Survey Protocols and Strategies for Assessing Streaked Horned Lark Site Occupancy Status, Population Abundance, and Trends

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Recommended citation:

Pearson, S.F., M. Linders, I. Keren, H. Anderson, R. Moore, G. Slater, and A. Kreager. 2016. Survey protocols and strategies for assessing streaked horned lark site occupancy status, population abundance, and trends. Wildlife Science Division, Washington Department of Fish and Wildlife, Olympia, Washington.

Introduction

The streaked horned lark (*Eremophila alpestris strigata*) is listed as threatened under the Federal Endangered Species Act (USFWS 2013) and as endangered by the State of Washington, yet no standardized range-wide survey protocol or monitoring strategy exists. Assessing population distribution, abundance and trends is critical for making informed management decisions and to understand relationships between animal populations and environmental conditions. Such information is used to describe changes in the size of rare or declining populations, identify mechanisms for population changes, assess changes in ecological conditions, and evaluate the effectiveness of conservation actions (e.g., progress towards recovery).

To gain a better understanding of lark distribution and abundance, we advocate a hierarchical approach (see Olson and Pearson 2014). This hierarchical approach consists of three components:

1. <u>A probability of occurrence map</u> that determines the sampling frame where one should look for and count larks. This map would preferably be range-wide (or regional) in scale and portray the species probability of occurrence based on habitat suitability and current distribution. This is a landscape-scale assessment. The extent of the map may be defined by political, geographical, and/or biological boundaries.
2. A statistically-based <u>sampling plan</u> (or set of plans) to monitor population trends within occupied sites (a temporal assessment that may be conducted at the site or landscape scale). Trends may be based on abundance or occurrence as appropriate.
3. <u>Survey protocols</u> for determining site occupancy status within suitable habitat - site scale assessment. Once the best places to look for the species have been identified, these protocols help determine how to search in a manner that is likely to detect the species if it is present.

The first step in this process is to develop a landscape-scale map that would quantitatively or qualitatively express the probability of lark occurrence within the defined map extent based on factors determined to affect occupancy. This map would then be used to concentrate survey, management, conservation, and other efforts in areas where occurrence probability is moderate to high, while also enabling such efforts to be reduced or eliminated in areas of low probability of occurrence. This results in a much more efficient and for a statistically based sampling approach. The second step is to develop species-specific survey protocols to determine site occupancy status using methods that take into account the uncertainty associated with detecting the presence of animals. The final step is to develop a strategy for assessing species abundance and trends within occupied sites.

We organize this document as follows:

1) Recommendations on developing a probability of occurrence map and, in the absence of such a map, a potential interim sampling framework approach. These recommendations allow us to move forward with surveys even though the occurrence map has not been built.

2) Lark breeding phenology and detectability information needed to develop occupancy and survey protocols.
3) Sampling strategy for assessing breeding season lark abundance and trend at sites with public access and recommendations for potential road–side surveys for sites without public access.
4) Field protocols for assessing a site's occupancy status by breeding larks.

Developing the sampling frame (probability of occurrence map)

The sampling frame is the space where one is either going to assess occupancy, abundance, and or trend. In Washington State, the sampling frame was originally defined by Rogers (1999, 2000). Rogers essentially created a probability of occurrence map for Washington using habitat and historic occurrence criteria. He started with a map of the State depicting all of the townships. He then identified townships with relatively recent lark records (1960 or later) and potential or suitable nesting habitat (see Rogers 1999 for details) – these were identified as high priority survey sites. He also identified lower priority survey sites, which consisted of patches of unknown or marginal habitat conditions with older nesting records. Habitat conditions were determined by visually interpreting orthographic photographs. Using this approach to identify sites and using established survey methods, he detected forty-nine singing streaked horned larks in 11 of the 86 townships surveyed in 1999. Additional surveys were conducted by MacLaren (2000) to survey the last few high priority survey townships not surveyed by Rogers and to survey the remaining lower priority townships. She also conducted repeat surveys at occupied sites. Since these original surveys, a number of additional surveys have been conducted (including within season replicated surveys) on suitable habitat near currently occupied sites (see Pearson and Hopey 2004, Pearson et al. 2005, and Anderson and Slater 2015). Finally, to fill in any missing occupied sites, formal requests have gone out to birding listservs to request notifications of observed horned larks within the breeding season in order to identify locations of potential breeders. Finally, state and federal biologists periodically monitor eBird (ebird.org/) to look for horned lark records from skilled birders during the nesting period. As a consequence of these relatively systematic and intensive efforts, many and perhaps most of the potential nesting sites in western Washington and on the Columbia River islands/shore of Oregon and Washington have been identified.

Extensive surveys have also been conducted in Oregon (e.g., Altman 1999, ODFW 2008, 2010, Moore 2010). The ODFW (2010) survey effort, for example, focused on historically occupied sites and potentially suitable habitat. In addition, they attempted to spread their sampling effort throughout the Willamette Valley and across the various physiographic regions and within areas that historically supported grasslands. Assessing site occupancy status and Lark abundance and trend in the Valley are complicated because it is largely a privately owned agricultural matrix (no public access) with a shifting mosaic of potential habitat. As a consequence, our knowledge of the lark's distribution and abundance within the Valley is incomplete.

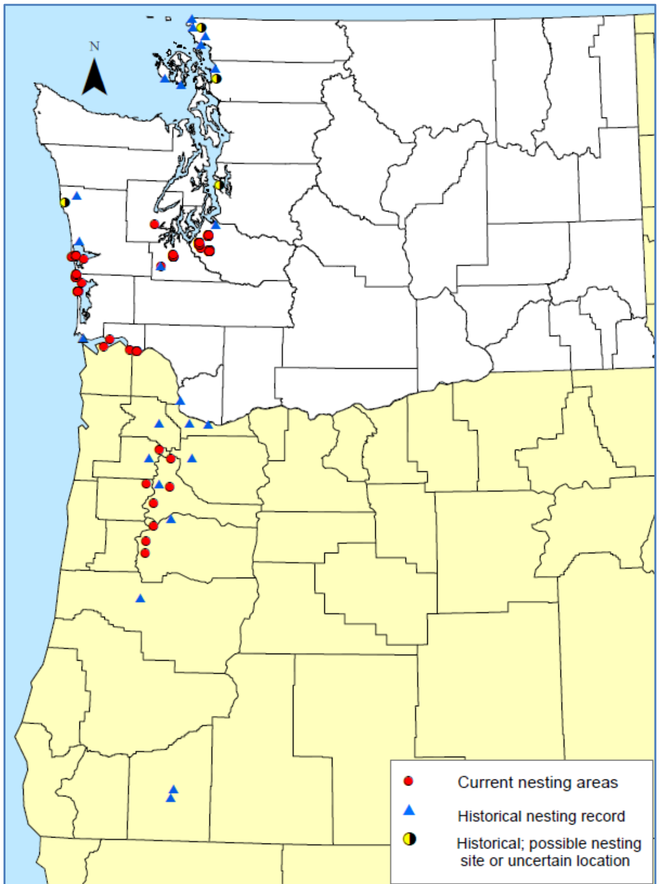

Figure 1. *Historic and relatively current nesting locations (Stinson 2005).*

Given this historic context and the data currently available, this is an ideal time to build a probability of occurrence map for the lark. Preferably, this map would cover the current and historic range of the species.

However, the streaked horned lark presents unique challenges for developing such a map. This species depends on specific habitats during the nesting and non-nesting periods – large open and sparsely vegetated habitats dominated by grasses and forbs (see Anderson and Pearson 2015). Many of the occupied sites are continuously occupied because the habitat is maintained in this condition, for example, airports, field edges and road sides. While other sites tend to be ephemeral because they are generally early successional and, without additional disturbance, succeed to other habitat types. As a result, it is difficult to predict the distribution of suitable habitat conditions over space and time. Even with good broad-scale assessment tools such as remote sensing techniques, it would be necessary to update this map at regular intervals - perhaps, every 5-10 years - to account for the ever-changing conditions. Unfortunately, these techniques have not been completely developed for the lark (but see Anderson 2009, 2013).

Despite these difficulties, we believe it is possible to build a coarse region-specific landscape probability of occurrence map that would be extremely useful. We recommend starting with a map of historical lark occurrence in the Georgia Basin, Puget Trough, Willamette Valley, and Rogue River Valley (Figure 1). We recommend dividing this historically occupied area into strata based on a combination of land cover types and population dynamics. For example, one could potentially split the occupied portion of the range into the following strata: 1) southern Puget Trough, 2) lower Columbia River and Washington coast, 3) north and western Willamette Valley, and 4) south and eastern Willamette Valley. These strata are initial suggestions, determining the specific strata and their boundaries would be defined as a component of this mapping project.

Within defined strata, removing unsuitable habitat would narrow the sampling frame considerably. For example, streaked horned larks are not known to use habitats: (1) Above 800' in elevation; (2) Any landscape with > 10 % tree canopy cover; (3) Urban landscapes without large patches of open habitat; and (4) Lakes, wetlands with permanently standing water, and forested wetlands. A map with these and potentially other variables removed could be used as the sampling frame. Or alternatively, one could try some relatively straightforward GIS modeling to further refine this map to build a predictive map for each of the geographic strata.

To accomplish this, one could use a modelling approach to examine the relationship between site occupancy and a variety of predictor variables. The occupancy assessments that were conducted at fairly large scales to identify occupied and unoccupied sites (Altman 1999, ODFW 2008, 2009, Rogers 1999, MacLaren 2000) could be used for this effort. A variety of variables could potentially be used to explain lark occupancy pattern including elevation, slope, soils, and large scale land use/land cover information (especially agriculture for the Willamette Valley), field size (Willamette Valley), proportion of contiguous farm land, and distance to nearest occupied site. If the probability of occupancy is related to the distance from known occupied sites, and we suspect that it is, this variable alone could be helpful in identifying and focusing areas for survey.

Recent analyses by the Center for Natural Lands Management in cooperation with CoreGIS, indicates that remotely derived variables can be used to identify potential lark habitat (Anderson 2013). They found that Normalized Difference Vegetation Index (NDVI) rasters, which measure photosynthetic activity or greenness in each square meter pixel, was useful in classifying a variety of plant cover types. In particular, it was useful in identifying bare ground, grass/forb, and horsetail/grass cover. Again, because of the ephemeral nature of lark habitat, it may be necessary to periodically "refresh" these probability of occurrence maps. The specifics of the analytical approach and the variables to include would be worked out as part of this recommended mapping effort.

Once a probability of occurrence map is developed, it could be used to develop a spatially appropriate sampling strategy suitable for each region. Particularly, it would help us determine where to focus occupancy and abundance sampling efforts using the protocols developed in this document. For the agricultural landscape of the Willamette Valley, it may be important to integrate both occupancy and abundance/trend protocols simultaneously.

Developing protocols for assessing site occupancy and abundance

The probability of occurrence map tells us where to focus our survey effort. Here we focus on developing protocols that will define how and when we should conduct surveys. We define the appropriate temporal window using information on breeding phenology, and we selected analytical and survey methods that are likely to maximize lark detection by addressing the issues that influence detectability.

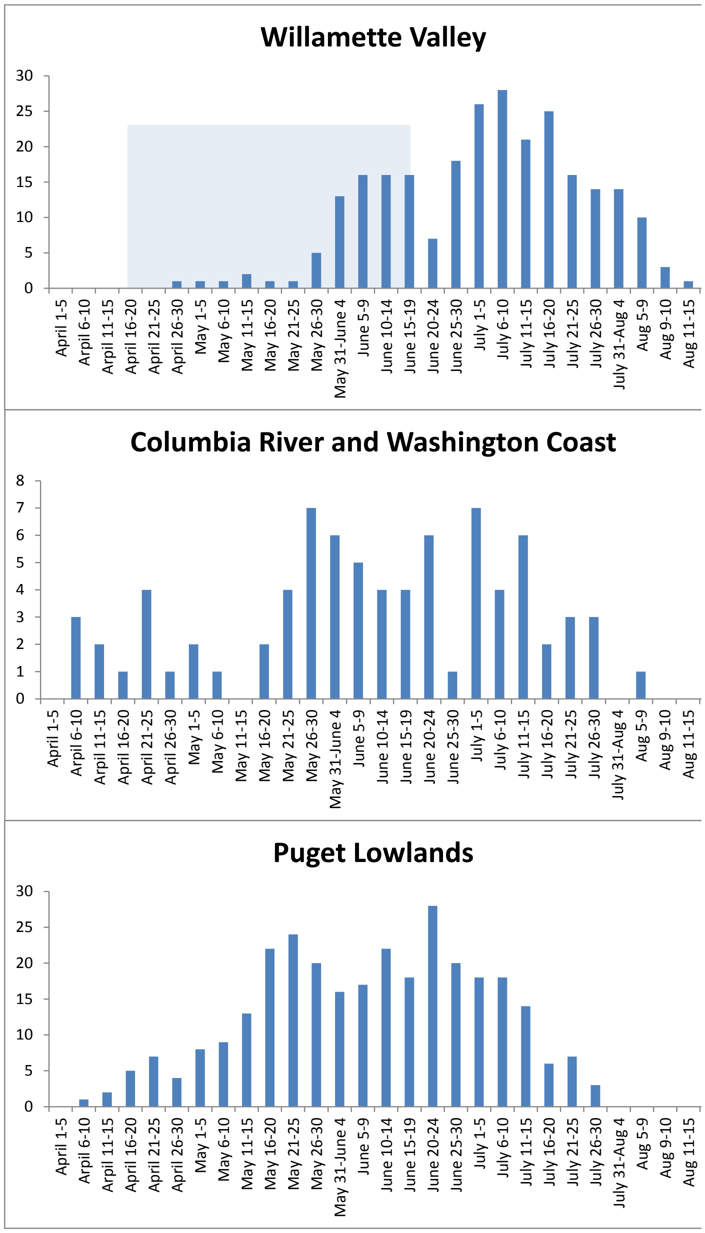

Figure 2. *Clutch initiation by geographic region. Clutch initiation dates include all nests that could be dated in the Puget lowlands, Washington coast, and lower Columbia River. For the Willamette Valley, only information from successful nests was available and most early nests failed (R. Moore pers. com.). As a result, very few of the early nests are included in this graph and the first clutch initiation dates appear later in the year than when they actually occur. We shade this area of uncertainty in that panel. Randy Moore indicates that most first nests are initiated by May 15 in the Valley.*

Using breeding phenology to define the nesting period survey window

Our goal is to develop nesting period survey protocol and consequently, we don't provide information on survey protocols for other times of the year. The "population" of birds that nest in the Puget Sound region is primarily migratory (Pearson et al. 2005) with birds from this region moving to the Columbia River, Washington coast, or the Willamette Valley during the late fall and winter months where they are found in large mixed species and mixed lark subspecies flocks (Pearson et al. 2005). Larks throughout the rest of the range may be partially migratory or non-migratory (Pearson et al. 2005). For the migratory portion of the population, birds leave their over-wintering grounds and arrive on nesting sites in mid- to late-February (Pearson and Hopey 2004, Wolf and Anderson 2014). Conversely, they leave the breeding sites in mid- to late-October (Wolf and Anderson 2014). In the spring, males arrive on the breeding grounds first followed by females several weeks later (Pearson and Hopey 2004). Singing and flight displays occur shortly after females arrive on nesting sites (Pearson and Hopey 2004) with periodic singing occurring prior to female arrival.

Most approaches for assessing either site occupancy or regional abundance and trend require/assume site closure or no movement of individuals among sites during the survey window. In our experience and throughout the range, there is considerable movement of birds among sites in the early spring prior to clutch initiation

(March to mid-April) as birds are settling into their breeding sites. Therefore, we use clutch initiation dates, a time period when larks are more settled and committed to a specific site, to establish appropriate survey windows for assessing both site occupancy and lark abundance (Figure 2).

Based on clutch initiation information, we recommend that the survey window begin no earlier than late April in all regions. By mid-July, the frequency of male singing declines as fewer nests are being initiated and fewer mates/territories are being defended. In addition, the number of young-of-the-year on these sites increases dramatically after mid-June. This can influence adult population detection because males are feeding young and not displaying (singing and flight displays) or can result in false assignment of young-of-the-year to adults if birds are only detected by call or flight. In other words, there would be an apparent change in the abundance not resulting from a change in the adult population.

For adult abundance estimates it is desirable to narrow the survey window to minimize the opportunity for potential movement among sites and reduce the number of young birds detected. To accomplish this, we recommend abundance surveys occur between 1 May and the end of June. For occupancy surveys we recommend a survey window from mid-April to mid-July because occupancy status on a given site can potentially change throughout the nesting period (e.g., a bird moves between sites because of vegetative succession, nest failure or predator presence at a given site), and because we are not necessarily interested in assessing abundance with occupancy surveys.

Factors influencing detectability

Non-detection during a survey does not mean that a species was absent from a site unless the probability of detecting the species (detectability) was 100%. The fact that probability of detecting a species is almost never 100% leads to a fundamental problem -- the measure of occupancy is confounded with the detectability of the species. Specifically, an observed "absence" occurs if either the species was present at the site but not detected, or the species was truly absent. The same is true when attempting to estimate density or abundance. Because only a portion of the population is detected during a given visit to a site, it is important to survey in a manner that will maximize the probability of detection and to address issues of detectability in the selected analytical methods.

One's ability to detect a lark, given that it is present, can be influenced by a variety of environmental and non-environmental factors. As a result, apparent changes in abundance or site occupancy status over time can be influenced by these factors rather than true changes in abundance or occupancy. For example, if an experienced crew is used in the first year and another, less experienced crew, in the second year, differences in apparent abundance between years could be attributed to differences in the abilities of the two field crews. Alternatively, inter-annual changes in ratio of males to females could have significant impacts on estimates of abundance because male larks draw attention to themselves with territorial displays while females are relatively quiet and cryptic, leading to significant differences in detectability between sexes (See Keren and Pearson 2015). To address these issues, we developed consistent protocols for surveys to minimize factors that can be controlled and address issues of detectability in the analytical method used to assess changes in abundance or occupancy over time (Keren and Pearson 2015).

Table 1. Factors influencing detection.

Observer
• Skill level (especially with grassland birds) • Eyesight and hearing abilities
Environmental conditions
• Density of vegetation • External noise such as airplanes at airports or road noise
Weather conditions
• Wind • Rain
Bird behavior
• Singing Visual detection vs. aural detections (song or call). In larks, only the males sing • Actively displaying (males) vs slinking quietly through the habitat (females) or other behaviors that influence whether or not a bird is detected by sight or sound. • Singing rates that are influenced by local population density or whether or not a male is paired. • Singing rates and other behaviors that change with time of day and/or as the nesting period progresses.

Identifying the factors that influence lark detectability from survey data

In 2014, we initiated a pilot study on two islands of the Columbia River that used distance sampling techniques (Buckland et al. 2001) to help us better understand, in part, the relationship between detectability and distance from an observer (for full description of pilot see Anderson and Slater 2015). In Figure 3 below, we plot the number of birds detected as a function of distance from the observer and whether or not the detected bird was a male or female, and whether it was initially detected by song/call (aural detection) or visually. Females were almost exclusively detected visually (27 out of 29 detections) and, in general, nearly all birds detected visually, regardless of sex, were detected within 75m. We also conducted a similar analysis with data from Oregon Department of Fish and Wildlife's Willamette Valley grassland surveys conducted in 2008 (ODFW 2008). This survey used road-side point counts and did not include information on sex and detection type (visual vs. aural) and, as a result this information does not appear for the Willamette Valley panel in Figure 3. There were 94 point count stations with two visits each where larks were detected on at least one of those visits.

For the Columbia River distance surveys, male and female detection probabilities were similar for visual detections. Overall, the detection probability for males was higher than for females likely due to many males being detected both by sight and sound while females were essentially only detected visually (93% of female detections). Notice that detection distances for males and females detected visually is relatively small when compared to males detected aurally in Figure 3. Even for visual detections, males spend more time in open habitat and on higher topographic positions or perches making them more visible to observers and, unlike females, they perform flight displays while singing also making them relatively easy to detect.

Our preliminary analyses of repeated abundance surveys using the protocol in Appendix 2 from the Puget Sound region and from the lower Columbia River/Washington Coast region between 2010 and 2014 support the results from the pilot distance sampling effort on the Columbia River. We found that male detection was higher than that for females in both regions (46-53% vs. 26-28%), which was likely driven by the detection factors discussed above. In fact, based on this survey effort (n = 25 sites, 2010-2014), we detected 1,536 males during repeated visits to these sites (not necessarily unique individuals but they are unique detections) and 49% were detected by song/call. During the same effort, we detected 542 females and only 4% were detected by call indicating a significant difference in the method of detection which ultimately influences detectability. In addition, we found that wind reduced detection probability for males in the Puget Sound region indicating the importance of not conducting surveys under higher wind conditions.

Because virtually all visual detections occurred within 75m (see Figure 3) and detection probability goes up when truncated at 75m when compared to longer distances, we recommend that surveys designed to assess site occupancy should be conducted in a manner so that all suitable lark habitat at a given site within 75 m of an observer is covered. See occupancy protocol in Appendix 1.

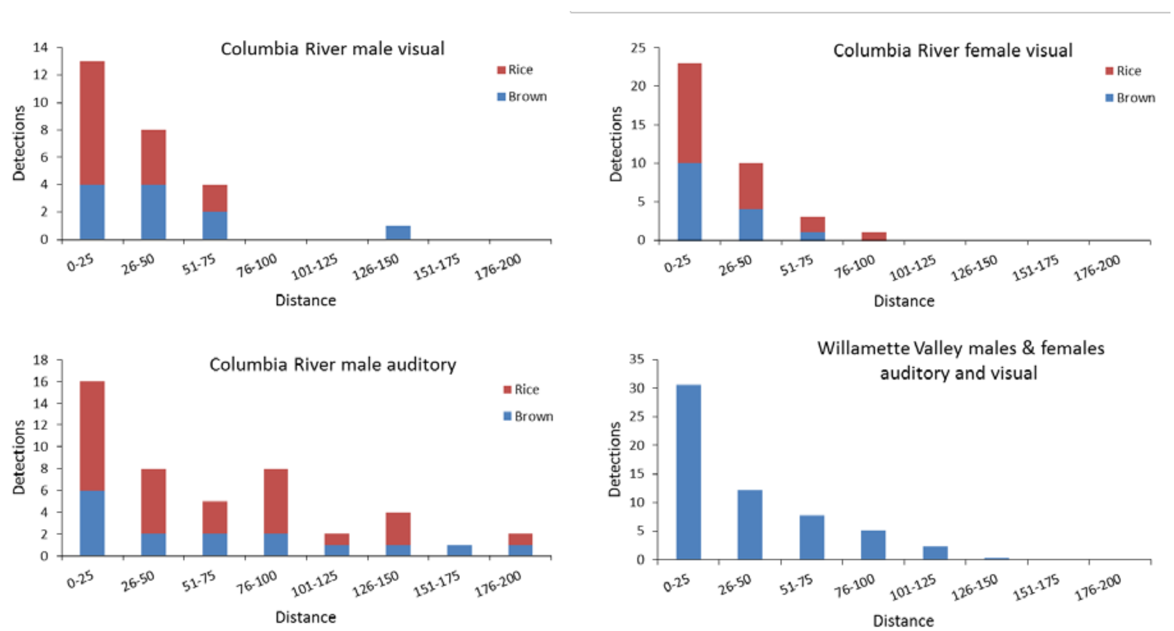

Figure 3. *Number of lark detections by distance (in 25m bins) of male and female streaked horned larks on the lower Columbia River using line transects (perpendicular distances from the transect) and in the Willamette Valley using road-side point counts (radial distances from the observer). Note that the radial distances from the Willamette Valley were standardized by area within distance bins to make them comparable to the other graphs. Columbia River surveys occurred on Rice and Brown islands.*

Accounting for detectability when assessing site occupancy status
Even when surveying within 75m, one's ability to detect a lark that is present is less than 100% with a single visit. As a result, repeated visits to a site are needed to increase the probability of correctly determining a given site's occupancy status. To examine the effect of repeated visits on our ability to assess a site's occupancy status, it is first necessary to calculate lark detection probabilities (p). We focus on male detection probabilities because sex ratios in passerines generally, and for the lark specifically, tend to be male-biased. As a result, it is possible for a site to be occupied by a single male but extremely unlikely for a site to be occupied by a single female during the nesting period without her also having a mate. For this assessment, we assume that the site is walked slowly by an observer so that no suitable habitat is observed from a distance greater than 75m. We also focus on visual detections only because we could imagine a site being occupied by a single non-singing male (at least during one or two hour survey window).

Using the program Distance derived detection from the Columbia River survey effort in 2014, the detection probability for males detected visually within 67 m was 63-64% (area under the curve). This detection probability only pertains to the two islands and the single year included in this study (see Anderson and Slater 2015). Because this effort was limited in temporal and spatial scope, we also examined visual male detection probability using repeated visits from the broader scale and site survey effort in the Puget lowlands, Washington coast and Columbia River (2010-2014). For this survey, we used an N-mixture analysis approach and found male detection probability to be around 46-53% which is lower than what we found from our independent Distance analysis (Keren and Pearson 2015). This difference may be the result of sampling relatively open sites in the two-site lower Columbia effort where it is easier to detect birds visually and where there were a reasonable number of birds. In contrast, the broader assessment included sites with one or two lark pairs to sites with many pairs and included a wide variety of habitats - from dredged material islands with different habitat characteristics, airports, and native prairies - that influence lark detectability. Also in our broader assessment, we found that detection probability was lower in the Puget lowlands when compared to the relatively open habitat of the Columbia River dredge material islands, which is expected. The take home message here is <u>not</u> that one method of determining detection probability is necessarily better, but that it is important to consider that detection probability is influenced by the local lark population size and by local environmental conditions that influence our ability to see and hear larks. In addition, detection probability is influenced by the field methods used (timing, weather restrictions, skill of the observers, etc.). The detection probabilities calculated in this document were derived by relatively skilled observers following the protocols in the appendices of this document. This final influence is a critical assumption when applying these probabilities.

In Figure 4 we plot the relationship between detection probability and number of site visits using the detection probability from both the Columbia River (2014) effort and the broader Puget lowland and Columbia River surveys (2010-2014). Using the lower detection rate from the broader survey (Figure 4, right graph), there is an 84% probability of assessing site occupancy with three visits, a 91% probability with four visits, and a 95% probability with five visits. This all assumes that surveys are conducted following the protocol in Appendix 1. Again, the probability of correctly assessing site occupancy would increase fairly dramatically with an increase in the number of larks actually present at the site. If we use the results from the Columbia River Distance Sampling, there is an 86% probability of assessing site occupancy with three visits, a 93% probability with four visits, and a 96% probability with five visits.

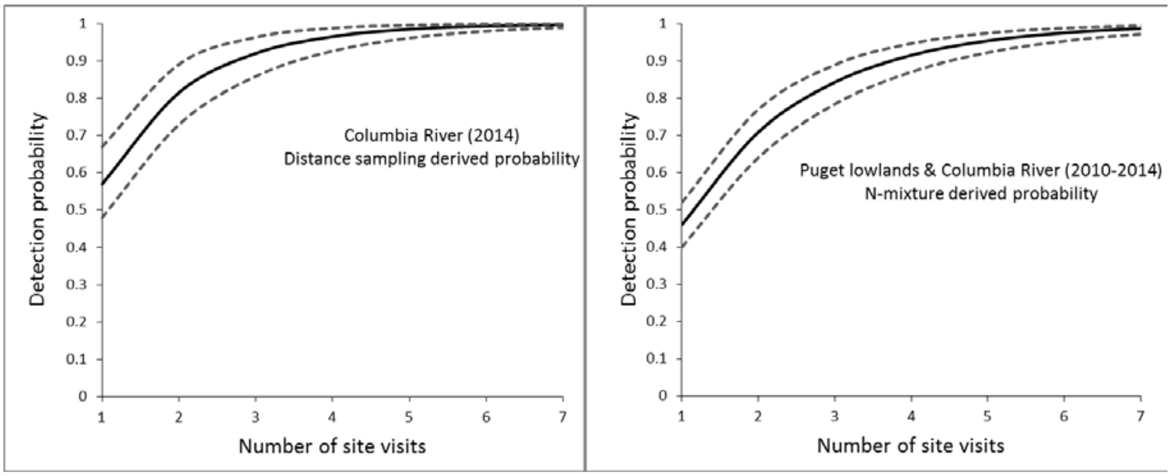

Figure 4. *Assuming a site is occupied, this is the relationship between detection probability and the number of visits to a site using either the detection probability derived from the program Distance using samples from two Columbia River sites in 2014 (left) or that derived using repeated site surveys from may sites in the Puget lowlands, lower Columbia River and Washington coast between 2010 and 2014 (right).*

Assessing site occupancy from road-side counts

Looking at the repeated road-side point counts from a single season (2008) in the Willamette Valley that were conducted by Oregon Department of Fish and Wildlife (ODFW 2008), there is a 62% (SE = 3.6%) probability of detecting larks at a given point count station (n = 93) if they are present at the site. There may be a very different probability of detection within the center of the site that is not surveyed by the road-side point count. We suspect this may be true because larks are often but not always concentrated around field edges that have open habitat. As a consequence, we do not recommend road-side surveys to assess site occupancy status, especially for large sites that may have high quality habitat in the interior. This does not preclude the use of road-side surveys for assessing population trends (see below).

Occupancy & Abundance/trend Protocols

We use the information above on breeding phenology, factors that influence detectability and probability of detection to develop both site occupancy and population abundance and trend protocols. For site occupancy, our goal is to develop a protocol that, when repeated, provides the desired probability of correctly assigning site occupancy status. For abundance and trend, our goal is to provide reasonably precise estimates of abundance and trend using protocol that is readily used by multiple partners.

Site occupancy

Assessing site occupancy status can be critical for determining the distribution of a species or for assessing change in site occupancy over time within suitable habitat (see Anderson and Pearson 2015). Alternatively, within appropriate habitat and for regulatory purposes, one may be required to determine if a site is occupied by breeding streaked horned larks prior to conducting activities that could impact suitable habitat or the species. To assess site occupancy status, we recommend following the protocol in Appendix 1 and check with the US Fish and Wildlife Service to determine the number of surveys that will be needed to be conducted. The objective of this protocol is to have a high probability of detecting the presence of larks at a given site during the breeding period.

Assessing abundance and trends at relatively permanent sites with access

We currently have a reasonably accurate assessment of where streaked horned larks breed in Washington and on the lower Columbia River in Oregon and Washington. This is not to say that all potentially occupied sites have been surveyed and that we fully understand the locations of all breeding birds.

For these occupied sites in the Puget lowlands, lower Columbia River, and for "permanently" occupied sites in the Willamette valley (e.g., Basket Slough and Finley National Wildlife Refuges and the airports) with site access, we recommend assessing abundance and trends using repeated visits to strip transects (150m apart) that cover all of the suitable nesting habitat as defined in Anderson and Pearson (2015). We also considered using line transect or Distance Sampling techniques but are currently not recommending this approach because such surveys require accurate estimates of distance (which is notoriously difficult to achieve, especially with high frequency song) and regular assessment of observers' abilities to accurately estimate distances. With several different agencies and organizations involved in these surveys, we felt that obtaining accurate estimates of distance would be very difficult with adequate quality control.

Instead, we recommend addressing issues of detectability within and among seasons by using repeated visits within season (n = 3 minimum) and an N-mixture modelling approach that incorporates detectability into the model (Dorazio and Royle 2005). We recommend conducting surveys annually for the first five years and then move into surveys every two to three years unless more frequent surveys are needed for management. For detailed protocol see Appendix 2 and for a preliminary description of our analytical approach and results between 2010 and 2014, please refer to Keren and Pearson (2015). In much of Washington and along the lower Columbia River of Oregon and Washington, it may be feasible and desirable to survey the entire suitable habitat at regular intervals. Intervals can range from 1 to five years or more depending on the need for such information.

Assessing abundance and trends in the agricultural landscape of the Willamette Valley

In this document, we don't develop protocol or survey strategies for landscapes dominated by private agriculture. Because so much of the Willamette Valley will likely have moderate to high probability of occurrence (but likely low abundance), using the methods described above will not be tenable in this core part of the subspecies' breeding range. Adding to the difficulty is the fact that the valley is dominated by private agricultural land where access for surveying is impossible or difficult. Here we present a couple of survey strategies to consider. For all of these strategies, we would again recommend starting with a probability of occurrence map as described above that could help stratify the effort and make sampling much more efficient.

A potential sampling approach would be to take advantage of an ongoing survey effort that uses volunteers to gather data. The Breeding Bird Survey (BBS) is a cooperative effort between the U.S. Geological Survey's Patuxent Wildlife Research Center and Environment Canada's Canadian Wildlife Service to monitor the status and trends of North American bird populations. Following a rigorous protocol, BBS data are collected by thousands of volunteers who survey thousands of randomly established roadside routes throughout North America. The sample unit for the BBS is a roadside survey route, and each route is surveyed by a single volunteer observer one time each year during a morning in late-spring/early summer (May-June). Each route is composed of 50 stops, at which a 3 min point count is conducted and all birds heard or seen within ~400 m of the point are counted. BBS analysis approach has been subject to a thorough statistical review (e.g., Link and Sauer 2002, 2007, Sauer et al. 2008, Sauer et al. 2011) and consists of very long-term datasets (≥ 45 years locally) that are well documented. Potential issues to consider if using this sampling approach are statistical power to assess trends (number of routes), representativeness of routes, and the relationship between routes and suitable habitat. If these concerns are addressed, this approach will likely be a good approach for assessing population trends.

Moore (2008c) intentionally developed a survey protocol based on the BBS effort but that addresses these potential issues. Under his strategy, the sampling frame is populated with primary sampling blocks (e.g., 1 minute latitude by 1 minute longitude), and then sampling blocks are randomly selected for sampling during a given survey year. Within the selected blocks, all accessible roadways and all suitable breeding habitat along the roadways are identified. Point count stations are systematically placed along road edges with suitable habitat. Moore (2008c) also describes an approach for estimating the amount of suitable nesting habitat in the sampling blocks and ultimately extrapolating the abundance estimates derived from the point count stations to the total habitat available. Density estimates accounting for detectability can be derived using information on time-of-detection and either a closed population removal analytical framework (Farnsworth et al. 2002) or closed population capture-recapture framework (Alldredge et al. 2007), both of which have been adapted to generate estimates of detection probabilities and density from point count data (Moore 2008c). Although a bit complicated analytically, the additional information needed for these approaches while in the field is relatively easy to acquire.

Another citizen science sampling approach that holds some promise is the use of eBird to assess population distribution and trends. eBird documents the presence or absence of species, as well as bird abundance through checklist data that are entered on-line by the birding community. eBird data have been used to model species probabilities of occurrence across space and time. Spatio-Temporal Exploratory Models (STEM) have been developed using eBird data (Finke et al. 2010). These models relate environmental predictors to observed occurrences that allow researchers to make occurrence predictions at unsampled areas. Recent modelling efforts suggest that eBird data can be used to model relative abundance and ultimately population trend (Johnston et al. 2015). Given the current sparsity of focused eBird data in the regions of the Valley where larks are most abundant, it would likely require a focused lark or agriculture-specific monitoring effort for eBird data to be suitable for estimating lark trend or abundance. However, eBird already provides meaningful information on new localities to check for breeding larks throughout the range based on birders reported sightings.

Regardless of the approach selected, all of these methods may suffer from the same problem in the private agricultural landscape where access is confined to public roads – the potential bias associated with roadside surveys. If larks are more abundant along road edges in an agricultural landscape, then attributing densities resulting from roadside surveys to the interior of an agricultural field is problematic. However, as long as this bias is systematic (e.g., lark density is almost always greater along roads) and it is understood, then these methods would be adequate for estimating population size. To determine if this potential bias exists and to develop a method for addressing it we recommend research project focusing on this relationship. However, this is not necessarily a problem if we are only interested in trend estimates and not population size.

Again, additional effort is needed before selecting a monitoring strategy. Regardless of the strategy selected, it would be ideal to integrate abundance estimates and trends derived from regions where public access is possible with regions where public access is not possible.

In the appendices that follow, we provide occupancy and abundance/trend protocol and a sample data sheet.

Acknowledgements

We thank all of the field biologists in Oregon and Washington that contributed to the various field efforts that informed this protocol development. We thank Bob Altman, Michelle Tirhi, Eric Holman, and Martha Jensen for helpful comments on an earlier version of this document. A special thanks to Martha Jensen, Cat Brown, and Kim Flotlin for supporting this work. This work was funded by US Fish and Wildlife Contract F13AF01196

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Appendix 1: Streaked Horned Lark Site Occupancy Protocol

Introduction: This is not a regulatory document or intended to function as a regulatory document. If landowners are assessing site occupancy status per requirements under the Endangered Species Act, it is critical to work with US Fish and Wildlife Service on how to apply this or other protocols. The effectiveness of this protocol in assessing site occupancy is contingent upon surveyors meeting the outlined qualifications of this document and following the methods outlined below.

Goal: Assess with high confidence a site's occupancy status by streaked horned larks during a given nesting season in suitable habitat. The number of surveys needed to have high confidence in a site's occupancy status for a given year depends on one's comfort level (see Figure 4 above). For determining lark distribution at a state-wide level, three visits may be adequate. However, for regulatory purposes, it is up to the regulating agency to work with the land owner/manager to select the number of site visits needed to meet the detection probability that they believe will minimize risks to a listed species. It is important to keep in mind that occupancy status can change between years and that the purpose of this document is to assess site occupancy status within a given nesting season.

Survey window: Mid-April to mid-July

Method: Survey the entire portion of the site dominated by grasses and forbs (suitable habitat) using strip transects (150 m wide – 75 m to each side of the observer). For information on suitable habitat for breeding larks, please see Anderson and Pearson 2015. Place parallel transects across suitable portions of the site starting 75m from the edge and then every 150m from each other (please see above for justification for this distance). The placement of transects can be accomplished in an ArcGIS environment to identify potential habitat. Once the transects have been identified and mapped, they can be loaded onto a hand-held gps unit. Observers should walk at a slow pace and stop periodically to listen for singing or calling birds.

Number of surveys and survey window: The number of surveys required for a given site will need to be determined by consulting with US Fish and Wildlife Service for regulatory purposes. For our efforts to determine the distribution and abundance of this species, we recommend a minimum of 3 surveys per site within a nesting season (one in late April, a second in mid-June and a final survey in early to mid-July). Please see above for explanation for our information on why we selected the survey window that we did and for information on the relationship between the number of visits and correctly determining a site's occupancy status.

Surveyors: Should be experienced with grassland bird surveys, very competent using binoculars and spotting scopes, should be able to identify all of the grassland associated birds in western Washington and Oregon by sight and sound, and have excellent hearing and eyesight (corrected). Should also be able to distinguish young of the year larks from adults and distinguish the different subspecies of horned larks from each other. Consider testing/training of observers – a training approach needs to be developed.

Time of day: Start surveys within one half hour of sunrise and should be completed by 11:00 am. Surveys can be started before sunrise. Start and finish earlier on days where the temperature will be > 80° F.

Environmental conditions: If conditions such as wind, rain or external noises are affecting your ability to detect larks, then you should reconsider conducting the survey at that time. Some general guidelines:

- Wind: < 15 mph (a couple of brief gusts in excess of 15 are ok)
- Rain: Little to no precipitation (light drizzle and brief showers are fine)
- External noises: does the noise impair your ability to detect larks consistently? (periodic airplane noise where the survey can be halted during the noise and resumed after is not an issue)

Data to be recorded (please see data sheet, Appendix 3):

- General
    - Site name (please be consistent)
    - Date: DD-Mon-YYYY (e.g., 26 Feb 2010)
    - Observers (full name)
    - Length of all transects (in meters) added together for the site. Note: there is no need to number transects or to record transect number.
    - Start and end time (24 hour clock)
- Environmental
    - Average wind speed for the survey (in mph, e.g., 5mph – not 5.3mph)
    - Average temperature for the survey (in Fahrenheit, e.g., 65°F not 65.2°F)
- Bird detection information
    - Species (e.g., SHLA)
    - Age (YOY = young of the year, A = adult, U = unknown)
    - Sex (M = male, F= female, U = unknown)
    - Behavior at the second detected (this is what allowed you to detect the bird)
        - AUD = detected by song or call, VIS = detected by observing with your eyes
            - If AUDIO - when first detected, indicate if it was detected by Song = S, call = C
    - Other behavior (this information is not essential but helps us determine if the site is being used for breeding).
        - Singing = S
        - Flight display = FD
        - Male-female observed together = MF
        - Copulating = CO
        - Carrying nest material = NM
        - Carrying food = FC

        - Nest observed = N (record location with gps and take all precautions to avoid luring predators to the nest. Please do not touch the nest or approach closer than a couple of meters. Note nest contents.
- Behavior codes: These codes provide various forms of evidence of local breeding from the presence of territorial males (weakest evidence) to evidence of local production of young (strongest evidence). These are currently intended to be used qualitatively.
- Maps
    - WDFW/ODFW and USFWS would like to receive orthographic maps of your survey that includes your survey transects, the locations of all birds detected (initial locations), and nest locations.

Appendix 2: Streaked Horned Lark Abundance and Trend Protocol

Goal: Assess regional changes in the breeding season abundance of adult streaked horned larks at sites consistently used by nesting streaked horned larks and where site access is possible and reliable (all Washington sites, lower Columbia River sites and sites like the Corvallis Airport, and the valley National Wildlife Refuges – Finley, Basket Slough). The effectiveness of this protocol is contingent upon surveyors meeting the outlined qualifications of this document and following the methods outlined below.

Survey window: May and June

Method: Survey the entire portion of the site dominated by grasses and forbs (suitable habitat) using strip transects (150 m wide – 75 m to each side of the observer). For information on suitable habitat for breeding larks, please see Anderson and Pearson 2015. Place parallel transects across suitable portions of the site starting 75m from the edge and then every 150m from each other (please see above for justification for this distance). The placement of transects can be accomplished in an ArcGIS environment to identify potential habitat. Once the transects have been identified, they can be loaded onto a hand-held gps unit. Observers should walk at a slow pace and stop periodically to listen for singing or calling birds.

Number of surveys and survey window: A minimum of 2 surveys per site within a given nesting season but preferably 3 surveys evenly between early May and late June. Please see above for explanation for the number of visits and for the survey window.

Surveyors: Should be experienced with grassland bird surveys, very competent using binoculars and spotting scopes, should be able to identify all of the grassland associated birds in western Washington and Oregon by sight and sound, and have excellent hearing and eyesight (corrected). Should also be able to distinguish young of the year larks from adults and distinguish the different subspecies of horned larks from each other. Consider testing/training of observers – a training approach needs to be developed.

Time of day: Ideally, start surveys within a half hour of sunrise and complete surveys by 11:00 am. Surveys can be started before sunrise. We recognize that surveying the Columbia River islands is a challenge and we therefore recommend relaxing these timing restrictions for those surveys to allow for time to transit to and between islands. Start and finish earlier on days where the temperature will be > 80° F.

Environmental conditions: If conditions such as wind, rain or external noises are affecting your ability to detect larks, then you should reconsider conducting the survey at that time. Some general guidelines:

- Wind: < 15 mph (a couple of brief gusts in excess of 15 are ok)
- Rain: Little to no precipitation (light drizzle and brief showers are fine)

- External noises: does the noise impair your ability to detect larks consistently? (periodic airplane noise where the survey can be halted during the noise and resumed after is not an issue)

Data to be recorded (please see data sheet, Appendix 3):

- General
  - Site name (please be consistent)
  - Date: DD-Mon-YYYY (e.g., 26 Feb 2010)
  - Observers (full name)
  - Length of all transects (in meters) added together for the site (do not change the location or length of transect covered between visits within a season!!!). Note: there is no need to number transects or to record transect number.
  - Start and end time (24hour clock)
- Environmental
  - Average wind speed for the survey (in mph, e.g., 5mph – not 5.3mph)
  - Average temperature for the survey (in Fahrenheit, e.g., 65°F not 65.2°F)
- Bird detection information
  - Species (e.g., SHLA)
  - Age (YOY = young of the year, A = adult, U = unknown)
  - Sex (M = male, F= female, U = unknown)
  - Behavior at the second detected (this is what allowed you to detect the bird)
    - AUD = detected by song or call, VIS = detected by observing with your eyes
      - If AUDIO - when first detected, indicate if it was detected by Song = S, call = C
  - Other behavior (this information is not essential but helps us determine if the site is being used for breeding).
    - Singing = S
    - Flight display = FD
    - Male-female observed together = MF
    - Copulating = CO
    - Carrying nest material = NM
    - Carrying food = FC
    - Nest observed = N (record location with gps and take all precautions to avoid luring predators to the nest. Please do not touch the nest or approach closer than a couple of meters. Note nest contents.
- Behavior codes: These codes provide various forms of evidence of local breeding from the presence of territorial males (weakest evidence) to evidence of local production of young (strongest evidence). These are currently intended to be used qualitatively.
- Maps
  - WDFW/ODFW (depending on the State) and USFWS would receive orthographic maps of your survey that includes your survey transects, the locations of all birds detected (initial locations), and nest locations.

Streaked Horned Lark Bird Detection Form (20 March 2015)

Site:_______________________________ Date (DD-Mon-YYYY):___________________OBSERVER: _____________________

Start time (24 hr):____________________ End time (24hr):______________________ OBSERVER (2): ___________________

Ave. temp (°F):________ Ave. wind (mph):__________

Predators/competitors (tally number)	
WEME	
AMCR	
CORA	
CORVID	
NOHA	
KILL	
VESP	
AMKE	
Other	

Data Codes

Age: A = Adult, YOY = young of the year, U = unknown

Sex: M = Male, F = Female, U = unknown

Initial Detection (choose only one):

If audio: If initial detection was audio pick **S**ong or **C**all

Other Behavior (circle all that apply): S= Song, FD = flight display, MF = male within few meters of female, CO = copulation, NM = nest material, FC = food carry

Bird#	**Time**	**Age**	**Sex**	**Initial Detctn**	**If AUDIO Pick 1**		**Other Behavior Circle all that apply**						**Notes - If banded record color.**
1				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
2				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
3				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
4				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
5				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
6				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
7				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
8				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
9				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
10				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
11				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
12				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
13				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
14				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
15				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	
16				VIS / AUD	S	C	S	FD	MF	CO	NM	FC	

*Record color for left leg first, right leg second; record color top to bottom for each leg.

Bold is color code: **A**qua, **B**lue, **G**reen, Blac**K**, Brow**N**, **L**ime, **O**range, **P**ink, **R**ed, **S**ilver, **V**iolet, **W**hite, **Y**ellow