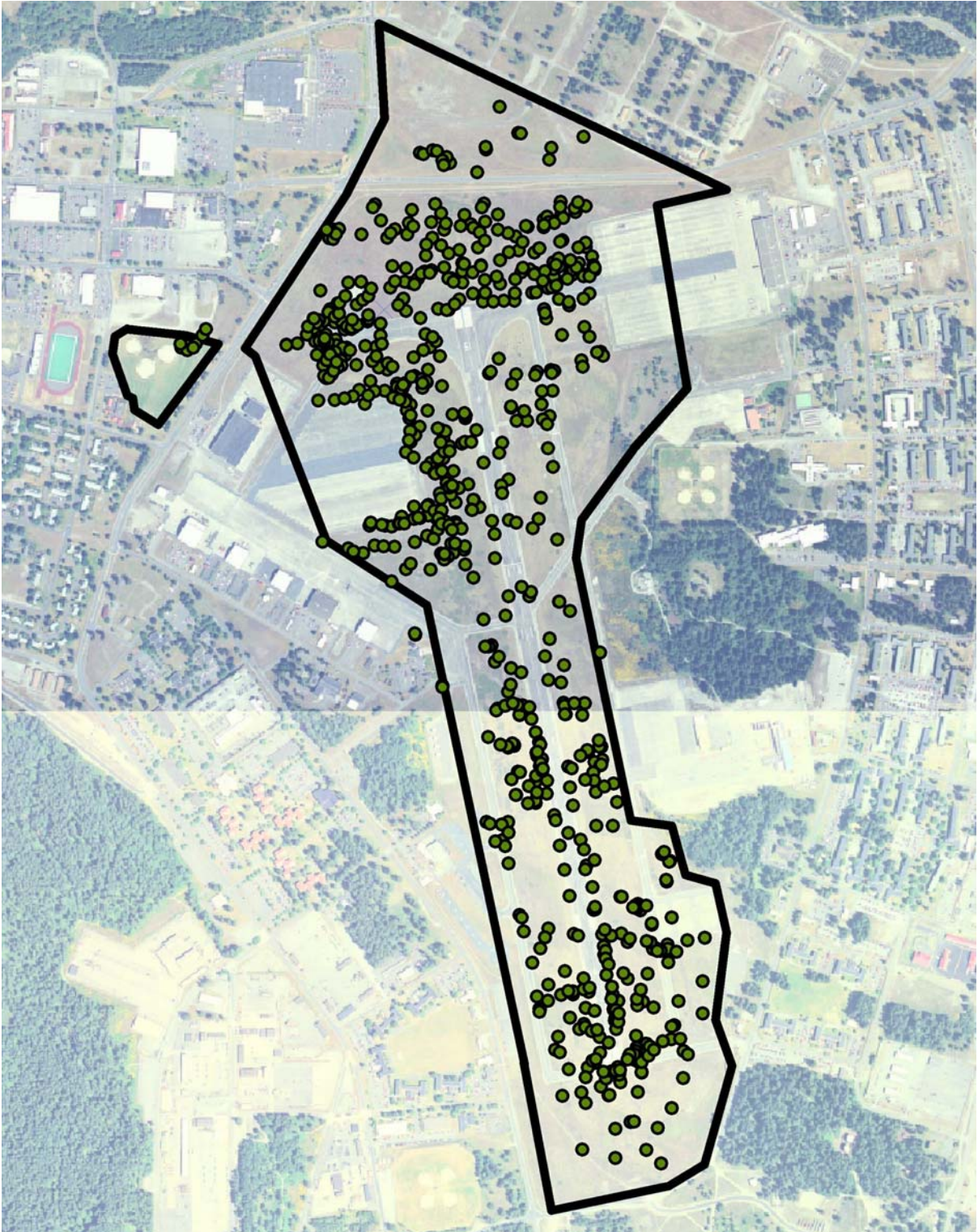
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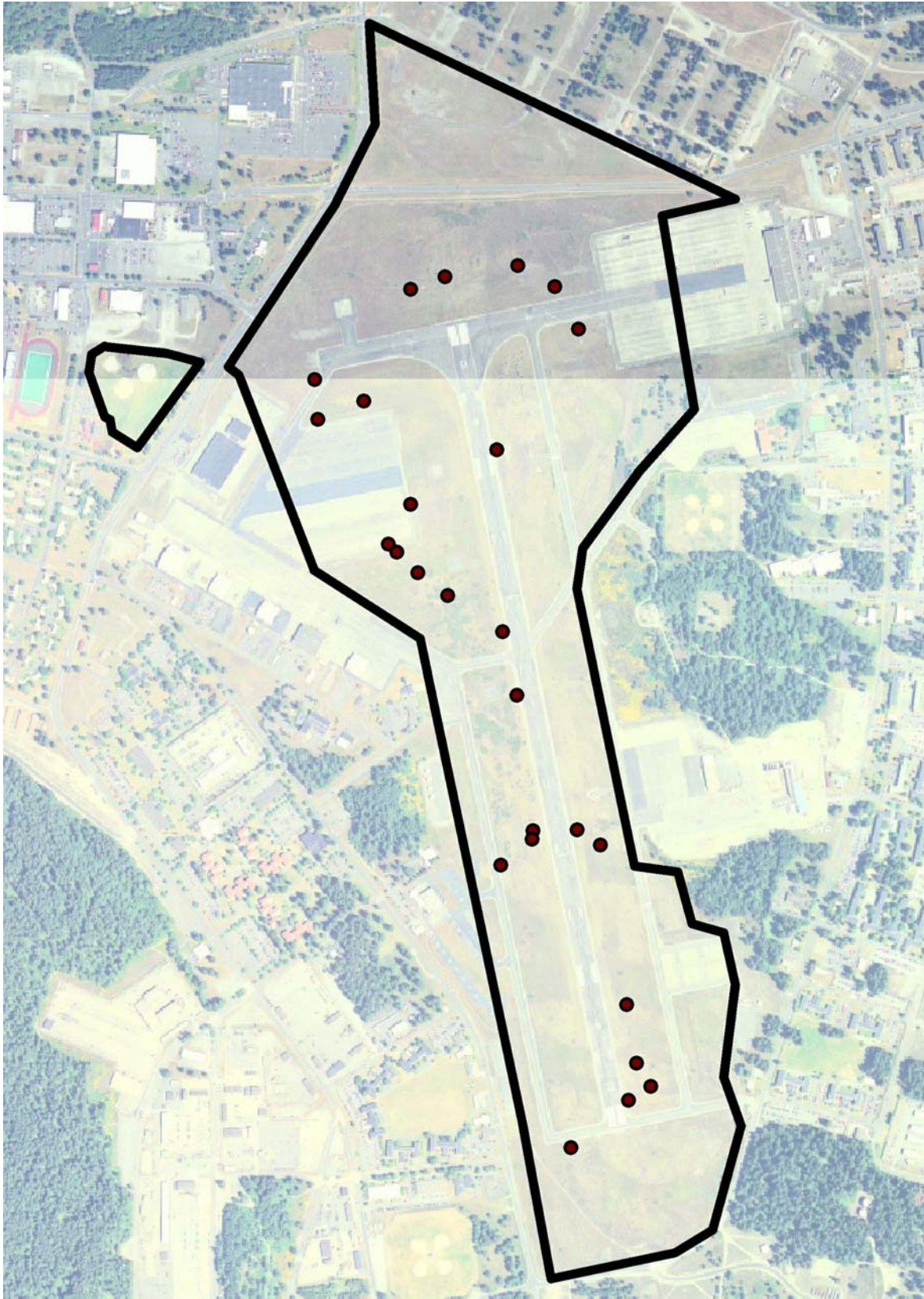
APPENDIX I

The following figures identify Streaked Horned Lark bird locations and nest sites at Gray Army Airfield, 13th Division Prairie, McChord Air Force Base, Damon Point, Midway Beach, and Whites Island. Bird locations were mapped during the 2004 breeding season at each site using the approach described in the Methods. Many of the localities undoubtedly represent the same birds detected numerous times and should not be used to infer bird abundance or density. Nest locations are from the 2004 field season. All nest sites were GPSed at the end of the field season using a Trimble GeoExplorer CE with differential correction.

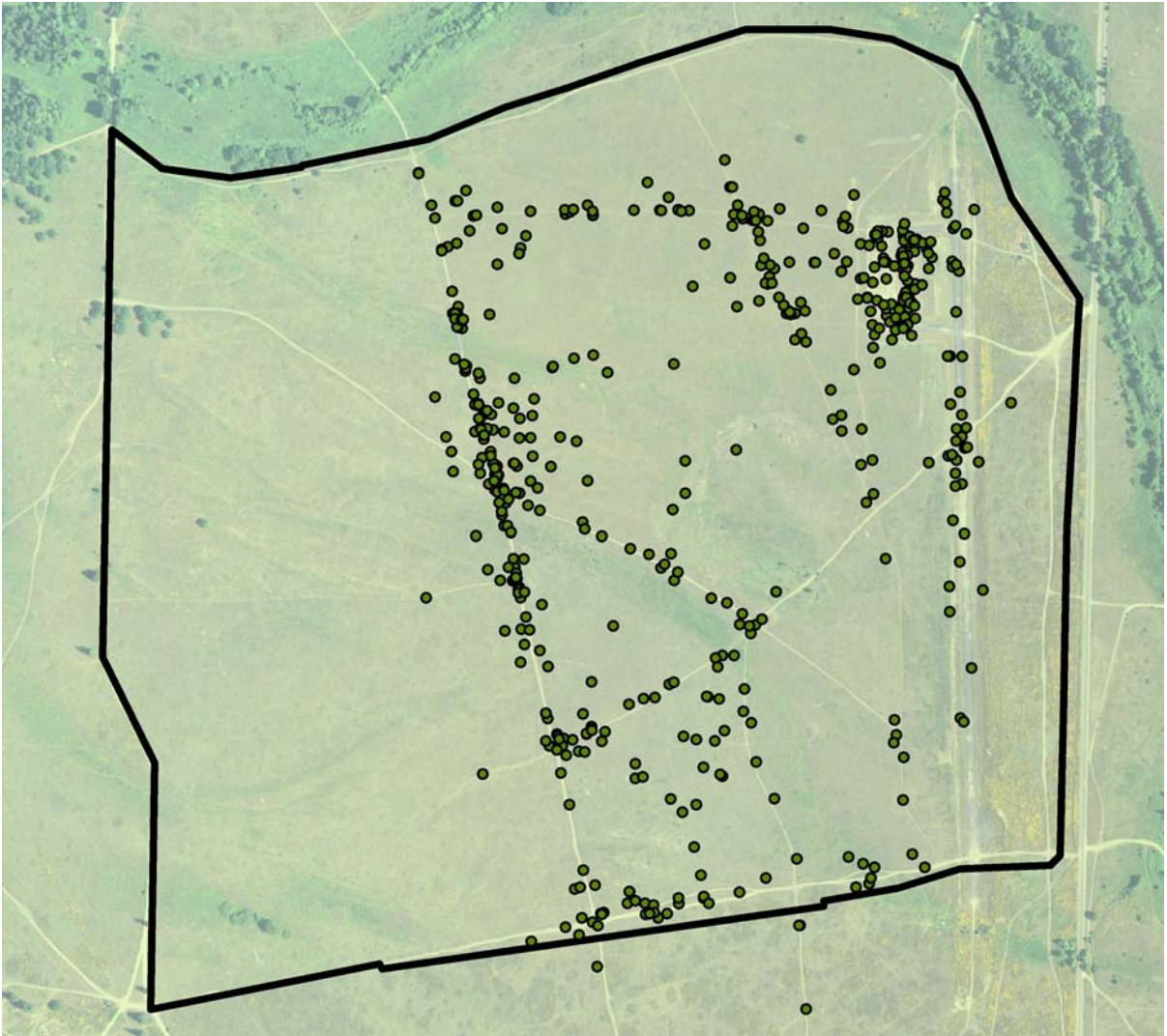
A) Gray Army Airfield bird locations



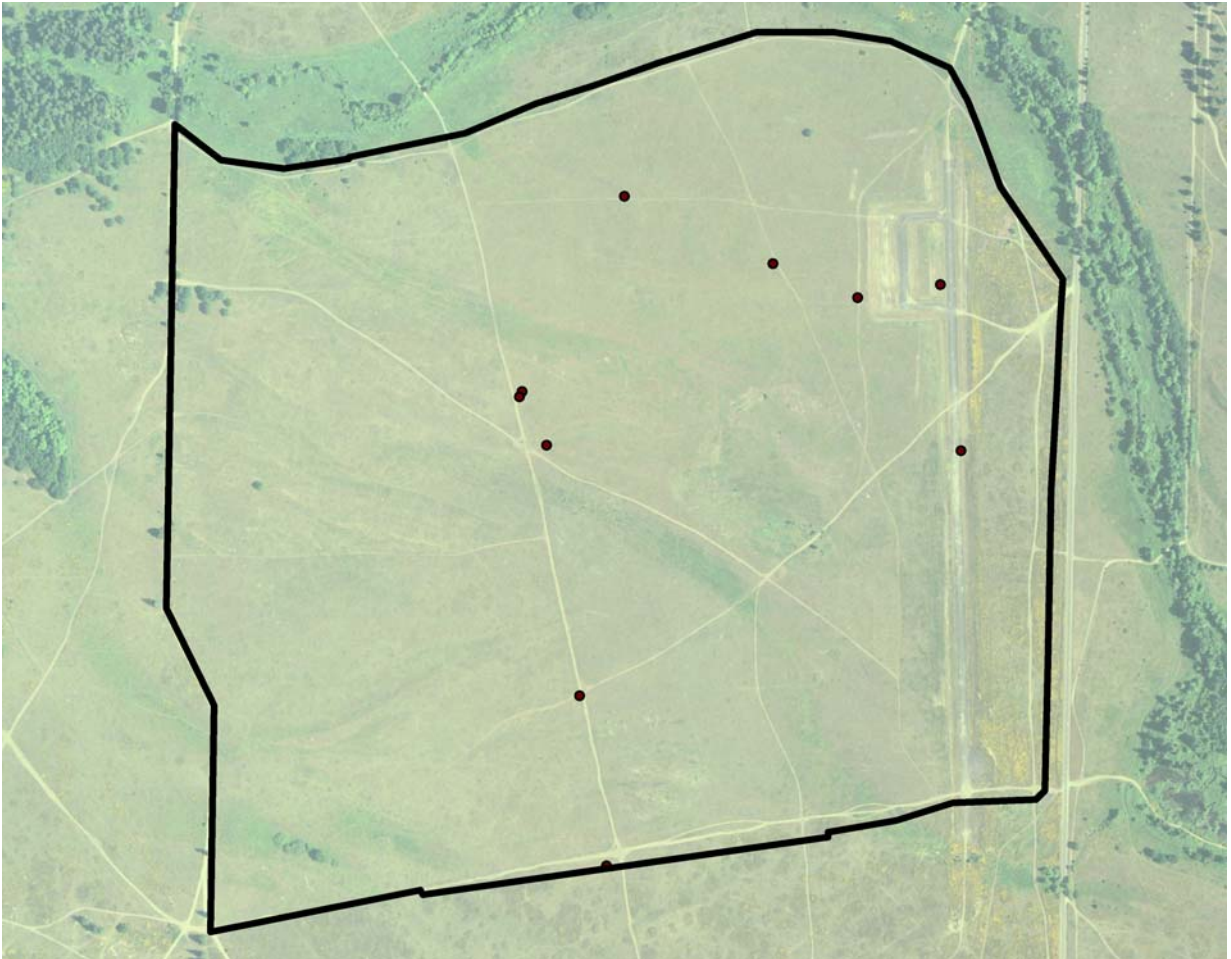
B) Gray Army Airfield Nest locations



C) 13th Division Prairie bird locations



D) 13th Division Prairie nest locations



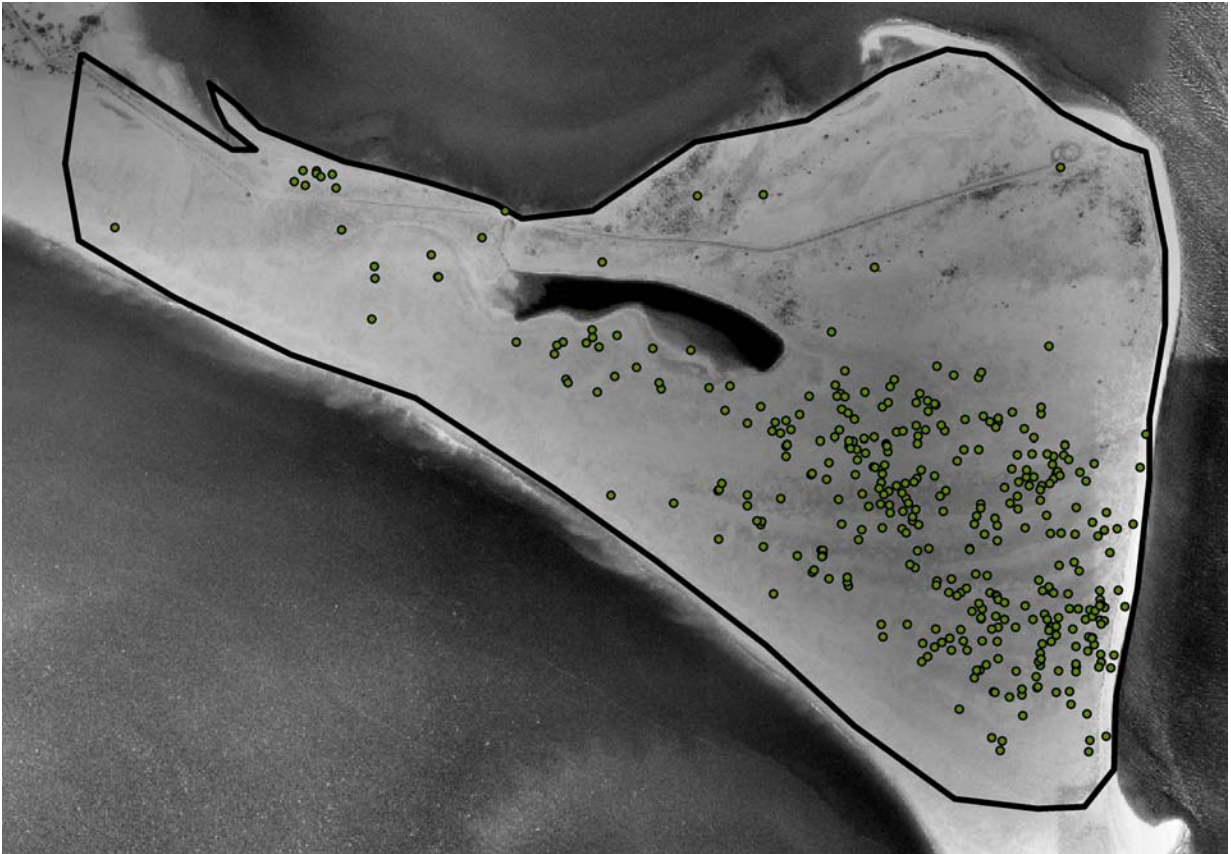
E) McChord Air Force Base bird locations



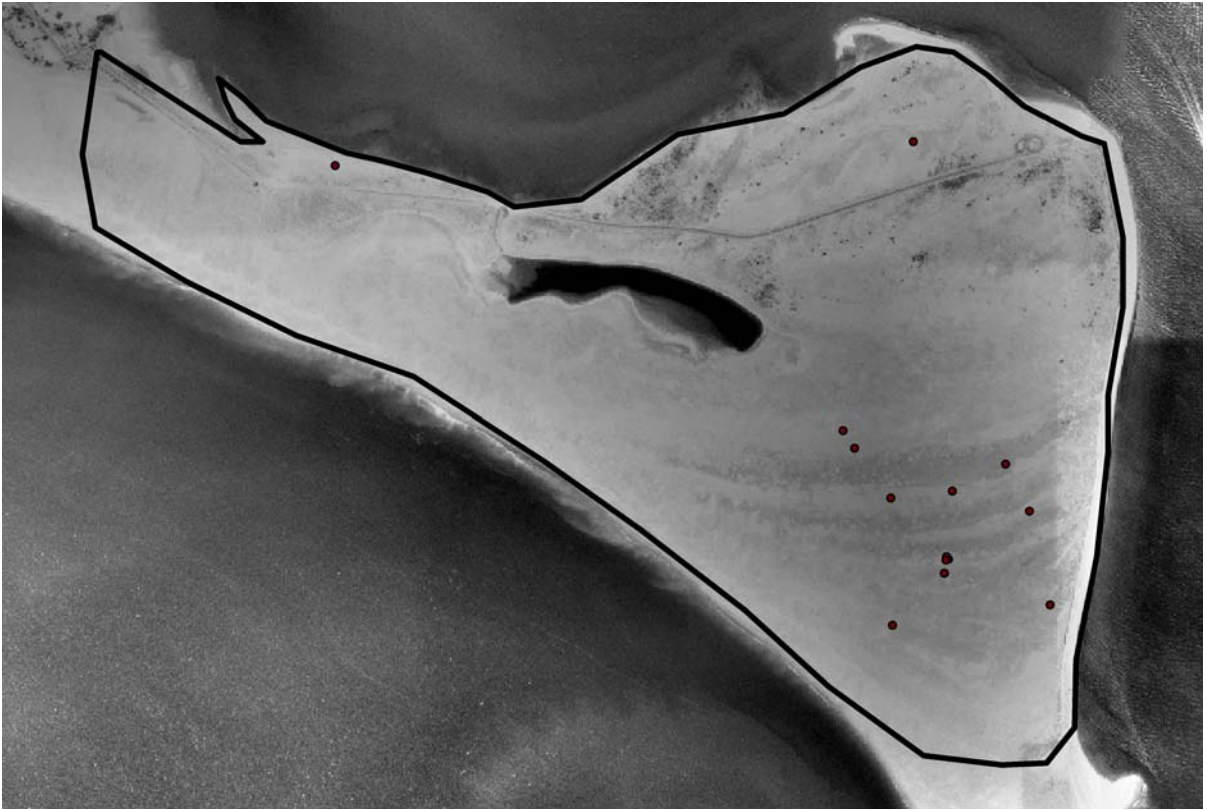
F) McChord Air Force Base nest locations



G) Damon Point bird locations



H) Damon Point nest locations



I) Midway Beach bird locations



J) Midway Beach Nest locations



K) Whites Island bird locations



L) Whites island nest locations

