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Spatial Analysis of Oregon Vesper Sparrow Territories in Western Washington

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ABSTRACT

Spatial Analysis of Oregon Vesper Sparrow

Territories in Western Washington

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The Oregon Vesper Sparrow (*Pooecetes gramineus affinis*), a ground nesting passerine species considered threatened in Washington state, is in the process of being petitioned for listing under the U.S. Endangered Species Act. Breeding populations of this prairie obligate species have declined over the last century in Washington state due to the destruction of prairie habitat, further fragmenting their available habitat and isolating populations. Prairie habitats in North America have drastically declined in the last century largely due to anthropogenic pressures such as urbanization and agriculture. Many researchers consider grassland bird species to be the most threatened group of birds in the United States. My research examines the landscape composition of two currently occupied Oregon Vesper Sparrow breeding sites in western Washington, the North Weir prairie and the Artillery Impact Range (AIA) on Joint Base Lewis McChord. I included tree presence and distance to nearest road edge in logistic regression models for nest territories occupied by Oregon Vesper Sparrow breeding pairs during the 2018 and 2019 breeding seasons, and unoccupied random locations. Occupied nest territories tended to be closer to roads on the AIA in 2018, but other site/year combinations did not yield significant differences between occupied and unoccupied locations. Scientific literature on this subspecies of the Vesper Sparrow (*Pooectes gramineus*) is limited, and the results of my spatial analysis may aid researchers and land managers in conservation efforts for this nearly extirpated species when considering landscape composition in fragmented prairies.

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Acknowledgments

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Introduction

From the fruition of Euro-american settlement from coast to coast spanning into the 21st century, North American prairie habitats, once the continent's dominant ecoregion, have shifted dramatically in size, composition, and function (Herkert et al. 2003). Such effects can significantly alter ecosystem services for native and migratory species. The principle feature of North American grasslands is the dominance of herbaceous vegetation with low, but varying, numbers of shrubs and scattered trees (Samson and Knopf 1996). Today all three prairie landscape types, tall-grass, mixed-grass, and short-grass continue to disappear under the pressures of urban expansion, agricultural land use, and infrastructure development (Altman 2011; Herkert et al. 2003).

Grasslands, or prairies, are among the most distinctive and endangered wildlife habitats in Oregon and Washington with an array of vertebrates which occur rarely anywhere else on the west coast (Johnson and O'Neil 2001). They specifically are found in close proximity to where most of the human population reside in Washington State, which has resulted in continued prairie landscape fragmentation and habitat degradation. Some prairies found in western Washington can be characterized by open landscapes of herbaceous plants, occurrence of periodic fire, seasonal flooding, and variation of soil composition created by vegetation and successional conditions of native flora (Agee 1993).

Savannas in the Pacific Northwest, such as the Puget Lowlands are dry prairies with presence of widely scattered trees or small open-canopy tree groves with <30% cover (Agee 1993). This contrasts with wet prairies, such as the Willamette Valley of Oregon where the soil is hydric (Caplow and Miller 2004). Soil type assessment of pre-Euro-American settlement indicate the South Puget Lowlands contained over 60,000 ha of prairie habitat, approximately 10% of the total landscape. Since then there have been major shifts in the overall landscape structure. Current estimates of total prairie composition is just 5,000 ha, with 91% of that total contained in the Joint Base Lewis-McChord military installation (Crawford and Hall 1997). Only about 3% of the original prairies remain as unbroken (non-fragmented) prairie habitat, with the majority of that (71% or 862 ha) on Joint Base Lewis-McChord managed lands.

The sharp decline of prairie habitat in areas of western Washington and Oregon is largely associated with shifting management practices of the landscape since the mid 1800's. When considering changes from historical prairie conditions to modern conditions, fire manipulation, agricultural development and urbanization have been strong pressures in instigating these changes (Johnson and O'Neil 2001). Original fire burning practices on prairie habitats by indigenous communities are viewed as not detrimental to grassland habitats during that time (Shelvey and Boyd 2000; Hamman et al. 2011). Tribal communities used fire to halt forests from encroaching on prairie habitats, as well as to maximize camas (*Camassia quamash*) production, at least in South Puget Sound (Storm and Shebitz 2006). In turn, ensuring viable hunting and foraging grounds were present to sustain the communities, creating an equilibrium relationship between the needs of the tribes and the sustainability of the environment (White 1975; J. G. Cooper 1859). However, fire suppression practices by Euro-Americans in mid 1800s began to significantly degrade prairie habitat, allowing thatch, moss and forest vegetation inhibit the growth and succession of native prairie vegetation (Boyd 1999; Hamman et al. 2011; Taylor and Boss 1975).

Most prairie and shrubland habitats across the states have been affected by decades of livestock grazing, a major avenue for the introduction of exotic and invasive vegetation to displace native vegetation (Daubenmire 1988). These changes to native herb communities due to excessive grazing and fire can result in climax of zoonotic communities which differ historically to the habitat and lessen the environmental services for native species (Daubenmire 1988). The homogenous structure of these disturbed habitats results in lower diversity in some taxa such as arboreal mammals or canopy nesting birds (Johnson and O'Neil 2001). Losses of grassland in the Puget Lowlands equate to >90%, while the Willamette Valley has experienced even greater losses of >99% (Crawford and Hall 1997; Altman 2011).

Species highly susceptible to land disturbance pressures include native, prairie specialist plants, unable to compete with the volume density of forest species, and grassland birds (Foster and Shaff 2003; Peterjohn and Sauer 1999). Grassland birds are amongst the most affected by these habitat shifts and are considered to be the most threatened group of birds in North America (McLaughlin et al. 2014; Peterjohn and Sauer 1999; Coppedge et al. 2001). High sensitivity to ecosystem shifts of grassland birds stem from a number of factors including food supply, shelter needs, space requirements, micro-habitats, landscape composition, and increased populations of competitors and/or predators (Newton 1998; Snow 1954; Fuller 2012). Present trends in grassland avifauna populations worldwide are in decline for native and endemic species while an increase of exotic species, such as the European Starling (*Sturnus vulgaris*), are increasing the offset of native to invasive species ratios on the prairies (Knopf 1994). One such species is the Oregon Vesper Sparrow (*Pooecetes gramineus affinis*). Oregon Vesper Sparrows require prairie-oak mixed grass habitat in the Pacific Northwest for optimal breeding and brood rearing conditions (Altman 2011). As this state listed "species of concern" loses breeding habitat, populations become increasingly isolated and observations increasingly become anecdotal than quantifiable, galvanizing advocates for enlistment under the Endangered Species Act (Altman 2011; Kurth 2018).

Within the history of scientific literature and observational reports, Oregon Vesper Sparrows were much more abundant than they are today. During the time of Euro-American settlement in the Pacific North West from the 1800's to the 1900's the species were able to persist in newly created agricultural grasslands such as hayfields and pasture and described as "abundant or common" (Anthony 1886; Dawson and Bowles 1909; Hoffmann 1927). Soon after, declines in breeding populations started to trend as noted by land surveyors and researchers. Contemporary research in the scientific literature marks the continuation of declining population trends of the species in western Washington and Oregon (Altman 2011). For example, 1996 censusing of species highly associated with native grasslands found the Oregon Vesper Sparrow and Western Meadowlark (*Sturnella neglecta*) to be considered uncommon or rare (Johnson and O'Neil 2001).

Oregon Vesper Sparrows and other grassland birds are ground nesting species, utilizing forbs and tall grasses to create nest cavities in the soil on the prairies (Altman 2011; 2017; Canada 2018). Ground nesting is an adaptation to life in an herbaceous, open landscape. Birds are able to utilize vegetation height, cover, and density to conceal their nests from predators and competitors (Burger, Burger, and Faaborg 1994). In Washington and Oregon, Oregon Vesper Sparrows are considered uncommon, scattered widely in areas of the Willamette Valley and the Puget Lowlands in the Puget Lowlands

(Altman 2011). The species regularly occur only in the San Juan Islands and on prairies of the South Puget Lowlands, especially on Joint Base Lewis-McCord managed lands, such as the North and South Weir prairies, and were once considered abundant throughout the Puget Sound and on the Nisqually plains (R. E. Rogers 2000; J. G. Cooper 1859).

In the wake of shifting matrices in grassland landscapes, the mechanisms of Oregon Vesper Sparrow decline remain largely unexamined. Especially in one of the few habitats where the species regularly visit during the breeding season, the North Weir prairie, broken into upper and lower Weir. The same can be said for the majority of prairie obligate species. Understanding the implications of habitat loss, landscape shifts, and fragmentation of said areas in relation to grassland bird species is considered by many to still be poorly understood (Davis et al. 2006; Winter et al. 2006; Grant, Madden, and Berkey 2004).

The goal of my research is to examine possible associations between landscape components within the matrix, and nest selection of Oregon Vesper Sparrow breeding populations in the Weir prairies. Furthermore, I will explore why research regarding grassland birds and prairie habitats are difficult to quantify and often involve opposing study methods and results. Utilizing field observations taken by the Center for Natural Lands Management and myself, ESRI's ArcGIS software for mapping and spatial analysis and a verifiable, approach to the issue, I hope to provide data and insights valuable for the conservation and management of the Oregon Vesper Sparrow.

Literature Review

Oregon Vesper Sparrow Background

The Oregon Vesper Sparrow (*Pooecetes gramineus affinis*), a ground nesting passerine bird classified as one of four, some contest one of three (A.O.U. 1957), subspecies of the Vesper Sparrow (*Pooecetes gramineus*) (Sibley 2001; Pyle 1997), has been a species of concern for conservation groups and land managers in recent decades. Currently the species is under petition for enlistment and protection under the Endangered Species Act (Kurth 2018). Washington and Oregon list the Oregon Vesper Sparrow as a species of concern but is considered endangered by the Canadian government (Beauchesne 2006). The 2000 Oregon-Washington PIF Bird Conservation Plan stated the objective to "Maintain or target for establishment >10 breeding populations (i.e., >10 pairs) in grassland habitats in each sub-province (i.e., ecoregion) in the next 10 years (by 2010)" (Altman 2000). In 2017, the population establishment objectives of the Oregon-Washington PIF for the Puget Lowlands were, "Increase the current estimated Population of 175 birds by ≥ 77% to ≥309 birds" (Altman 2017).

Due to the species decline over the last century and increasing isolation of breeding populations, little scientific research has been done on this subspecies other than a few preliminary studies. For instance, while the Oregon Vesper Sparrow has been accepted as a distinct subspecies of the Vesper Sparrow based on the morphological species concept (Pyle 1997). No genetic information has been collected for assessment (Altman 2017). While the application of the morphological species concept is widely used to differentiate species, it has potential limitations when considering subspecies. A species such as the Oregon Vesper Sparrow being geographically isolated from Vesper Sparrow with similar phylogenetic characteristics is subject to scrutiny if it is an actual subspecies within this particular species concept. A condition of the morphological species concept is two different species cannot reproduce sexually (Simpson 1951). Oregon Vesper Sparrow populations are the only breeding populations of all Vesper Sparrow populations and subspecies populations west of the Cascade Mountains (Altman 2011; A.O.U. 1957). Due to isolation of breeding populations between the two species and the similarities in characteristics, the genetic species concept may be better suited for species classification. For instance, identifying *P. g. affinis* from the *P. g. confinis*, a subspecies which frequents Nebraska, in field conditions has not been successfully (Campbell et al. 2001).

Acquiring genetic information, or genome, from Oregon Vesper Sparrow populations will allow researchers to compare it against that of Vesper Sparrow populations. The genomic comparisons between the two species will prompt species classification under the genetic species concept, classifying populations as separate species which have the ability interbreed but are considered genetically distinct (Baker and Bradley 2006). The genetic species concept is considered advantageous over the morphological species concept in understanding biodiversity and speciation of animals over the evolutionary process (Baker and Bradley 2006).

Range & Breeding

Oregon Vesper Sparrow range reaches from Southern Canada down to South California(Altman 2011; 2017) (**Figure 1**). Breeding ranges are restricted to fragmented prairie remnants in Southwestern British Columbia, western Washington, Western Oregon, and Northern California (Altman 2017; A.O.U. 1957; Campbell et al. 2001). The breeding season typically lasts from April to mid/late June and migratory dispersal post breeding season is undocumented in terms of flight patterns and pathways (Altman 2017). Wintering range occupation for the species are estimated to occur from September to April in Southern California (Willett 1933). However, there are no available records of movements or behavior within wintering ranges and it is assumed Oregon Vesper Sparrow populations occupy the lowlands of southwestern British Columbia during the summer (Campbell et al. 2001).

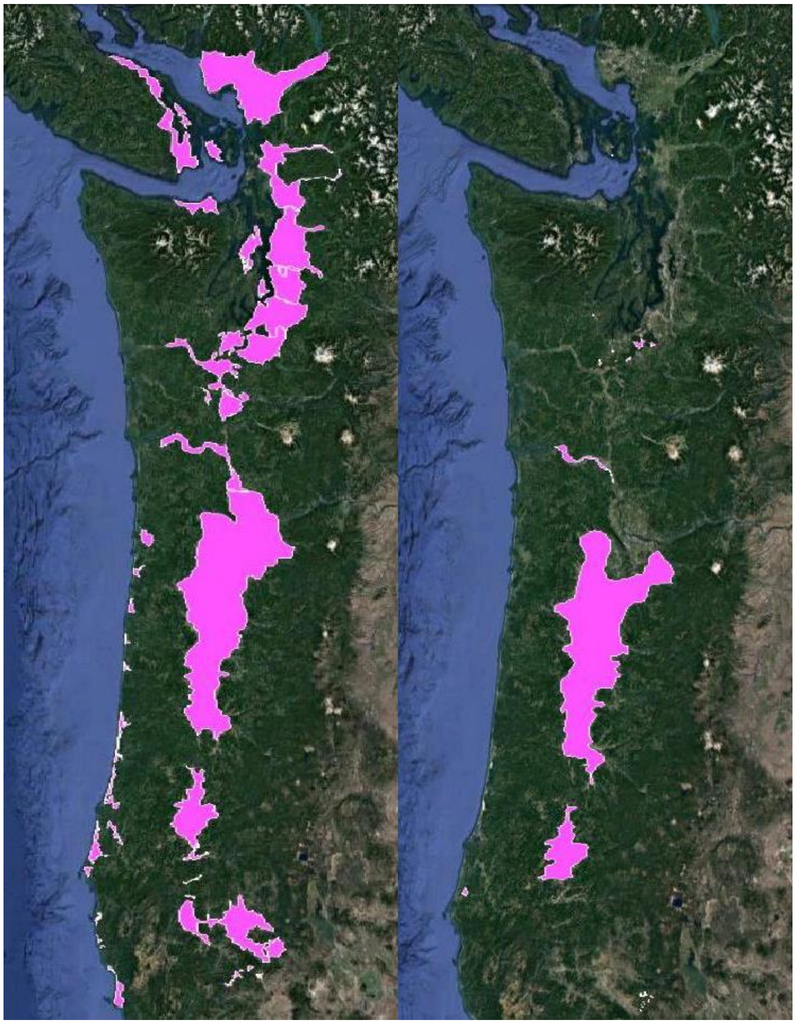

Figure 1. Historic Oregon Vesper Sparrow Distribution (Left) vs Current Distribution (Right) (Altman 2017).

Within the last century, sightings of Oregon Vesper Sparrow sightings has become more anecdotal, likely due to the increase of habitat loss and urbanization and uncertainty in field identification (Herkert et al. 2003; P. W. Dunwiddie and Bakker 2011; Altman 2011). There is high confidence that 95% of Oregon Vesper Sparrow breeding range lies within U.S. Forest Service and Joint Base Lewis-McCord managed lands in Washington and western Oregon (Altman 2017). The prevalence of breeding habitats within these administered lands points to a possible positive correlation between managed protected lands and the needs of a habitat specialist.

Oregon Vesper Sparrows could be considered habitat specialists based on their requirement of prairie habitat to breed, making them prairie obligate (Rosenzweig 1981; Kurth 2018). However, this is contested as they have also been referred to as moderate habitat generalists due to the general nature of their prairie habitat needs (Altman 2017). I argue they are more accurately categorized as habitat specialists, contesting the generalist label, due to the lack of published systematic research and the increasing lack of habitat availability. Habitat specialists are defined as having improved phenotypic fitness in a particular specialized habitat, reducing energetic searching and foraging costs within said habitat (Rosenzweig 1981). As prairie habitat loss persists, particularly in Washington and Oregon, we can expect the possibility of further declining Oregon Vesper Sparrow populations as they are unlikely to adapt to other common forms of habitat like urban or forest.

Feeding and Nesting Timeline

Feeding habits of the Oregon Vesper Sparrow are unknown, although I have observed them carrying insects back to the nests and others report they also feed on low forbs and dandelion seeds (*Taraxacum officinale*) (Altman 2017). (Rodenhouse and Best 1994) observed foraging activities for insects through vegetation exclusively through their breeding territories. It is likely they have a flexible, opportunistic diet due to the climate variance between their breeding and wintering ranges (Altman 2017).

During the nesting season, females build nests out of grasses and rootlets in shallow depressions on the ground, often next to clumps of vegetation, dirt clods or under a tree or shrub (Jones, and Cornely 2002; Marshall, Hunter, and Conreras 2003) . Nesting success is relatively high at 64% with average clutch size of four eggs (Altman 2017). There is limited data on average incubation time of the Oregon Vesper Sparrow. Although, Vesper Sparrow incubation is averaged at 12 – 13 days, nestlings fledge from the nest after 9 – 10 days and are dependent on their parents for 20 – 30 additional days (Bent 1968). During this time, adults move their young to shrubby areas for cover as they are still dependent or semi-dependent on the care of their parents (Altman 2017).

Avian Prairie Species Under Threat

Like the Oregon Vesper Sparrow, many avian species requiring the breeding habitats on prairies in North America are ground nesting, making them significantly susceptible to the negative influences of fragmentation and habitat loss (Herkert et al. 2003; Fahrig 2003); such as the Horned Lark (*Eremophila alpestris*) and Sprague's Pipit (*Anthus spragueii*) (Grant, Madden, and Berkey 2004). Widespread prairie loss generates adverse habitat conditions, resulting in many experts stating grassland birds as the most threatened group of avian species in North America (Peterjohn and Sauer 1999). In part because prairie obligate species require regional specific shrub and forb cover (Altman 2011) for nest excavation and laying on the open ground, making them significantly more sensitive to habitat fragmentation than generalists (Burger, Burger, and Faaborg 1994). Decades of scientific research indicates declines in grassland bird populations result from habitat fragmentation and edge effects related disturbances (Burger, Burger, and Faaborg 1994; Herkert et al. 2003). Smaller fragment sizes of habitat can lead to increase in nest predation and the introduction of predators from neighboring habitat types caused by edge effect exposure (Herkert et al. 2003).

Fragmentation & Habitat Loss

Fragmentation occurs when a landscape is broken apart in its continuity, resulting in habitat loss (Fahrig 2003), which can lower habitat quality and viability for local populations. The theory of landscape fragmentation and how it effects populations at the local scale and ephemeral populations within the concerned area has been well researched in the theoretical realm (Anderwartha and Birch 1984). To that point, (Fahrig and Merriam 1994) argue when these models are put into practice they can become problematic in application for they don't take into consideration the specifics of landscape spatial structure. Fahrig and Merriam define landscape spatial structure as the spatial relationships among the landscape components. These components include the overall habitat matrix, which are imbedded with habitat patches, or any discrete area utilized by species for breeding, foraging, or its established niche (Fahrig and Merriam 1994).

The complexity and challenges researchers have when examining and quantifying the effects of habitat fragmentation in field conditions may be due to not distinguishing the process of habitat loss from the process of habitat fragmentation. Thus, results may not be consistent with the theory on how habitat fragmentation affects populations and biodiversity. The habitat fragmentation concept is derived from the isolation biogeography theory, measuring the variables and relationship of island isolation from a mainland (Fahrig 2003). Isolation in the concept of habitat fragmentation is a result of habitat loss and implies loss of connectivity, even though connectivity still exists throughout the landscape for populations to utilize.

Fahrig (2003) argues fragmentation and habitat loss should be measured independently to understand the nature of biodiversity loss resulting from fragmentation. She states habitat loss is consistently negative for biodiversity while fragmentation is much weaker on the scale of negativity for biodiversity loss, while in some cases has been shown to have positive influences on species populations. Habitat loss reduces trophic chain length (Komonen et al. 2000), the number of habitat specialists and large bodied species (Gibbs and Stanton 2001), and breeding success of occupying populations (Pither and Taylor 1998).

Habitat types can also vary within the composition of a landscape. Fragmentation does not take into consideration the inherent differences of habitat type within the overall landscape which already existed (Mac Nally, Bennett, and Horrocks 2000). Furthermore, characterization of habitat fragmentation is strictly qualitative; meaning a landscape is either continuous or fragmented (Fahrig 2003). This theoretical design does not permit a true relationship between the degree and magnitude of biodiversity response to be examined.

An additional point Fahrig uses to support her claim is habitat fragmentation theory generally implies a reduction in habitat amount, increase in habitat patch quantity, decrease in patch size, and increased isolation between patches. In real world practicality, a fragmented landscape can have only 1 or a few of these conditions rather than all at once. Briefly, consider the condition of patch size in more detail within theoretical and real-world conditions. In theory, patch size can be an ambiguous measurement of fragmentation and often leads to misinterpretation of results because both fragmentation and habitat loss result in smaller patches (Niemela 2001)

While studies reflect smaller patches can lower biodiversity in a fragmented landscape, it can also increase biodiversity by proving habitat for immigrating populations and refuge for prey species, which improves predator-prey dynamics (Huffaker 1958; Bowman, Cappuccino, and Fahrig 2002). Additionally, smaller patches can vary the types of habitat within the landscape; a condition which provides beneficial services for certain species (Law and Dickman 1998).

The dispute of this viewpoint which strays from the conventional way of viewing and approaching the concept of habitat fragmentation should be noted. (Fletcher et al. 2018) agrees with Fahrig that habitat loss has well known negative impacts on biodiversity and small scale fragments may have conservation value for biodiversity and ecosystem services (Mitchell, Bennett, and Gonzalez 2014). Also, the term 'habitat fragmentation' can be loosely referred to overall process of habitat configuration change. Yet, he argues Fahrig's description on habitat fragmentation and habitat loss is not valid; because habitat loss and fragmentation are not empirically independent but are frequently linked.

Further criticism of Fahrig from Fletcher state Fahrig's view of fragmentation being beneficial to biodiversity runs counter to mainstream empirical and theoretical literature of the ecological research community. Essentially stating the consensus is not aware to the positive effects of habitat fragmentation. In turn leading to major implications for the ongoing management of fragmented ecosystems on a global scale. Fahrig's review of literature to support her claims were composed only of landscape scale studies, ignoring patch scale studies, complex effects of fragmentation were not included, and results were taken solely from tables and figures while the main text of research was ignored.

In response to Fletcher, (Fahrig et al. 2019) disagrees with the criticism made about her statements theorizing the largely positive effects of habitat fragmentation. Based on Fletcher's argument of habitat fragmentation having negative effects on biodiversity and ecosystem services is extrapolated from studies which largely only consider patch-scale patterns and mechanisms, edge effects and patch isolation. Fahrig claims this line of research is unreliable because mechanism dynamics are ignored on the landscape scale and can counteract negative effects in patch scale models by increasing habitat diversity. Extrapolating small scale mechanisms to large scale models of habitat fragmentation is not a basis for predicting fragmentation implications as these types of models are not predictable in nature. (Fahrig 2003; 1998) contemplates the dynamics of habitat fragmentation at a landscape matrix scale rather than small scale habitat patches. Habitats vary in shapes and sizes, thus the fragmented patches within the matrix can have differing effects on overall habitat quality, which species can respond to in a variety of ways (Fahrig et al. 2019). Because most of the habitat fragmentation studies are focused on small scale studies, the true effects of the process are confounded when applied to larger landscape scales. In turn, this may be a reason why many of the studies of fragmentation on habitats where avian assemblages are affected can contradict each other and still not shed full light on the issue after decades of research.

Regarding my research, which implicitly seeks to understand the implications of habitat fragmentation on nesting success of Oregon Vesper Sparrow breeding populations; I examine fragmentation on the landscape scale matrix, rather than individual patches within my study area. Without the limitations of time and resources, I would have preferred to have examined this to fuller extent incorporating predator, soil and corridor variables within and between my study sites. The distinction of habitat fragmentation from habitat loss is implied within my study design. If the effects of fragmentation are not significant or non-existent within the bounds of my research a design testing habitat loss independent of fragmentation will be recommended.

Fragmentation: Changes in Landscape Composition

Extinctions of local populations within fragmented habitats are common and population survivability or recolonization are dependent on the spatial relationships among landscape elements. These elements include patch size and shape, movement ability within the inner-patch matrix, and dispersal characteristics of the species and temporal changes in the landscape (Fahrig and Merriam 1994).

Patches: Size, Shape and Interconnection

Local population persistence in the wake of fragmented habitat has shown to be dependent on the size of a patch; as shown by (Verboom et al. 1991) in studying patch size and persistence of European Nuthatch (*Sitta europea*) local populations. Additionally, population survival is dependent on patch shape when considering the distance from edge to patch. (Gates and Gysel 1978) find that local populations of passerine birds increased at the edge bordering field and forest habitat, but with consequences of increased rates in nest parasitism and predation.

Quality of the patch has influence of survival and abundance of local populations as well. Lower habitat quality is usually associated with smaller area of patch interior with greater edge habitat, fewer species and resources, and lack of local habitat specialist populations; resulting in lower reproductive which effects recolonization, an essential factor in local species survivability (Herkert et al. 2003; Skagen, Adams, and Adams 2005). Patch quality influences habitat dispersal throughout the matrix to which an organism can move from one patch to the next. These dispersal routes, or corridors, connect habitat patches to one another and either enhance or reduce population survivability (Fahrig and Merriam 1994; Henein, Wegner, and Merriam 1998; Hobbs, Higgs, and Harris 2009).

However, (Lefkovitch and Fahrig 1985) suggest total number of dispersal routes within a landscape may be less important than corridor configuration in relation to the landscape patches, the overall structure and component make-up of the landscape. The spatial patterns of habitat patches are considered the most important factor in population sustainability because the dispersal routes within the spatial pattern of the matrix can allow or hinder populations to find new patches (Fahrig 1998). In other words, the smaller the dispersal distances between small patches, the better chance of survivability.

Temporal Shifts in Habitat

The time scale plays a critical role in landscape viability as well. Gradual or abrupt changes within the landscape structure over time due to fragmentation or habitat removal increase or decrease in quality and number of dispersal routes; and spatial reorganization of the patches occur normally on longer time scales, especially in prairie habitat (Altman 2011; Urban and Keitt 2001). Whether these changes are naturally occurring or due to anthropogenic influences, the effect of the landscape structure influences local and regional population survivability with it. Survivability of regional populations during these temporal changes depends on the dispersal behavior which are learned or genetically based due to strong selection pressure over time (Merriam 1991).

If dispersal behavior is greater than the rate of change in a landscape's spatial structure the species has a greater chance of surviving because of the ability to move around the matrix, integrating resources from the patches and offset searching costs (Fahrig and Merriam 1994; Fahrig 2003; Rosenzweig 1981). This can be particularly important in local populations consisting of habitat specialists like the Oregon Vesper Sparrow.

Prairie Loss in the Pacific Northwest

All three prairie landscape types, tall-grass, mixed-grass and short-grass, continue to disappear under the pressures of urban expansion, agricultural land use transformation, and infrastructure development (Altman 2011). Tall-grass prairie has lost 82-99% of total habitat while short-grass prairie, the least disturbed prairie type, covers just 40% of original range; mixed-grass prairie has declined 72-99% across its traditional territory (Samson and Knopf 1996).

In the western United States mixed-grass prairies can be located on coastal regions with unique vegetation crucial to prairie species biodiversity. Prairies and savannahs in California, Oregon and Washington provide critical habitat for habitat specialists which require the dry and open conditions in otherwise coniferous dominated regions (Altman 2011; Franklin and Dyrness 1973; Hanna and Dunn 1997). In western Washington, 9% of the original 73,000 ha grasslands are present, with only 2-3% dominated by native species (Crawford and Hall 1997; Chappell et al. 2001).

Land use and urban development pressures in the Pacific Northwest continue to degrade native prairie-oak habitats, making these ecoregions one of the most threatened in the region and most threatened bird habitats in the United States (Floberg et al. 2004). Coastal oak (*Quercus garryana*), also known as garry oak or white oak, a tree species found along the coasts from California to British Columbia crucial for prairie bird assemblages, is increasingly found in isolated patches resulting from encroachment by non-prairie species such as the non-native Scotch broom (*Cytisus scoparius*) and native Douglas fir (*Pseudotsuga menziesii*) (Hanna and Dunn 1997; Feldman and Krannitz 2004; Altman 2011). The Puget Lowlands of Washington retain only 10% of original prairie-oak habitat (Hall, Crawford, and Stephens 1995), while less than 1% grassland prairie remains in the Willamette Valley (Alverson 2005). Loss of these habitats is not new. Since Euro-American settlement, the south Puget Sound has lost over 50% of crucial oak-prairie habitat to land conversion and development (Hanna and Dunn 1997) (**Figure 2**). The largest remnants of prairie ecosystems today are contained and managed by Joint Base Lewis-McChord (P. W. Dunwiddie and Bakker 2011; Maan 2017) (**Figure 3**).

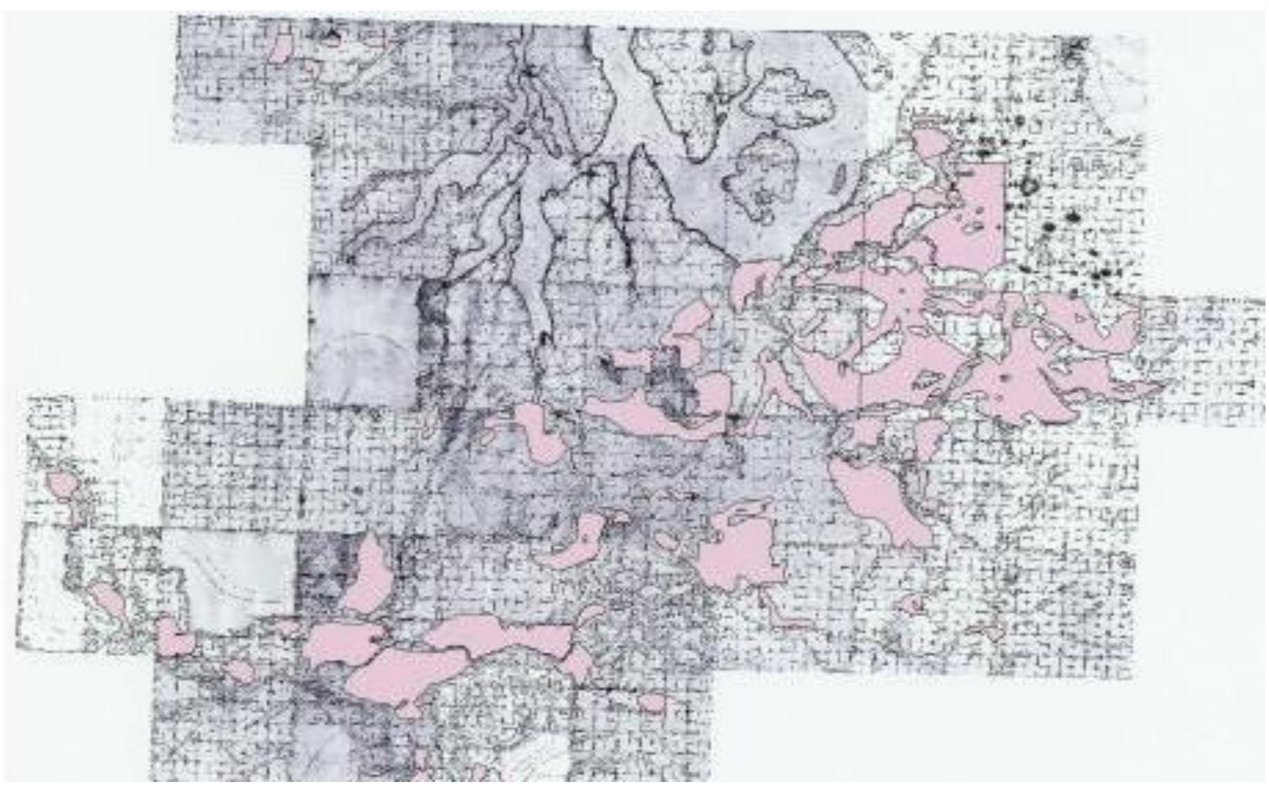

Figure 2 Surveyed prairies through 1853-1876 (Easterly, Salstrom, and Chappell 2005)

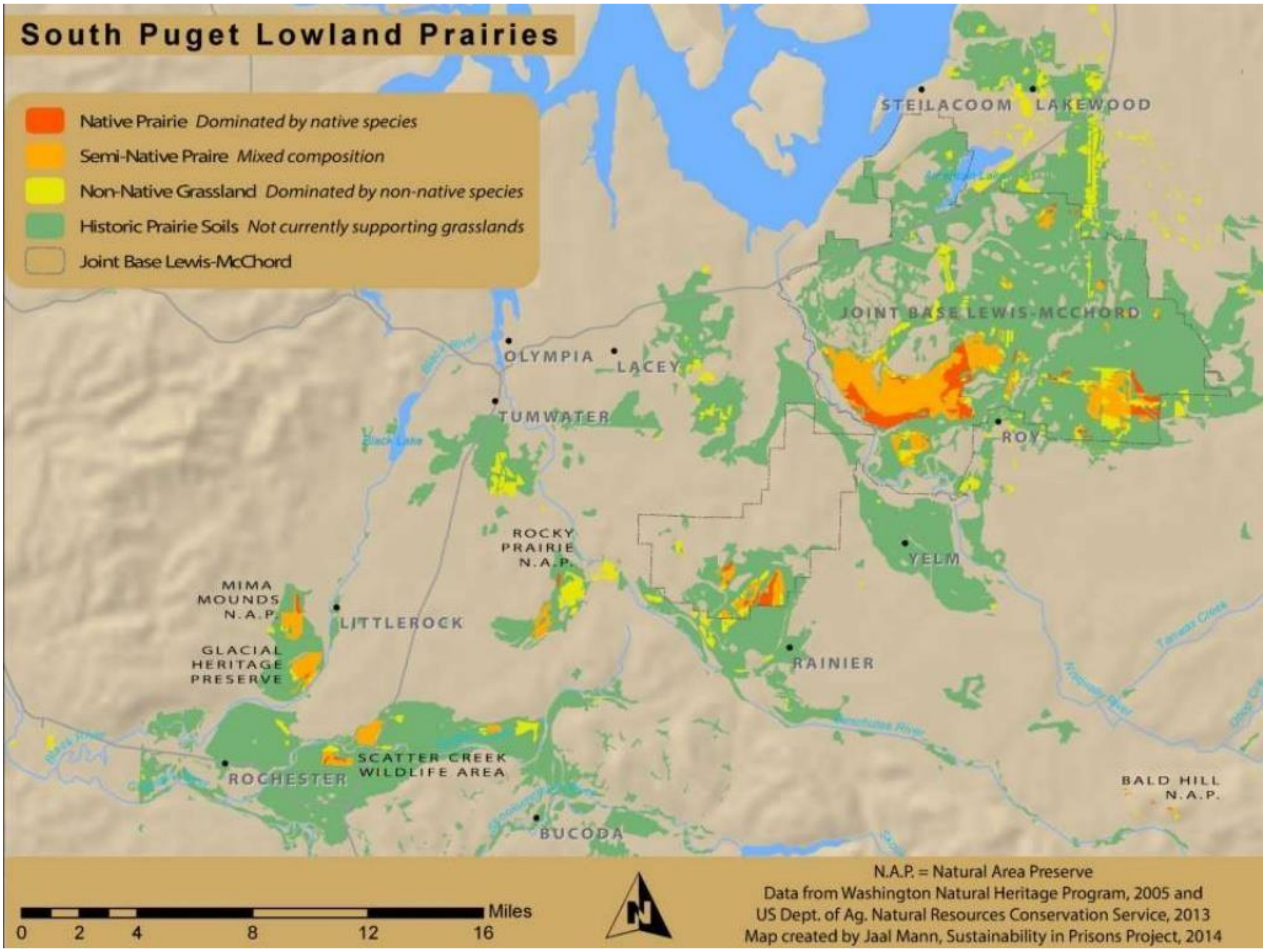

Figure 3 Major prairies of the South Puget Sound (Maan 2017)

Over time, anthropogenic pressures on prairie habitat alters habitat matrix, increase edge habitat and decrease interior habitat, thus isolating the continuity of viable breeding habitat and resources (Fahrig and Merriam 1994). It is important to note prairies in the Pacific Northwest have undergone maintenance and disturbance by indigenous peoples burning and harvesting the prairies for food and cultural significant plants; such as camas bulbs (*Camassia spp.*), chocolate lily corms (*Fritillaria affins*), and bracken rhizomes (*Pteridium aquilinum*) (Boyd 1999). These practices are believed to have been done with methods which did not threaten prairie habitat but manage the prairies for future sustainability and use, a practice known as Traditional Ecological Knowledge, or TEK (Trosper 2007).

The most pressing threats to prairies of the Pacific Northwest today include population growth, the Willamette Valley ecoregion is expected to increase by 28% between 2010 and 2030, further fragmenting the landscape and reducing prairie connectivity. Encroachment by woodland tree species and invasive species which continue to displace native prairie tree and shrubs (Foster and Shaff 2003; P. Dunwiddie et al. 2006). Finally, climate change is projected to cause major losses of native species from the smaller and more isolated prairies (B. M. Rogers et al. 2011).

Critical habitats and endemic species are finding refuge from anthropogenic changes and climate shifts in active and abandoned military bases across the United States. Military bases border off land for operations and section off adjacent uninhabited habitat with high level of security and access restrictions provide; creating habitat areas largely unaffected by effects of agricultural and urban development (Giocomo 2005). The Department of Defense manages over 10 million ha in the U.S., many of which are grassland habitats that provide optimal for ground training for troops and habitat for grassland obligate birds and vegetation (Eberly 2002; Giocomo 2005).

In California, approximately 250 rare flora and fauna taxa are found in habitats provided in military managed lands, several of which occur rarely outside the bases (D. S. Cooper and Perlman 1997). Over 14,000 acres of grassland habitat is contained in Joint Base Lewis-McChord managed lands, at least 37 categorized as distinct prairies (Kronland and Martin 2015). Over 11,00 acres are designated Priority Habitat Areas where habitat management practices are required to maintain, improve or create habitat for federal-listed and threatened species, such as the Taylor's checkerspot butterfly (*Euphydryas editha taylor*), Streaked-Horned Lark (*Eremophila alpestris strigata*), and two subspecies of Mazama pocket gopher (*Thomomys Mazama glacialis, T.m. yelmensis*) (Fish and Wildlife Service 2012; U.S. Fish and Wildlife Service 2013; Kronland and Martin 2015)

A Brief Review in Avian Prairie Habitat Fragmentation

From Southwest British Columbia through western Washington into Northern Oregon are some of the most heavily urban populated areas where prairie habitats were initially found (Franklin and Dyrness 1973). Increase in non-native plants coincide with species loss (Dennehy et al. 2011) and 40% of major flora in the south Puget Sound prairies are exotic or invasive from other continents. Fire suppression and conversion of oak woodlands to conifer stands for timber production has also been a major influencer on prairie loss (Apostol and Sinclair 2012; Hanna and Dunn 1997; Crawford and Hall 1997; Hamman et al. 2011).

These pressures increase habitat configuration complexity of prairies, creating edge habitats where native species and specialist species sustainability is poor by decreasing patch size and displacing optimal dispersal routes for native avifauna (Burger, Burger, and Faaborg 1994; Fahrig 2003). The small patch size fails to provide eco-service requirements to support and maintain species populations and fitness. Additional consequences posed by habitat fragmentation and loss include increased occurrence of negative edge effects.

Edge effects affect interior habitat of a fragmented patch resulting from patch border exposure. These can include intrusion of invasive woody species, increase population and displacement by urban species, and the higher exposure rate of native species to invasive predators (Burger, Burger, and Faaborg 1994; Feldman and Krannitz 2004; Grant, Madden, and Berkey 2004). While these effects have been well documented, the exact nature of habitat loss associated with fragmentation is complex and warrants further investigation (Skagen, Adams, and Adams 2005; Herkert et al. 2003).

For instance, how predator populations respond to fragmentation is relatively unknown. By association, pinpointing the implications of prairie bird populations to predators in a habitat undergoing habitat loss is difficult. Noting (Chalfoun, Thompson, and Ratnaswamy 2002), predators from different regions and locales, like raptors and coyotes (*Canis latrans*), differ in hunting strategies and responses to habitat fragmentation, adding to the variability on nesting success rate of grassland birds (Union and

Foundation 1998). Skagen et al. (2005) mentions observations of Lark Buntings (*Calamospiza melanocorys*) and Horned Larks chasing ground squirrels from their nests in a study observing nest and artificial nest survivability relating to patch size. However, highly fragmented areas with increased edge effects can expose interior patch habitat to larger predators from neighboring habitats against which passeriform species, cannot defend. While the larger patches have increased interior habitat for grassland birds to nest, new and larger predators can roam and hunt in the increased area of the interior habitat. Focusing on patch size, while important, is not the only variable nesting success rate of grassland birds in response to habitat fragmentation.

(Herkert et al. 2003) studied nesting success throughout the mid-continental United States. Unlike to the Skagen et al. (2005) study, the fragmented prairie dimensions in this study ranged from 24 to over 40,000 ha. The authors reported net nest losses to predation of 54-68% in fragments (patches) less than 100 ha and 78-84% in fragments more than 1000 ha. Grassland birds in the study include: Dickcissel (*Spiza american*), Eastern Meadowlark (*Stumella magna*), Henslow's Sparrow (*Ammodramus henslowiij*), and Grasshopper Sparrow (*Ammodramus savannarum*). Area predators associated with prairie nest predation are mice, foxes, coyotes, weasels, crows, and skunks.

The Herkert et al. (2003) study supports its hypothesis of nest survival lowest in smaller patches and higher in larger patches, while contrasting with the results of (Skagen, Adams, and Adams 2005), who found the non-artificial nests were negatively affected as patch size increased. Furthermore, responses of Brown-headed Cowbird (*Molothrus ater*) brood parasitism on ground nests due to fragmentation are measured by Herkert et al. Brown-headed cowbirds, considered detrimental to reproductive success in nesting birds, add their eggs to the brood of other birds. The unsuspecting parent of the parasitized nest will often raise the parasitic chick at the expense of their own young, Brown-headed Cowbird chicks grow faster and outcompete original chicks for food from nesting parents (Herkert et al. 2003).

Habitat fragmentation and patch size have not been linked directly to brood parasitism. Rather, Brown-headed Cowbird abundance is linked to brood parasitism rates and population densities are found inconsistent throughout the study areas. The results suggest smaller habitat fragments are less likely to support breeding density and success rates of grassland birds. In this case, increased predation rates in smaller fragments is influenced by easier accessibility of predators to nests with less habitat cover.

Herkert et al. (2003) found nest predation rates of grassland birds consistently lower in habitat fragments over 10,000 ha. (Winter et al. 2006; Paton 1994) suggested fragments approximately 10,000 ha are minimally affected from edge effects, such as increased predation and invasive species encroachment. Edge effects show greatest prominence in habitat fragments less than 50m because the smaller interior habitat area is less likely to offset edge effects (Paton 1994; Winter et al. 2006). Prior to the study, Herkert hypothesized edge effects should have been most evident in prairie fragments less than 100 ha. The researchers note adverse edge effects appeared for habitat less than 100 ha for the Dickcissel and Henslow's Sparrow, the Grasshopper Sparrow and Eastern Meadowlark. Also, brood parasitism and nest predation rates are inconsistent across the five states in the Herkert et al. study.

Most research focuses on abiotic environmental conditions, possibly accounting for the poorly understood relationship of grassland bird population declines and habitat fragmentation. (Lockhart and Koper 2018) stated, when independently considering habitat patch size and habitat configuration, grassland obligate birds respond significantly stronger to habitat configuration. Predator presence and predation rates followed this pattern. Species specific predator behavior responses to landscape variabilities affected by prairie fragmentation is an unknown factor causing difficulties in assessing prairie restoration needs and setting restoration goals for land managers. As suggested by (Fahrig and Merriam 1994), this lack of information can lead to restoration plans which don't consider the full needs of a prairie ecosystem.

Adjacent Habitat Influence

(Feldman and Krannitz 2004) studied seven sites in Victoria, British Columbia, Canada for adjacent habitat effects on bird assemblages in coastal oak habitats fragmented by urbanization. The study examined coniferous, coastal prairie and urban habitats, measuring each for tree volume, and the extent of shrub and forb cover. Four of the total 43 avian species were exclusively observed in the oak habitat and not in the coniferous habitat included, California Quail (*Callipepla californica*), Warbling Vireo (*Vireo gilvus*), White-Crowned Sparrow (*Zonotrichia leucophrys*), and Yellow Warbler (*Dendroica petechia*).

According to the study, oak ecosystems adjacent to urban habitats experienced lower bird assemblages, with increased presence of urban generalist avian species in the oak ecosystems. Bark gleaning insect-eating bird species undergo displacement by ground-foraging seed-eating urban bird species when in close proximity to urban environments (Blair 1996). Urban bird species dominating oak habitats could hinder the reproduction of shrub and forb species crucial for prairie oak bird species. Coniferous habitat contained the most bird assemblages and is the dominant environmental influencer altering oak habitat (Feldman and Krannitz 2004). The researchers reported that fragmented oak habitat surrounded by coniferous habitat supported bird species from both types, while urban bird species dominated oak habitat surrounded by urbanized habitat type.

Expansion of exotic and woody plants, fire suppression and other ecological drivers influence or are influenced by fragmentation which further diminish prairie ecosystem services (Samson and Knopf 1996). Throughout the southern Great Plains, grassland bird species population declines coincide with increased juniper (*Juniperus virginiana*) encroachment into prairies (Coppedge et al. 2001). In North Dakota, South Dakota, and Montana less than 404,000 ha of mixed-grass prairie has been lost (Higgins, Naugle, and Forman 2002). Comparable with predator responses to fragmentation, few scientific studies directly examine grassland bird species breeding response to woody plant coverage and composition (Grant, Madden, and Berkey 2004).

In addition to edge effects, patch size, and predator response to fragmentation, how influential is woody species encroachment on grassland bird populations? In 1995 and 1996, Grant et al. 2004 conducted observational research into the woody tree and shrub invasion in mixed-grass prairies and the implications for breeding grassland birds at the Clark Sayler National Wildlife Refuge, North Dakota. The 23,900-ha mixed-grass prairie located within Souris Lake Plain, once dominated by a native wheatgrass (*Stipa-Agropyron*), is now interspersed with exotic smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa prantensis*) (Grant, Madden, and Berkey 2004). Additionally, at the wildlife refuge's southern border, mixed-grass prairie displacement has nearly doubled in the past 60 years by non-native trees and shrubs, primarily aspen (*Populus tremuloides*) and willow (*Salix* spp.) (Grant, Madden, and Berkey 2004).

The 2004 Grant study recorded 49 bird species in 192 100-m plots with up to 250 m between prairies in close proximity to woodland encroachment. The researchers measured litter depth, vegetation density, and live vegetation percentage. They later noted the presence or absence of breeding grassland birds. As woody vegetation presence increased the probability of breeding bird species presence decreased for 11 out of 15 grassland species. The researchers concluded that bird species breeding density negatively respond to growth in height of woody brush, shrubs and trees. Meaning grassland habitat was unsuitable for nine grassland bird species when woodland cover exceeds 25%. According to the study, woodland cover is the most important variable when considering breeding grassland bird species response. Savanah Sparrow (*Passerculus sandwichensis*), Bobolink (*Dolichonyx oryzivorus*), and Grasshopper Sparrow (*Ammodramus savannarum*) reached maximum breeding threshold at more than 80% treeless open cover prairie with occurrence probability declining by 50% at 10-25% woodland cover (Grant, Madden, and Berkey 2004).

The data also indicated that as the levels of woodland influenced litter increased, Horned Lark, Sprague's Pipit, and Vesper Sparrow occurrence decreased. The research supports (Jones 2001) conclusion that grassland birds specifically display fitness and survival advantages by selecting grassland over woodland habitats for breeding. Overall, research findings woodland obligate breeding bird species rapidly decline in occurrence as woodland cover increased 5-10% (Grant, Madden, and Berkey 2004).

Prairies and the Oregon Vesper Sparrow

Habitat Needs

Known habitat characteristics suitable for Oregon Vesper Sparrow breeding are prairies covered with short, patchy grass, tall forb cover mixed with exposed ground, with low tree and shrub cover. Another important factor is having diverse herbaceous vegetation within the breeding habitat. Bare ground with short vegetation is utilized for foraging. Moderate structured vegetation provides cover for ground nesting while scattered tall structured vegetation is used as perches for singing (Altman, 2017).

Almost half (48%) of the vegetation composition of pasture habitat where Oregon Vesper Sparrows were detected consisted of <10% shrub cover in pastures which were entirely herbaceous, 17% detected in pastures with 10-25% shrub cover (Altman 2000). Altman (2017) recorded percentage cover of vegetative growth form/condition at >800 plots within 800 territories where Oregon Vesper Sparrows have been detected from May through July 2015. 63% of the plots contained herbaceous vegetation, while >1% had woody debris (**Table 1**).

Table 1. Vegetation summary survey of 57 occupied Oregon Vesper Sparrow plots in the Puget Lowlands (Altman 2017)

Growth Condition	*% Plots Containin*
Herbaceous	63 %
Grass	60 %
Forb	40 %
Rock	14 %
Bare Ground	11 %
Moss/Lichen	9 %
Shrub	3 %
Woody Debris	>1 %
Thatch	>1%
Non-habitat	>1%
Tree	>1%

Feeding habits of the Oregon Vesper Sparrow are unknown, although they have been reportedly seen feeding on insects from low forbs and dandelion seeds (*Taraxacum officinale)* (Altman 2017). It is likely they have a flexible opportunistic diet due to the climate variance between their breeding and wintering ranges (Altman, 2017). They have been observed to forage for invertebrates from vegetation, exclusively within their territory during the breeding season (Rodenhouse and Best 1994).

The Oregon Vesper Sparrow and Fragmentation

Due to the limited data available on the Oregon Vesper Sparrow due to their low population densities and isolated habitats, little is known about their interactions within their environments. No information exists on any mutualistic, symbiotic, or parasitic relationships with other species. Likewise, no data exists on Oregon Vesper Sparrows falling prey to predators (Altman 2017). Although, predation of small to medium passerines by larger raptors makes it likely the Oregon Vesper Sparrow can fall prey to predatory birds, mammals and reptiles (Altman 2000).

Relating patch size to nest survival and reproductive success of grassland birds largely depends on edge effects of the fragmented habitat. If landscape spatial structure restricts movement between patches, the area required for population survival is large, as edge restricts habitat, further isolating Oregon Vesper Sparrow populations. If landscape spatial structure enhances movement, the area required for survival is smaller.

Some areas where Oregon Vesper Sparrows nest include grasslands and savannahs undergoing restoration management and airports. Within these locations, management practices like mowing can have significant negative effects on the reproduction of the species (Kershner and Bollinger 1996). During ecological restoration of a habitat manual and chemical removal of invasive and undesired vegetative species can lead to nesting failure and nest abandonment, even if done outside of the breeding season. No information exists on the effects of pesticides and herbicides on the Oregon Vesper Sparrow, although Vesper Sparrows may be vulnerable to pesticide use based on data from (Robbins 1992). Being a subspecies of the Vesper Sparrow, lacking information on the Oregon Vesper Sparrow is referred to its close relative of the Vesper Sparrow.

The encroachment of housing developments on Oregon Vesper Sparrow viable habitat poses and increasing threat of reproduction disturbance. Nesting sites may be subjected to recreational activities such an increase in foot-traffic and off leash domestic dogs (Canada 2018; R. E. Rogers 2000) . Additional degrading effects include horseback riding, hiking and bicycling (R. E. Rogers 2000). Domestic cats (*Felis catus*) have been noted as the greatest predation threat to an Oregon Vesper Sparrow population which formally occupied Nanaimo Airport on Vancouver Island (Altman 2017). Within the scant research on Oregon Vesper Sparrow species data on nest site selection based on landscape composition is not well known. More precisely, can nest selection in relation to the overall habitat matrix be spatially analyzed using Esri GIS software to detect the relationships and test their strength?

Methods

Pre-Monitoring Surveys

I obtained coordinates from the Center for Natural Lands Management of Oregon Vesper Sparrow nests in the North Weir prairie (upper and lower) on Fort Lewis Military Installation and the Artillery Impact Range, or the AIA, on Joint Base Lewis-McCord for 2017, 2018, and 2019. I selected these locations for my study area because the Center for Natural Lands Management has been authorized to operate in these military-controlled areas for their ongoing projects. Also, these are the areas of the Puget Lowlands which have the most consistent presence of Oregon Vesper Sparrow populations for the past three years, compared to other project sites. The Weir prairies are located southwest of Yelm and northwest of Rainier, WA. Access to the prairies is restricted to the general public due to onsite military training operations, prairie restoration and management, and the presence of endemic prairie flora and fauna. Permission for prairie access must be scheduled and approved with Center for Natural Lands Management and Joint Base Lewis-McCord military range control officials.

The initial survey areas of my study were established in 2015 by Center for Natural Lands Management staff on North Weir and AIA. The avian surveys were completed via occupancy transects and point counts. Occupancy transects are useful in establishing early detection and identification of breeding pairs and their territories, a useful methodology when surveying migratory birds like the Oregon Vesper Sparrow. The grid transects measured 25 x 25 m in areas selected for monitoring relationships between fire, vegetation, and bird assemblages. A single random point was placed onto each grid, from which a 150 meter transect line was constructed. Transects were at least 150 meters apart from each other and from any habitat or patch edge.

In North Weir, surveys were completed where suitable habitat for the Oregon Vesper Sparrow was present, the majority of the landscape where prairie habitat was dominant; patchy grasses, low numbers of evergreen forest trees encompassed by the prairie, and open range. On the AIA, Center for

Natural Lands Management faced considerable restrictions and inaccessibility for most of the area for survey due to unexploded ordinances present in the range. Under the supervision of Joint Base Lewis-McCord personnel transects were established in specific allowed areas of the AIA. Largely due to unexploded ordinances and regularly scheduled active artillery activity on the range, the area for surveys and study are unconventionally constrained when compared to the area of North Weir. Thus, a complete survey of the area was not completed, limiting the area considered 'available' in my approach.

During active nest survey monitoring from 2017 to 2019, transect surveys were completed moving from East to West or South to North, taking approximately 15 to 20 minutes to complete. In cases where high bird activity was occurring in an area not involved in the study area a transect was set up at that location. Transects ranged from estimated 50 to 200 meters with 2 to 4 surveyors at least 25 to 50 m apart. With bird activity in high grasses dragging a rope approximately 14 meters long between two surveyors with 1 or 2 more trailing was used in attempt to flush birds from their nests from the thick ground vegetation.

Oregon Vesper Sparrow Monitoring

During the spring of 2019, I joined Center for Natural Land Management researchers in North Weir for first-hand field experience in the data collection protocol, and to gain insight as to what variables might be associated with nest locations. My fieldwork included observing and aiding in locating ground nests, becoming familiar with identifying the Oregon Vesper Sparrow by sight, flight and vocalization, and become familiar with the characteristics of the landscape in the field rather than solely using satellite imagery. I was guided through the process every day in the field by two AmeriCorps researchers, and occasionally joined by the senior ornithologists and researchers.

Survey dates fell between May 1st to June 30th to coincide with the Oregon Vesper Sparrow breeding season. Males tend to arrive early in early May to set up territories. Thus, researchers mapped territories during this time while they males were still highly visible and vocal. Many males were colorbanded (unique combinations of colored bands on their tarsals) from previous seasons. Un-banded birds were tracked, trapped, banded and measured, then released. The mapping protocol used was qualitative, as mapping the territories is primarily used to aid researchers in tracking banded pairs back to a specific area, rather than quantifying territory boundaries. Surveying protocol was to begin counts at sunrise and continue until bird activity diminished significantly. In some cases, rain or intense fog may have factored into diminished bird activity, such as singing, and resulted in terminating surveys as early as 8:30 AM. Generally, if conditions resulted in < 200 meters of visibility, survey counts were put on hold until the following day. On days where weather conditions resulted in ample sunlight and diminished cloud cover, surveys could go until as late as 1:00 PM.

For my field research, I arrived in the field between 5:00 and 5:30 AM and stayed through ~1:00 PM Mondays, Wednesdays, and Fridays. The AmeriCorps researchers were present for observations even more often. Most of the surveys were concentrated in areas where the birds tended to frequent, such as the northeast area of the Upper Weir (**Figure 4**).

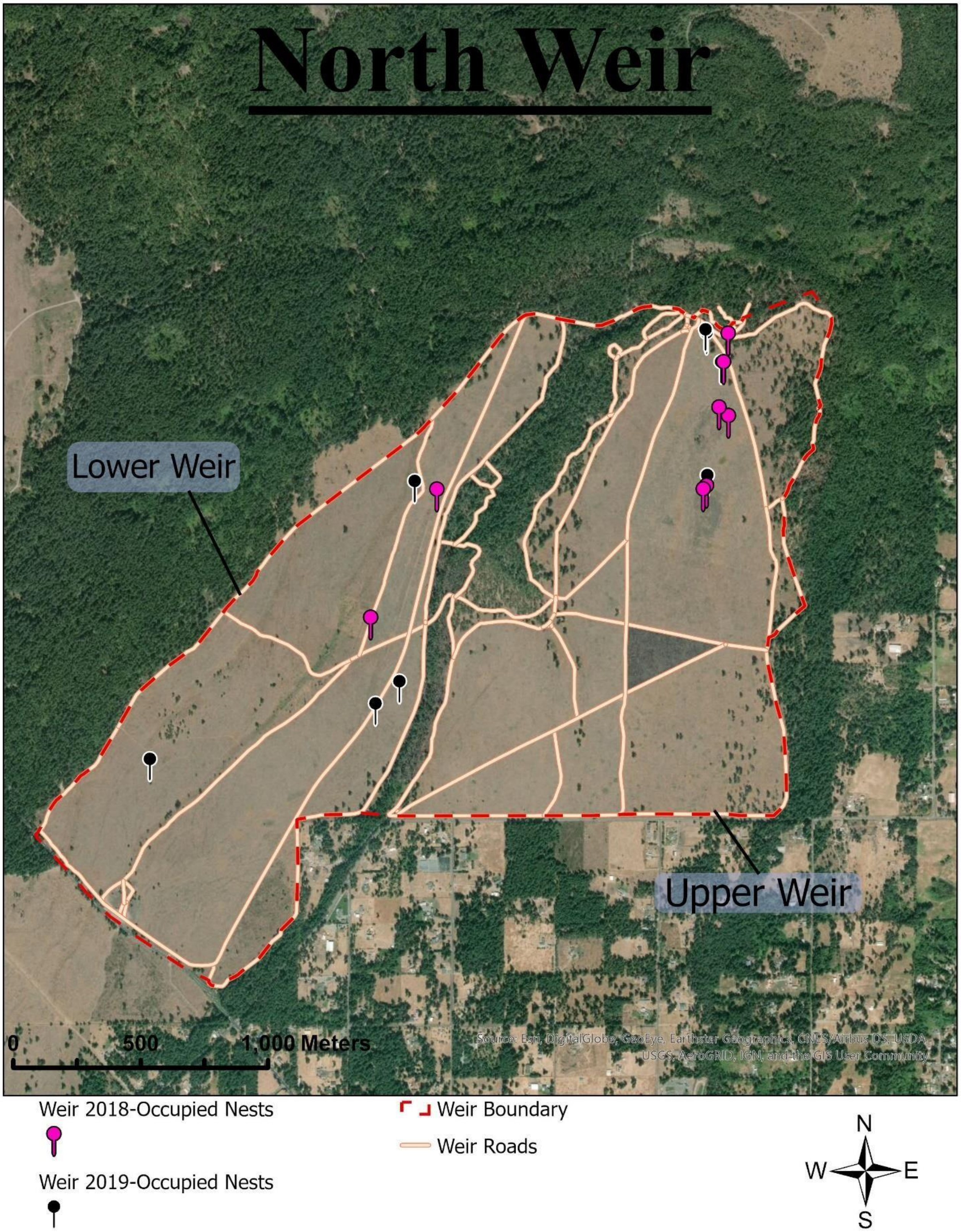

Figure 4 North Weir contains two sections, Upper Weir and Lower Weir

Oregon Vesper Sparrows heard or seen in any area of the Weirs prompted further investigation. From 5:15 till 7:00 we generally surveyed in pairs or independently, following cues from singing males. Between 7:00 and 8:00 we started the process of actively tracking males throughout their territories. At this stage of the season, breeding pairs had already excavated nest sites in the ground. Our objective was to track males through their territories to increase the chances of spotting the female. We had greater success in locating a nest by tracking a female than a male.

Encountering Birds

Point counts were used to identify breeding pairs and nests in addition to transects. No defined survey routes were present for point counts. Point counts were typically done alone or in pairs and lasted approximately 8 minutes in a single area where a bird was heard or seen. All birds within 150 meters distance were counted that were perched or flying between vegetation. Flyovers were not counted and were difficult to track, especially with the presence of other sparrow species similar in appearance to Oregon Vesper Sparrows, when flying. Perch stands, where Oregon Vesper Sparrows could be observed singing, were recorded by Center for Natural Lands Management staff. For the purpose of my research, I did not include these in my variables.

Most birds we encountered were accidentally flushed from a nest or the ground during a point count survey. When an Oregon Vesper Sparrow was spotted, we took great precaution when approaching the bird as to not flush it further from the area. Often times when the bird noticed us approaching it would perch and proceed to 'fuss call'. We kept a distance of approximately 40 to 60 meters from the bird as to not drive it from its territory or further from its nest.

Even with the flushing of a female just a few meters away, it was challenging to locate the nest from which she left. The ground of North Weir, while patchy, is carpeted with tall grasses, thick forbs, and scattered flowering shrubs. When observing the landscape from the ground, the vegetation appears similar and continuous, making it difficult to pinpoint a particular area where a bird might have flushed from. Adding to the complexity of finding nests, the females regularly lured us away from the nests, which is a typical behavioral adaptation of ground nesting grassland obligate birds. It is highly possible as we followed her from perch to perch after she was flushed, we were within her territory but getting further away from the nest than we expected. When we tracked the female to a perch, we kept a distance of approximately 40 meters. A few times we observed from 80 meters away from all sides when she was high in a Douglas fir, keeping an eye on her movement with binoculars and signaling to the other researchers using hand gestures. At times she would stay in that location for only a few minutes, but sometimes up to 15 or 20. Eventually she would drop to the ground, out of sight under the vegetation and proceed back to the nest, leaving us to examine the area on the ground for nests in the wrong area.

It often seemed as if the birds were phishing us away from the nest, rather than the researchers phishing them towards us. While the nest might not be in the immediate area of eyesight, it was generally within 50 meters. When the female disappeared by dropping back onto the ground, we attempted to flush her again after a few minutes to get a more accurate area of where the nest was located, with limited success. We were careful to not do this more than 3 or 4 times in one day as to not put unneeded stress on the female. Disturbing the males or females within the field during these months of the breeding season to an unnecessary amount could prove detrimental to their breeding success. By this time, all nests most likely contained eggs or nestlings of just a few days old. Too much researcher disturbance could impede their survival by keeping the female from incubating the eggs and keeping the nestlings warm; also, by keeping the male from feeding the female or nestlings. Food searching (foraging and hunting) energy expenditures are costly (Rosenzweig 1981).

Whether following a female to her nest or searching the ground in transects, we walked slowly, carefully and deliberately as to not accidentally step on any ground nests. The nests we observed were tucked at the base of tall grasses generally over a foot in height, making them difficult to locate. Numerous of times we observed a male perched on a tree or snag with food in his mouth, most likely insects. Holding the food in his mouth for several minutes perched, he was likely delivering food to the female as she incubated the eggs or feeding the hatchings. As with the female, we stayed back at least 40 meters to watch where he flew to gain an estimation of the location of the nest. During my time in the field, this strategy was not successful as he was not as quick to get back to the nest, would often swallow the food and fly away.

During the 2019 survey season, no nests in North Weir were found during the construction period of nesting. All nests found were either occupied with eggs or hatchlings. Located nests were logged with date, time, contents of nests and cartesian coordinates. Nests were visited every 2 to 4 days to record the progress of the eggs or hatchlings. When approaching the nest for progress update, a path was not used more than once, touching the nest or host plant with bare hands was not permitted. Limiting our time at the nest was paramount in addition to the previous steps as to prevent indirectly leaving physical or scent trails which predators could use as visual and chemical cues to find the nests.

Once the nestlings reached the age of at least 4 days they were ready for banding and measurements. Before handling the birds, hands were rubbed in the soil and vegetation litter to mask our scents. The measurement process was done as efficiently, quickly, and gently as possible, while the mother fuss-called at us from nearby vegetation as we handled the nestlings. The nestlings were placed into a soft sack and one by one were banded, weighed, tarsus length and pin feather scores recorded. By mid-June all nestlings have fledged and began taking flight. Eventually all Oregon Vesper Sparrows vacated the prairies to migrate south for the fall and winter months.

Data Management - GIS

ArcGIS Pro was used to process visual representation of the data and run geospatial analytics on the nest location data obtained from Center for Natural Lands Management. The data contains NestID, Year, and coordinates as Easting and Northing. I uploaded the information to ArcGIS using the XY Table to Point feature, exporting the data onto the map with coordinate system set to NAD 1983 HARN UTM Zone 10N to accurately represent the spatial dimensions of my study area.

Each nest site has a buffer feature layer of 64 meters to represent theorized habitat territory of the Vesper Sparrow (Reed 1986). No data currently exists within the scientific literature of Oregon Vesper Sparrow territory range. Since it is a subspecies of the Vesper Sparrow, 64 meters of the Vesper Sparrow territory range is used as a substitution. Within these buffer areas for each nest is where I analyzed the relationship between nest location and variables. These variables include tree species, distance to nearest tree, and distance to edge habitat. For North Weir, only 2018 and 2019 data were used due to the limited number of nest points for 2017 (**Figure 5**). As for the AIA, data from 2018 was used for analysis (**Figure 7**).

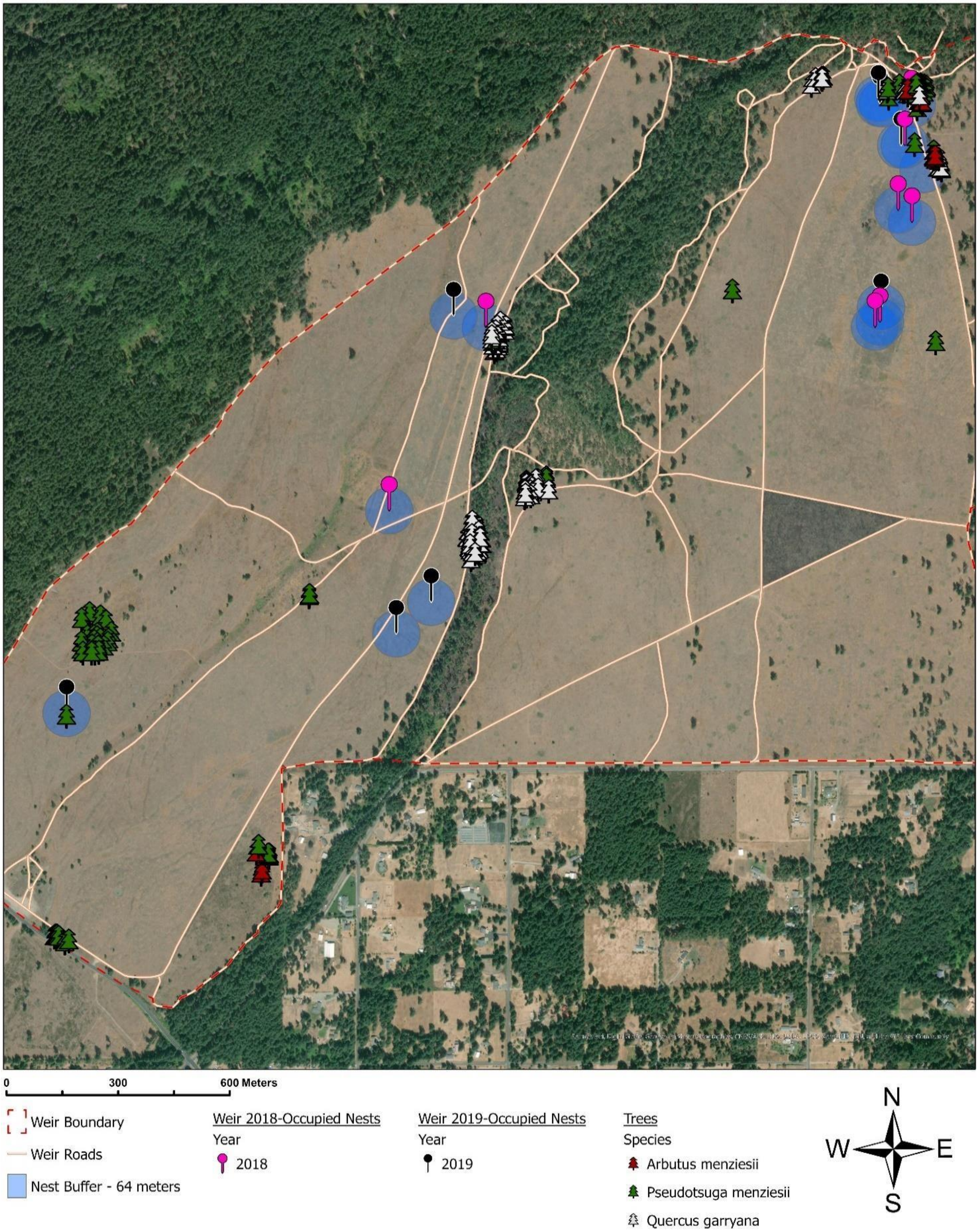

Figure 5 North Weir Occupied Nests, 2018 & 2019, with 64 meters buffer, tree species and roads

To obtain the accurate number of trees and the species I went back into the Weirs for ground truthing in the Winter of 2020. Attempting to do so from satellite imagery is possible but entails a greater chance for error in miscounting and misidentification. I uploaded a map containing the nest locations with buffer feature layers with Google-Maps to navigate the field to obtain the tree counts and species; which were logged and stored using the Esri GIS mobile application, Survey123.

Tree species present within buffers included Douglas-fir (*Pseudotsuga menziesii*), Garry Oak (*Quercus garryana*), and Pacific Madrone (*Arbutus menziesii*). The Douglas fir and Madrone still had vegetation, yet the Garry oak species did not during the winter months. Utilizing a dichotomous key and input form researchers who frequent the area for vegetation surveys, I am positive the leafless tree species I observed to be Garry oak. As for the AIA, the satellite imagery displays one species within a nest site buffer zone from 2018. Due to the constrains of my timeframe, I was not able to coordinate a time where I could be escorted into the AIA to ground truth the species of this single tree. The process to gain access the AIA can be time consuming process and navigating the area is dangerous due to artillery use. Under advice from Center for Natural Lands Management staff, I decided to forego ground truthing the AIA for a single tree species.

To obtain the count and weight of the tree species within each buffer I used the spatial join tool in ArcGIS Pro for the years of data used from the Weirs and AIA. Parameters of the spatial join for each year were the same. The target features were the grouped nest ID within a year, the tree species set as the join features, join operation-one to many, with an intersection of 64 meters. This operation provided a feature whose attribute table grouped the nests with an ID code.

From this attribute table I summarized statistics to produce a standalone table by calculating the count of tree species for the NestID fields, and kept track of the count of trees, which is broken up into tree species in the following fields*: Pseudotsuga menziesii*, *Arbutus menziesii, and Quercus garryana*.

As for the distance from nest location to nearby roads, I ran the Generate Near Table feature for each year. The input features in the parameters, what feature is the subject of this tool, was the grouped nest year, features to measure (new features) was the road line features I drew within the map, with a search distance of 64 meters using a planar method. The resulting stand-alone tables display the distance from nest sites to road by year. Ground truthing the roads which would be in the 64m buffer of any nests or control points on the Weirs was done during while truthing the trees. This was not done for the AIA because of access and project timeline constraints.

The process of spatial analyzing nest distance to road and tree density was also done for random nests in the control points. In ArcGIS Pro, the Create Random Points geoprocessing tool allows the user to create random points on a map. This is what I used for establishing my control points for my test on the prairies. The random nest points datasets are separated by year. The number of points generated for my control is equal to the number of found nests within that point. Random points in North Weir, **Figure 6**, and AIA, **Figure 8**, were constrained via the feature layers outlining the boundaries of the study areas. Minimum distance of each random point was 60 meters, to provide variability from the 64 meters habitat buffer. In North Weir, each random point was ground verified for road presence and tree species.

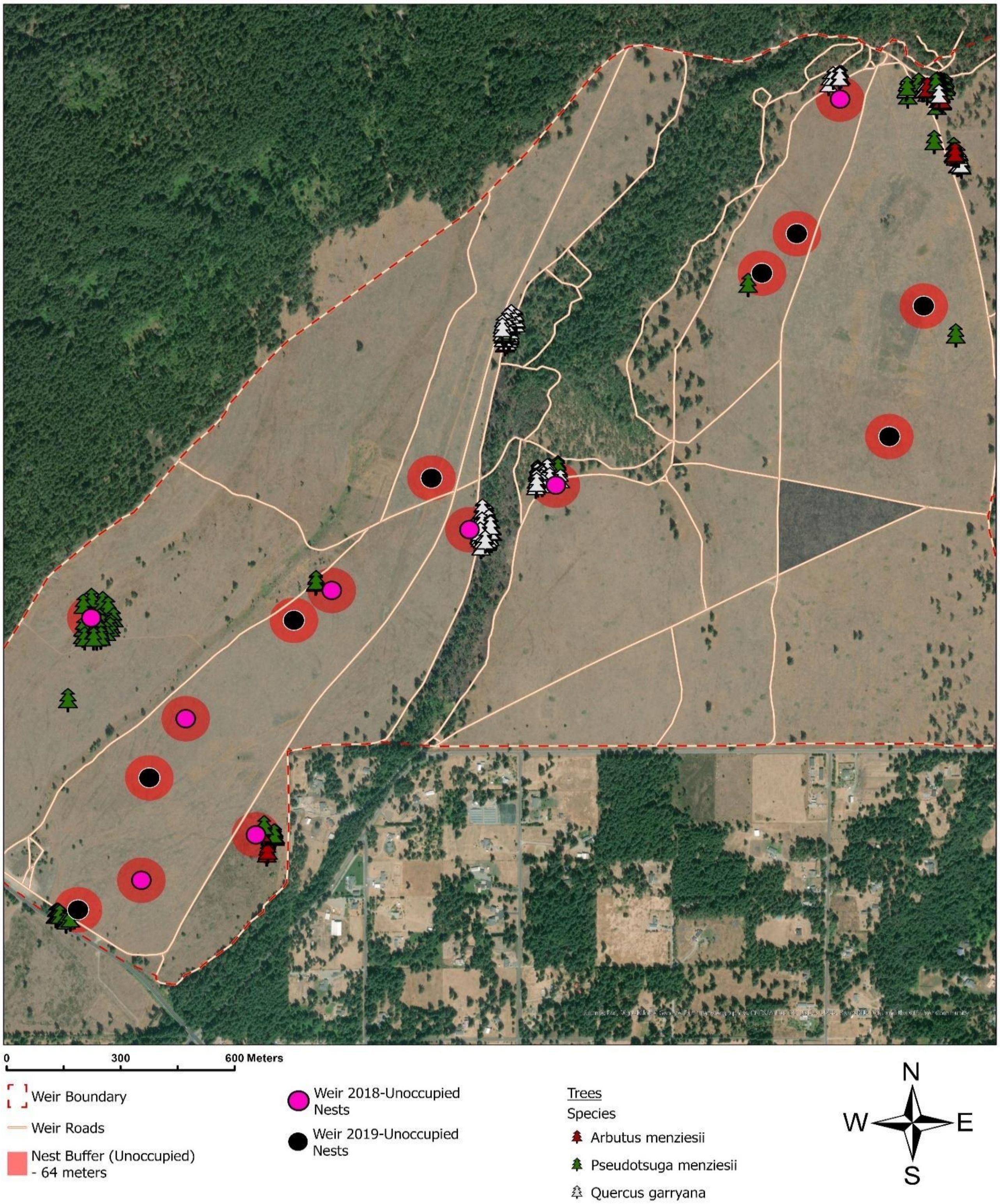

Figure 6 North Weir Unoccupied Nests, 2018 & 2019, with 64 meters buffer, tree species and roads

From the overall data of Oregon Vesper Sparrow nest locations in North Weir and AIA from 2017 to 2019 I established a minimum sample size limit of 7. Thus, for the AIA, data from 2018 was analyzed with a sample size of 11. From North Weir I used data from 2018 and 2019, both yielding a sample size of 8 individually. Data from North Weir 2017, AIA 2017 and 2019 yielded less than 7 respectively. A sample size too small for my analysis increases the likelihood of a Type II error and limiting power of the overall test. Data collected through CNLM and my fieldwork were organized in ArcGIS Pro and analyzed in R (R Core Team 2020).

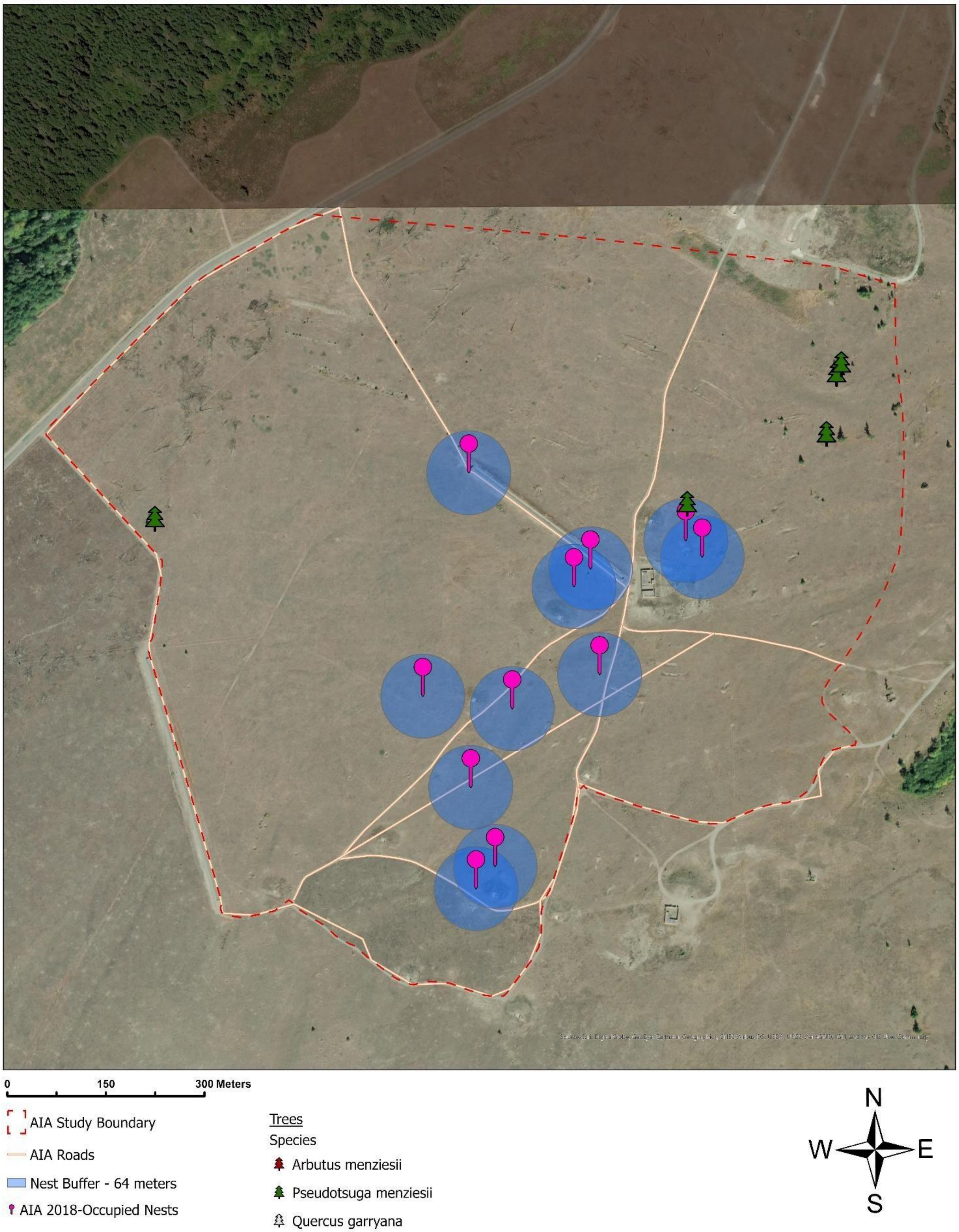

Figure 7 AIA Occupied Nests, 2018, with 64 meters buffer, tree species and roads

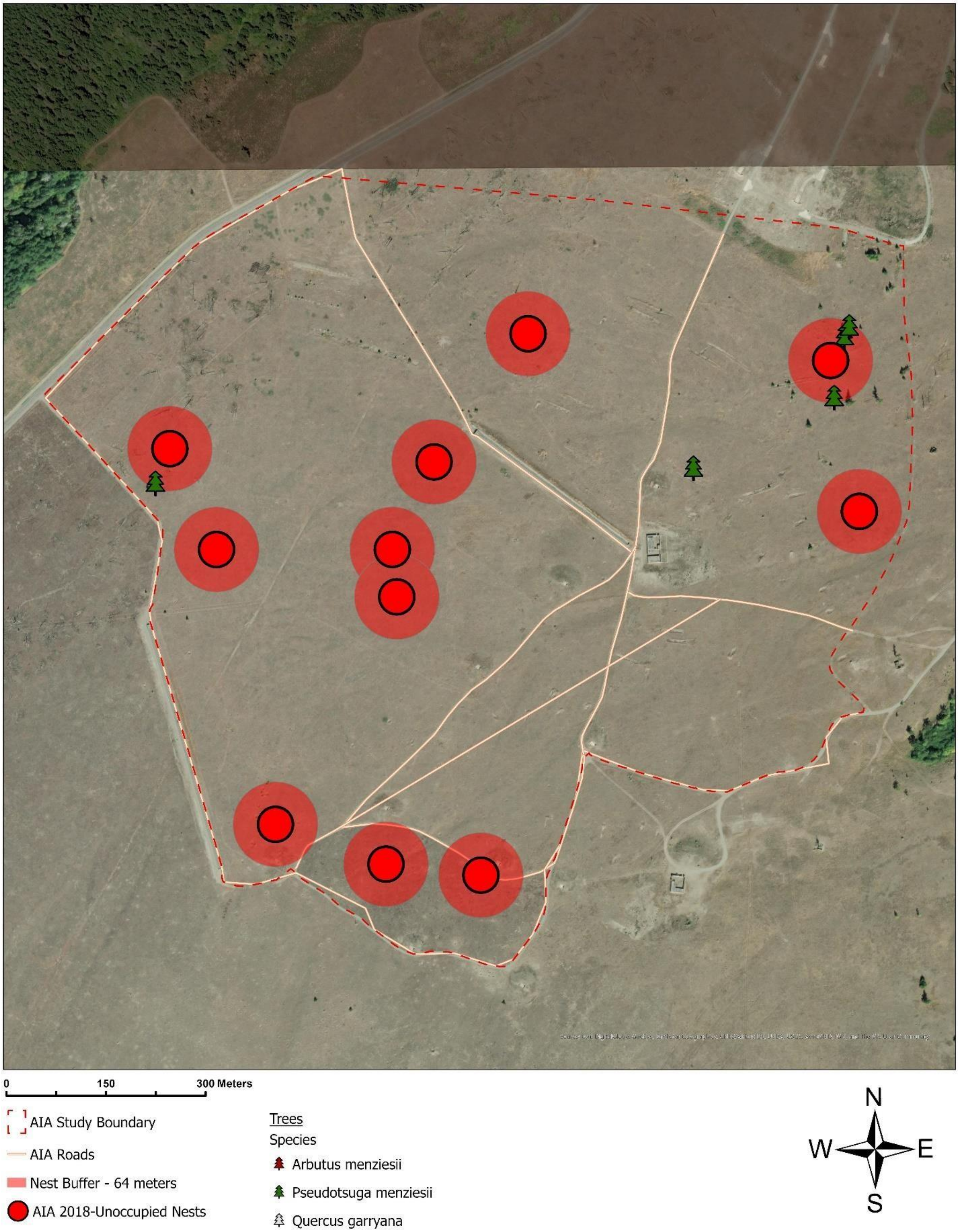

Figure 8 AIA Unoccupied Nests, 2018, with 64 meters buffer, tree species and roads

To test whether tree density or distance from road, habitat edge, corresponds with where a breeding Oregon Vesper Sparrow pair will nest within a particular location a logistic regression was used. The presence of a nest in this test in binary, occupied or unoccupied. Because all of the nests found within the data collected were occupied, random nests points for each dataset were created and are represented in the data tables with their own unique IDs. For any model returning a significant coefficient, I used a likelihood ratio test from the R package 'lmtest' to examine the model fit (Zeileis and Hothorn 2002). After, I visually examined residuals from the logistic regression plots for distribution, linear patterns and skews.

Results

Summary statistics of the variables collected in the field in relation to occupied and unoccupied nests, by site and year, are presented in **Tables 3, 4, 5** and **6**. **Table 3** contains statistics of tree species within 64 meters of occupied and unoccupied nests in the Weir prairies; **Table 5** presents the same for the AIA**. Table 4** has Weir summary statistics of road edge distance to occupied and unoccupied nests, similar in **Table 6** for the AIA.

Logistic regression analysis of the Weir prairies data in all three datasets showed no statistical significance in the relationships across all variables. **Table 7** represents the results of the logistic regression modeling between nests and trees, **Table 8** of distance to road.

Table 2 Weir Summary Statistics of trees ≤ 64 meters of nest

Weir	*Min*	*Max*	*Median*
2018 Occupied	0	30	0
2018 Unoccupied	0	77	8.5
2019 Occupied	0	4	0.5
2019 Unoccupied	0	8	0

Table 3 Weir Summary Statistics Road Distance from nests (m)

Weir	*Min*	*Max*	*Range*	*Median*	*Mean*
2018 Occupied	8.8	245.9	237.2	68.6	96.9
2018 Unoccupied	9.4	150.1	140.7	51.3	57.9
2019 Occupied	8.7	22.0	213.3	60.8	79.1
2019 Unoccupied	29.5	173.4	143.9	77.7	93.7

Table 4 AIA Summary Statistics of trees ≤ 64 meters of nest

AIA	*Min*	*Max*	*Median*
2018 Occupied	0	1	0
2018 Unoccupied	0	3	0

Table 5 AIA Summary Statistics Road Distance from nests

AIA	*Min*	*Max*	*Range*	*Median*	*Mean*
2018 Occupied	3.2	105.0	101.8	25.7	40.5
2018 Unoccupied	8.9	223.6	214.7	86.1	119.9

Table 6 Logistic Regression Results, p-value of tree presence > 64 meters of occupied nests

Dataset	*Species Total*	*Douglas Fir*	*Garry Oak*	*Arbutus*
	p-value	**p-value**	**p-value**	**p-value**
Weir 2018	0.303	0.633	0.392	~1
Weir 2019	0.909	0.903	0.995	N/A
AIA 2018	0.400	0.400	N/A	N/A

Table 7 Logistic Regression coefficient estimate and road distance statistics.

Dataset	*Logistic Regression*	*Distance from Road*	
	Coefficient Estimate	**p-value**	**Occupied ≤ 64 (meters)**
Weir 2018 Nests	-0.0574	0.106	22.2
Weir 2019 Nests	-0.0383	0.141	44.9
AIA 2018 Nests	**-0.0676**	**0.016 ***	23.0

Nest distance from road for AIA 2018 data had a statistically significant relationship to nest occupancy (**Table 8**). I compared the significant logistic model to a null model with a Likelihood Ratio Test ($\chi_1^2 = 15.99$ $p < 0.001$). As the distance from road to nest increases, the likelihood of nest occupation decreases. The occupied and unoccupied nest locations are plotted by their distance from road, for the AIA 2018 dataset (**Figure 9**), with the curve corresponding with the results of the logistic regression summary of **Table 8**. Oregon Vesper Sparrows occupied nests were more likely to be within 64 meters of a road, than random unoccupied locations on the AIA in 2018.

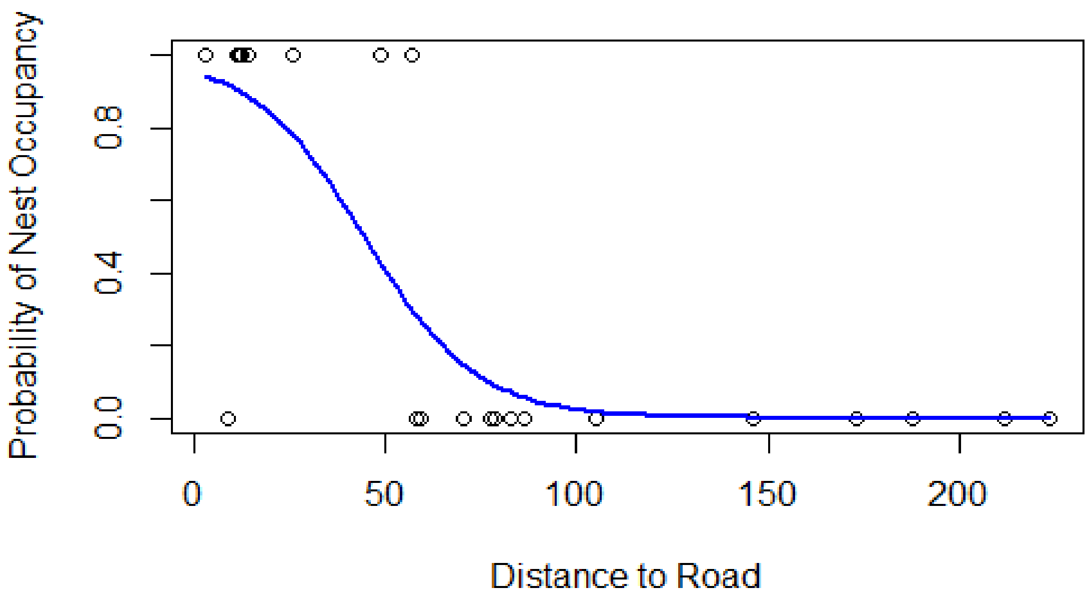

Figure 9 AIA 2018 occupied nests (y = 1) and unoccupied locations (y = 0) with their distance to road. Curve is plotted from the logistic regression

For the year 2018, occupied nests in North Weir, **A1**, were in general not within the 64m buffer of any trees, with the exception of nest TA21_18-01 and TA21_18-07, see **Figure 10**. Nest TA21_18-01 had 30 trees total within 64 meters, the majority being *Pesudotsuga menziesii* at 19. *Quercus garryana* was the most abundant tree present 64 meters from nest TA21-18-07 at 22 trees of the total of 26. Looking at the Random Nest Points, tree species were greater in numbers within 64 meters of these unoccupied randomly generated points. Nest WeRan18_18-02 having the most trees present at 77, 68 of those being *Quercus garryana*.

Data from tree presence within 64 meters of Weir nests in 2019 is categorized in Appendix A, **A1**. Tree presence is low across all occupied nests. Nests with greatest number of trees present within 64 meters are TA21_19-01 and TA21_19-06, *Pesudotsuga menziesii* counting for the majority of both at 3 (**Figure 6).** Arbutus menziesii are not present within 64 meters of any occupied or unoccupied randomly generated nests. The unoccupied random generated nests also had a low number of tree presence within the 64 meters buffer.

Referencing **A2**, Weir 2018, 4 out of 5 occupied nests were made within 64 meters of a road: TA21_18-01, TA21_18-06, TA21_18-07, and TA21_18-08, with an average distance of 22.24 meters. As reported in Table 8, there is no significant relationship of road distance within the dataset of Weir 2018 and Weir 2019. In **A3** we see 5 out of the 8 occupied nests met the threshold of having a road within 64 meters, TA21_19-01, TA21_19-05, TA21_19-06, TA_19-07, and TA_19-08. All with an average distance of 44.93 meters. Although, the table does report a significant relationship of occupied Oregon Vesper Sparrow nests present within 64 meters of a road structure.

A4 data is the trees counted within 64 meters of occupied and unoccupied random generated nests for the AIA in 2018. A single occupied nest had any tree presence within 64 meters, R76_18-05, 1 *Pesudotsuga menziesii*. This was the only tree species counted within the set boundary of the AIA. I established this boundary to encompass all occupied and random nests and their buffers. Communication with researchers who have frequented the AIA confirm it is likely the trees present are *Pesudotsuga menziesii*. Hence, this was the only species accounted for in the table. Nest distance from road data is represented in **A5**, where 8 out of 11 occupied nests are within 64 meters of a road, with an average distance of 23.0 meters (**Figure 10**).

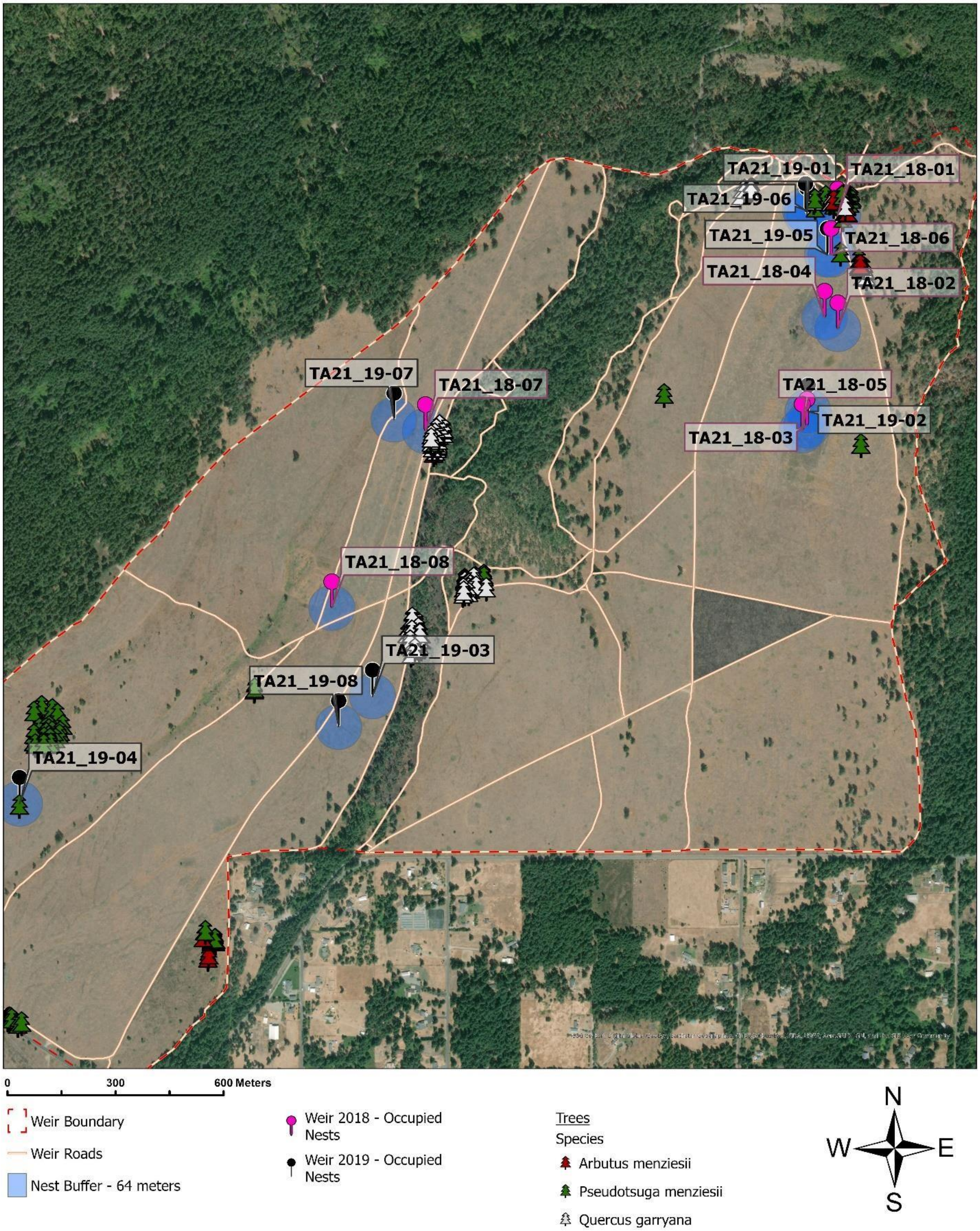

Figure 10 North Weir 2018 and 2019 Occupied Nests with ID

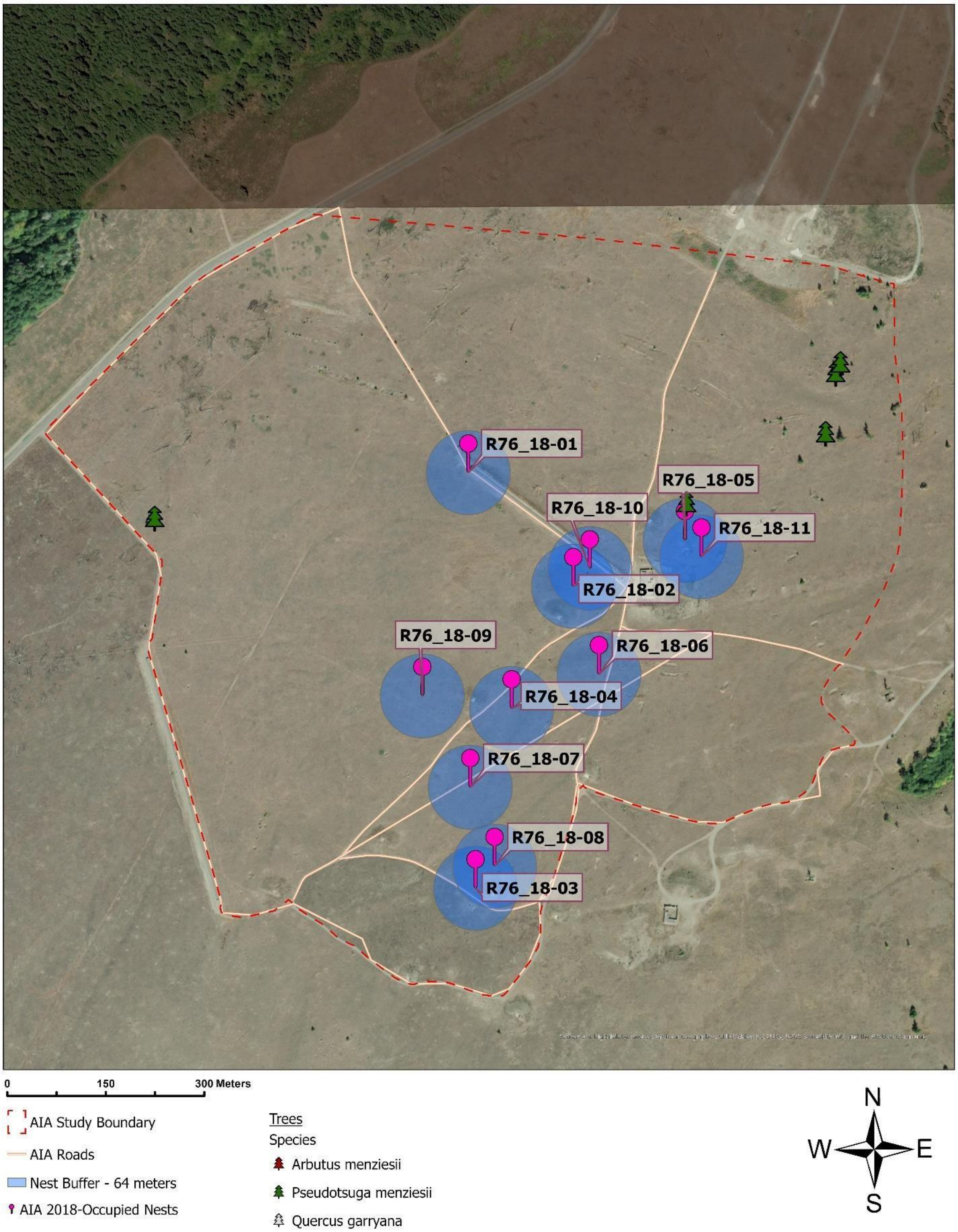

Figure 11 AIA 2018 Occupied nests with ID

Discussion

Tree Presence and Nests

Oregon Vesper Sparrows are ground nesters (Altman 2017; 2011), usually excavating nest sites in wide open areas of the prairies. **Figure 5** and **Table 1** show the most prominent trees classified within the inner boundaries of the prairie to be *Pesudotsuga menziesii*. Even from the North Weir 2019 data, which does not have as many tree counts, *Pesudotsuga menziesii* is the most dominant tree species present. On the AIA, regular artillery fire and military activities most likely account for the lack of trees within most of the interior area when compared to a prairie matrix such as the Weirs, **Figure 7**. *Pesudotsuga menziesii* are not considered to be endemic to the breeding success or nest placement of the Oregon Vesper Sparrow. *Quercus garryana* is a prairie oak species which may have positive implications in cases of prairie habitat ecosystem functionality, biodiversity, and avian assemblages (Taylor and Boss 1975; Hamman et al. 2011; Feldman and Krannitz 2004). However, from my data there appears to be no significant relationship of where the birds are choosing to lay their nests when considering the habitat matrix at the landscape scale. The same can be observed for *Arbutus menziesii*, which was the least present amongst all datasets and within 64 meters range of occupied nests. I observed in the field very few individuals or pairs of Oregon Vesper Sparrows utilizing trees for other than fuss calling at researchers or perching and singing. Yet, these behaviors I observed were done mainly from relatively low height shrubs. If I were to continue my research, I would then focus on shrub species and the frequency the birds utilize them for perching and singing. Analyzing correlations to the patterns of shrub height, width and species. While tree presence is generally associated with bird assemblages, when considering the Oregon Vesper Sparrow and other ground nesting prairie obligate species a different way of quantifying this relationship could drive research forward. If these birds are nesting on the ground, are for the most part threatened and declining in population, how can tree presence positively or negatively affect conservation efforts?

Nest Distance to Road

Distance of nest to road was chosen for this research because of the ground nesting behavior of the Oregon Vesper Sparrow. I was not given data other than the nest locations and had only the time and resources to measure variables on a landscape scale rather than the habitat scale, like grasses around nests. The Weir prairies may be considered unique for the habitat is highly restricted not only to the public, but to researchers and military personnel as well. As soon as you enter, you are greeted with signs stating all military and civilian vehicles are to stay on the roads and not enter the interior habitat, the prairies. Roads along the exterior are frequented by logging trucks. Road activity near the entrance are used by civilians, while the interior roads are frequented by researchers and the military. The measure of this frequency is unknown. I was curious if nesting on the ground, rather than in a tree, where foot traffic is relatively low and scarce compared to vehicle traffic influences nest placement. While all occupied nests were measured for distance from nearest road, only those within 64 meters were analyzed in the linear regression model, based on the (Reed 1986) information of Vesper Sparrow territory ranges.

While there was a significant logistic regression coefficient for distance to the closest road structure and nest occupancy within 64 meters on the AIA from 2018, the same is not true for the Weir in both datasets of 2018 and 2019. **Figure 11** compares the landscape matrix of the AIA to that of North Weir, their components are dissimilar. While North Weir had sections of habitat considered grassland prairies formed by glacial outwash (find citation), the AIA is frequently bombarded with ammunition fire and explosives. It has been reported by researchers that this type of military activity on the AIA sparks fires which may mimic naturally occurring fires on the prairies. Prairie fires are considered endemic to the stabilization of grassland prairie habitat when naturally occurring events are not overly suppressed or controlled burns are used to improve landscape composition, in turn improving biodiversity (Hamman et al. 2011).

In addition to the Oregon Vesper Sparrow, the Mazama pocket gopher (*Thomomys mazama*) and Taylor checkerspot butterfly (*Euphydryas editha taylori*) are also present in the AIA (U.S. Fish and

Wildlife Service 2013). Some researchers speculate this is because the fires are promoting stable prairie conditions. Current restoration projects on in upper Weir of North Weir include a 5-year strategic management plan accounting for wildlife and habitat restoration, administered by Central for Natural Lands Management and Joint Base Lewis-McCord staff.

Another factor to consider is the ability of researchers to survey for birds on the AIA. While surveys were done fully in the Weir prairies, safety concerns greatly restricted survey efforts for the AIA. The survey area of upper and lower Weir is bounded by forest habitat, highway, urban habitat and slopes, creating a barrier to which we could survey for Oregon Vesper Sparrow populations. The AIA is also bounded, but researchers do not have readily access to the entirety of it as in North Weir.

Occupancy surveys in the AIA for 2018 and 2019 were done primarily along the borders near the forest edge. The area where the nests were found, the data for my research, is in an area where roads are clustered within a small area. Surveys were conducted throughout the area shown in **Figure 11**, but it is still possible that the significant finding for nest occupancy with distance to road is due in part to unintentional observer bias, if they were more likely to notice nesting behavior in areas close to occupied nests. Even if surveys are completed for the entirety of the area, constraining PPE gear, time and frequency to survey limitations may hinder the ability to correctly estimate Oregon Vesper Sparrow population in the AIA. In creating the study boundary for the AIA, I was unable to obtain information regarding the exact boundaries of the survey area for nest monitoring. The boundary I created is the best approximation based on the data I received. During my time in North Weir I learned it can take days or weeks to locate a nest, even with general knowledge of where one is located. However, because I have never been to the AIA to observe how the grasses and vegetation are laid out, this is speculation. It could be ground nests are easier to find on the AIA than in North Weir, thus time and effort is not as consuming. If not, the real-world access limitations of the AIA could skew the theoretical logistical modeling of my test.

Analyzing relationships of habitat characteristics on the landscape scale on the Weir prairies did not yield any significant relationships for my research. However, it is interesting to note that the direction of the relationship between nest occupancy and distance from road is the same for the Weir sites (2018 and 2019), although non-significant, as the AIA 2018 relationship. Coefficient estimates of NEAR_DIST relationship with nest occupancy in **Table 8** further reflects the association. AIA 2018 has a coefficient estimate of -0.06765, compared to the Weir 2018 -0.05743 and Weir 2019 -0.0383, ever unit of 1 increase in NEAR_DIST, the less likely a nest will have occupancy. Is the relationship measured in **A5** for AIA 2018 a reflection of how Oregon Vesper Sparrow populations respond to habitat fragmentation in their breeding season, carrying out breeding behaviors like selecting nest locations? Consider my variables of nest location and road structure $\leq$ 64 meters of the nest. I measured the presence of the nearest road to the nest as explanatory variable, but not the specific edge effects of the roads themselves. While further research will be needed to analyze those effects, we can glean information from published research to bring this research full circle back into habitat fragmentation.

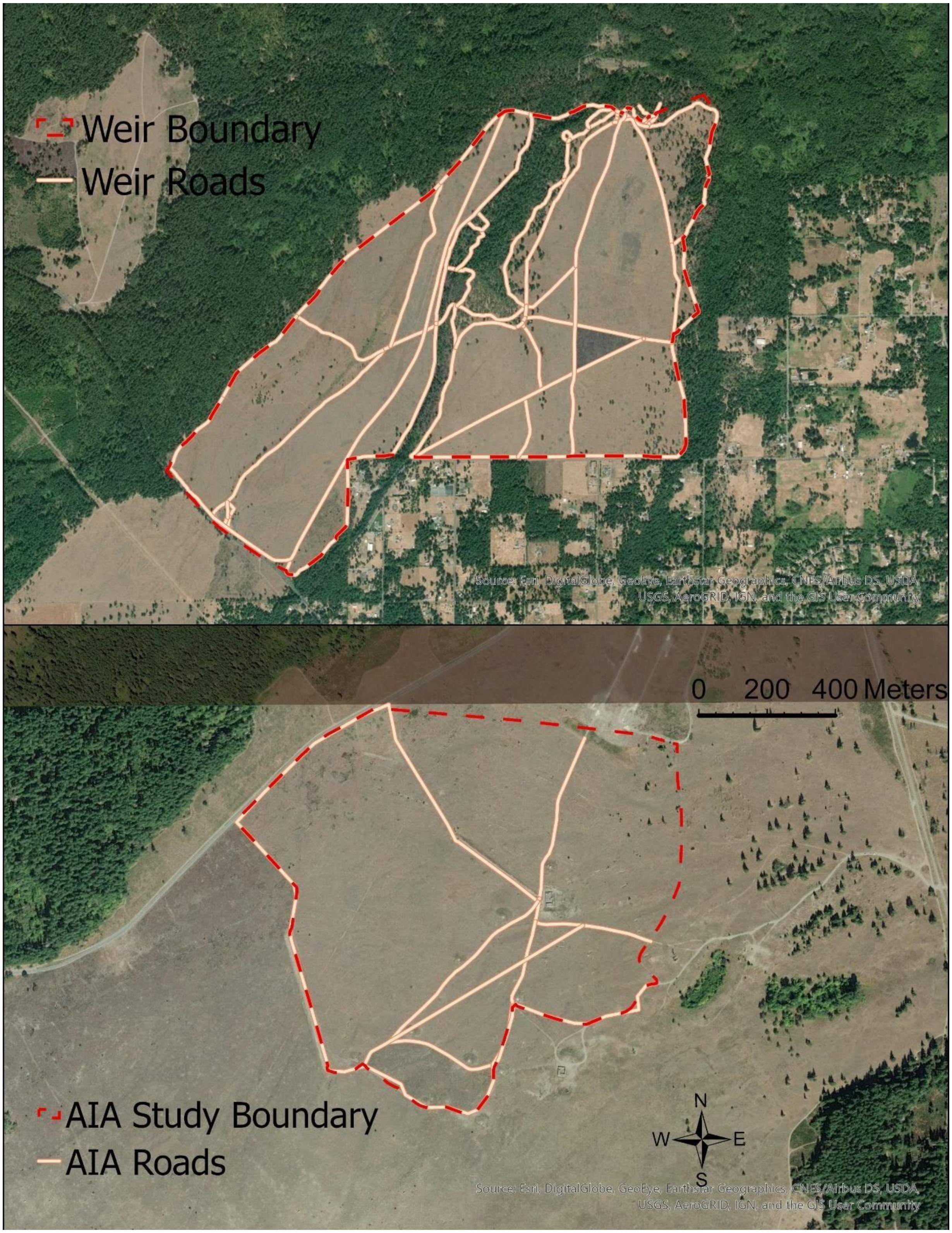

Figure 12 Comparison of boundaries and roads between study sites

Referring to **Figure 8** for the AIA and Weir prairies notice how the placement of the roads is breaking up the continuity of ground habitat made available for nesting. The interior of these areas in my study areas are considered patches. A series of these composes the matrix of the landscape. From a visual standpoint, one can argue the Weir prairies are more fragmented than the AIA. There is a linear relationship in that as patch size increases, distance from core habitat to edge does as well, potentially making it difficult for species to access other patches of the matrix (Davis et al. 2006). However, most bird species like the Oregon Vesper Sparrows can more able to bypass the patch core to edge distance with flight. Even so, this ability is affected by characterizations of their habitat and landscape matrix, meaning corridor protection, restoration and management of landscape vegetation are important when considering habitat connectivity and access for birds (Castellón and Sieving 2006).

Roads measured within my datasets are not major highways and have relatively low traffic and are not likely acting as a barrier from Oregon Vesper Sparrow accessing various patches of the landscape matrix. However, as ground nesters the roads may play a role in where they choose to excavate the ground for nest placement. The effects of nest success rate near non-high activity highway roads have been shown to have negative effects on nest survival (Webb et al. 2012) as well as no measurable significant effect (Dzialak et al. 2011). Roads primarily used for logging trucks in managed lands are known to act as corridor access into clearcut areas or shrublands for predators, potentially increasing occurrences of nest predation (Askins 1994; Small and Hunter 1988). These effects are not only based on the predator presence of the landscape but also the varying distance of nests to roads; and distance to clearcut edges have been found to have a stronger correlation with nest survival (Yahner and Mahan 1997).

During my time spent in North Weir prairies logging trucks along the outer perimeter on the western side of South Weir were frequent in the spring. Only one nest was in a patch which bordered this road but was not within 64 meters of it. From my observations, the rest of North Weir roads were infrequently used by researchers and people in 4-wheeled vehicles. In the AIA I find it highly unlikely the roads within the study area are used on a daily basis, if at all. The positive relationship of nest occupancy within 64 meters of a road on the AIA may be because the fires and artillery barrage in the area force people to stay off and likely deter predators from using the roads to access the Oregon Vesper Sparrow breeding habitat.

Many bird species return to breeding grounds season after season, like the European Pied Flycatcher (*Ficedula hypoleuca*) (Greenwood and Harvey 1982). While more data needs to be collected in future seasons, there is a possibility Oregon Vesper Sparrows may be returning to either North Weir prairie or AIA multiple breeding seasons. If so, research investigating if individual there is individual or pair preference for certain breeding areas within the habitat and what factors may be influencing those behaviors would be prudent in understanding Oregon Vesper Sparrow breeding behavior.

Conclusion

Prairie Habitat and Avian Assemblages

When considering what landscape characteristics to focus on in relation to Oregon Vesper Sparrow habitat management and species conservation, it can be difficult to put weight on variables which may prove to have significant correlation to breeding behaviors. How can we best put our resources and energy to strengthen the chances of a bounce back of Oregon Vesper Sparrow populations, reversing the trend attributed to breeding population isolation? Coming into my research, I expected if there were a significant relationship, it would be nests being constructed further away from trees, rather than nests closer to roads. This points to the majority of literature I reviewed examining fragmentation and bird assemblages stating unexpected results and, in some cases, results conflicting from those of other studies.

Birds are a fascinating and unique group of organisms when considering habitat fragmentation due to their ability to fly, allowing them some degree of freedom from the restrictions of confined habitat corridors in a degraded landscape matrix; especially bird species that seasonally migrate. Oregon Vesper

Sparrows being a species which nest in the ground on prairie habitat which is quickly disappearing in their breeding range adds further complications when conducting research. This habitat is not prevalent and disappearing not only within their breeding range, but all over the U.S impacting the continental wide communities of prairie obligate species. With the most intact prairies are found on military installations the argument could be made there is an increasing lack of access to research prairie obligate birds by the greater ornithological and ecological scientific community. However, the restrictions of these prairies on military managed lands are most likely the reason why these prairies have prevailed while others have disappeared.

Oregon Vesper Sparrow Conservation, Looking Forward

At the time of this thesis, Oregon Vesper Sparrows are not listed under the Endangered Species Act, thus funding to research the species and protect its habitat is not as prevalent as it could be. Lack of research on the species does little to push forward the efforts of the enlistment and conservation. If Oregon Vesper Sparrows are enlisted under the act, funding and policy will likely flow towards research in efforts to protect the species from full extirpation from western Washington and possibly extinction. My study may provide useful insight towards land managers and organizations which are studying the species or managing prairie habitat where Oregon Vesper Sparrow populations breed.

There are ongoing projects to not only analyze what habitat and landscape variables may influence Oregon Vesper Sparrow breeding behavior, but management plans to make non-viable habitat viable for Oregon Vesper Sparrow breeding are being implemented in western Washington, such as the Violet Prairie Scatter Creek Preserve in western Washington. As the species migrate to into the state for breeding season they may come upon such areas and utilize them for breeding habitat, increasing their chances of survival by lessening the effect of breeding isolation pockets within their range. How road and tree presence may influence nest site selection may aid land managers recognize the greater potential of landscape composition influence on nest site selection.

There needs to be more done by the ecological and ornithological communities in exploring how habitat and landscape components of the overall matrices affect Oregon Vesper Sparrow selection of breeding habitat. Additionally, genetic information, wintering behavior and habitat analysis, along with an investigative approach to the multitude of prairie fragmentation aspects mentioned throughout this paper will not only benefit Oregon Vesper Sparrows, but potentially the greater community of prairie endemic species as a whole.

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Appendix

Appendix A

A1 Weir nests from 2018. Occupied nests have a binary value of 1, random nest points (unoccupied) have a binary value of 0. Three species were measured within 64 meters of nests from this dataset, *Pseudotsuga menziesii*, *Quercus garryana*, and *Arbutus menziesii*.

NestID	*Occupancy*	*Species Total*	*Pseudotsuga*	*Quercus*	*Arbutus*
TA21_18-01	1	30	19	3	8
TA21_18-02	1	0	0	0	0
TA21_18-03	1	0	0	0	0
TA21_18-04	1	0	0	0	0
TA21_18-05	1	0	0	0	0
TA21_18-06	1	1	1	0	0
TA21_18-07	1	26	4	22	0
TA21_18-08	1	0	0	0	0
Random Nest Points					
WeRan_18-01	0	22	3	19	0
WeRan_18-02	0	77	3	68	1
WeRan_18-03	0	7	0	6	0
WeRan_18-04	0	30	28	0	0
WeRan_18-05	0	2	1	0	1
WeRan_18-06	0	0	0	0	0
WeRan_18-07	0	10	4	0	6
WeRan_18-08	0	0	0	0	0

A2 Weir nests from 2019. Occupied nests have a binary value of 1, random nest points (unoccupied) have a binary value of 0. Two species were measured within 64 meters of nests from this dataset, *Pseudotsuga menziesii, Quercus garryana*, and *Arbutus menziesi*

NestID	*Occupancy*	*Species Total*	*Pseudotsuga*	*Quercus*	*Arbutus*
TA21_19-01	1	4	3	1	0
TA21_19-02	1	0	0	0	0
TA21_19-03	1	0	0	0	0
TA21_19-04	1	1	1	0	0
TA21_19-05	1	1	1	0	0
TA21_19-06	1	4	3	1	0
TA21_19-07	1	0	0	0	0
TA21_19-08	1	0	0	0	0
Random Nest Points					
WeRan_19-01	0	0	0	0	0
WeRan_19-02	0	0	0	0	0
WeRan_19-03	0	0	0	0	0
WeRan_19-04	0	0	0	0	0
WeRan_19-05	0	0	0	0	0
WeRan_19-06	0	8	8	0	0
WeRan_19-07	0	0	0	0	0
WeRan_19-08	0	1	1	0	0

A3 Weir 2018 nest distance from road, measured in meters. Occupied nests within or equal to 64 meters from a road have a binary value of 1, occupied nests and random (unoccupied nests) at a distance greater than 64 meters from a road have a binary value of 0.

Nest ID	*Occupancy ≤ 64m*	*Meters from Road*
TA21_18-01	1	8.78
TA21_18-06	1	45.66
TA21_18-07	1	12.40
TA21_18-08	1	22.11
TA21_18-03	0	231.02
TA21_18-05	0	245.98
TA21_18-04	0	117.43
TA21_18-02	0	91.55
Random Nest Points		
Wcont_18-01	0	9.40
Wcont_18-02	0	18.20
Wcont_18-03	0	41.75
Wcont_18-04	0	66.45
Wcont_18-05	0	51.84
Wcont_18-06	0	75.07
Wcont_18-07	0	50.83
Wcont_18-08	0	150.08

A4 Weir 2019 nest distance from road, measured in meters. Occupied nests within or equal to 64 meters from a road have a binary value of 1, occupied nests and random (unoccupied nests) at a distance greater than 64 meters from a road have a binary value of 0.

Nest ID	*Occupancy ≤ 64m*	*Meters from Road*
TA21_19-01	1	62.60
TA21_19-05	1	55.32
TA21_19-06	1	58.98
TA21_19-07	1	8.70
TA21_19-08	1	39.05
TA21_19-04	0	120.25
TA21_19-02	0	222.04
TA21_19-03	0	65.79
Random Nest Points		
Wcont_19-01	0	162.47
Wcont_19-02	0	45.71
Wcont_19-03	0	137.38
Wcont_19-04	0	45.70
Wcont_19-05	0	173.44
Wcont_19-06	0	29.53
Wcont_19-07	0	56.69
Wcont_19-08	0	98.74

A5. Artillery Impact Range (AIA) nests from 2018. Occupied nests have a binary value of 1, random nest points (unoccupied) have a binary value of 0. Only one species of tree was measured within 64 meters of nests from this dataset, *Pseudotsuga menziesii*.

Nest ID	*Occupancy*	*Tree Sum*	*Pseudotsuga*
R76_18-01	1	0	0
R76_18-02	1	0	0
R76_18-03	1	0	0
R76_18-04	1	0	0
R76_18-05	1	1	1
R76_18-06	1	0	0
R76_18-07	1	0	0
R76_18-08	1	0	0
R76_18-09	1	0	0
R76_18-10	1	0	0
R76_18-11	1	0	0
Random Nest Point			
AIACon_18-01	0	0	0
AIACon_18-02	0	0	0
AIACon_18-03	0	0	0
AIACon_18-04	0	0	0
AIACon_18-05	0	0	0
AIACon_18-06	0	3	3
AIACon_18-07	0	1	1
AIACon_18-08	0	0	0
AIACon_18-09	0	0	0
AIACon_18-10	0	0	0
AIACon_18-11	0	0	0

A6 AIA 2018 nest distance from road, measured in meters. Occupied nests within or equal to 64 meters from a road have a binary value of 1, occupied nests and random (unoccupied nests) at a distance greater than 64 meters from a road have a binary value of 0.

Nest_ID	*Occupancy ≤ 64 m*	*Meters from Road*
R76_18-01	1	3.20
R76_18-02	1	48.55
R76_18-03	1	12.50
R76_18-04	1	25.70
R76_18-06	1	14.03
R76_18-07	1	11.04
R76_18-08	1	56.94
R76_18-10	1	11.86
R76_18-05	0	78.86
R76_18-11	0	104.98
R76_18-09	0	77.60
Random Nest Points		
AIACon_18-03	0	8.90
AIACon_18-09	0	58.05
AIACon_18-11	0	59.13
AIACon_18-08	0	172.85
AIACon_18-06	0	223.63
AIACon_18-05	0	146.30
AIACon_18-07	0	86.12
AIACon_18-02	0	82.98
AIACon_18-04	0	187.85
AIACon_18-01	0	211.62
AIACon_18-10	0	70.70