NEST-SITE SELECTION OF

WESTERN PURPLE MARTIN (*PROGNE SUBIS ARBORICOLA*)

ON JOINT BASE LEWIS-MCCHORD, WA

by

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A Thesis
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
June 2019

This Thesis for the Master of Environmental Studies Degree

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The Evergreen State College

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ABSTRACT

Nest-site selection of Western Purple Martin (*Progne subis arboricola*)
On Joint Base Lewis-McChord, WA

Tracey Scalici

The Western Purple Martin (*Progne subis arboricola*) is a secondary cavity-nesting swallow and subspecies of the Purple Martin (*Progne subis*). They are currently listed as a Species of Greatest Conservation Need in Washington State with population declines primarily attributed to loss of nesting habitat. They historically nested in natural cavities like abandoned woodpecker holes in dead trees (snags). The presence of snags is limited for several reasons including forestry practices and urbanization. Less than 5% of the estimated 700 pairs within Washington nest in snags including a small population located on Joint Base Lewis-McChord (JBLM), an active military base in western Washington. Little is known about the locations and characteristics of these natural nest sites. Over two breeding seasons in 2017-18, I surveyed JBLM for snag-nesting martins and collected data on confirmed nesting snags (N=24). I also collected data on random non-nesting snags (N=22) within 200 meters of nest snags. Nesting snags had significantly less canopy cover than non-nesting snags at zero and twenty-five meters. I found no significant differences in other variables measured. My results highlight the importance of JBLM as a source of natural nesting habitat and continued persistence of snag-nesting Western Purple Martin in Washington.

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Acknowledgements

Thank you to Joint Base Lewis-McChord Fish and Wildlife for the opportunity to perform research in such a unique environment. In particular, I would like to thank Todd Zuchowski, Jim Lynch, Dennis Buckingham, and Fiona Edwards who provided access, support, encouragement and enthusiasm for my research. I feel incredibly fortunate to have been able to study one of the great passions of my life, birds. Thank you to my thesis advisor John Withey, Ph. D. for all of his direction and support not only in the thesis writing process but during both survey years. Thank you to my fellow colleagues at Washington Department of Fish and Wildlife including Gretchen Blatz for her assistance and support, and my supervisor Eric Kraig whose flexibility allowed me to perform surveys even during our busiest time of year. Thank you to all those who assisted with surveys including several friends and colleagues as well as a great team of enthusiastic JBLM Fish and Wildlife interns. Special thanks to my friend Cherril Bowman who was a tried and true field companion and always up for a Purple Martin adventure. I am so grateful for all of your help. There were many family, friends, and co-workers who gave me encouragement throughout these three years. Although I can’t list you all, I want you to know how much your kind words meant to me. Finally, I want to thank my son Joshua who continually inspires me to be my best self.

INTRODUCTION

Human populations are expected to increase to nearly ten billion people by the end of the century, placing significant demands on finite natural resources. Consequences of this demand include an increase in urbanization, associated habitat destruction, and loss of biodiversity (Primack, 2014). Washington State is not immune to these pressures, with 2017 population estimates at just over 7.4 million people, a 20% increase from the year 2000 (U.S. Census Bureau, 2019). Many of the habitats affected by this growth are critical to the continued survival of fish and wildlife species.

In order to better manage and conserve the habitats important to these species, the Washington State Department of Fish and Wildlife (WDFW) developed the Priority Habitat and Species List (PHS List) with priority habitat types defined as those "with unique or significant value to many species" (Washington Department of Fish and Wildlife, 2018). Terrestrial habitats include riparian areas, prairies, shrub-steppe, oak woodlands, dunes, aspen stands, and old growth forest. Non-federal forested habitats within western Washington in particular, have been impacted by urbanization, with reported declines of 0.2 percent per year from 1976-2006 (Gray, Azuma, Lettman, & McKay, 2013). In their PHS List, WDFW listed snags as priority features within forest ecosystem habitats.

Snags are dead or dying trees that provide numerous benefits to forests including habitat and forage for a variety of organisms ranging from invertebrates and fungi, amphibians, reptiles, mammals, and birds (Neitro et al., 1985). When standing snags fall, their decomposition helps return nutrients such as nitrogen to the soil (Evelyn L Bull, Parks, & Torgersen, 1997; Hunter, 1990). Though the benefits of snags are well documented, they remain a common limiting factor in the success of wildlife species that rely on them (Newton, 1994).

In Washington State, millions of acres of forest are managed for a variety of purposes including revenue generation, public recreation, and fish and wildlife habitat. Meeting all these management needs is a considerable task, especially within intensively managed areas. Within these forests, snags are lacking (Cline et al.,1980; Hayes et al., 2005). Current state and federal forest management policies recommend retention of a minimal number of snags (generally 5 to 10 per acre), during timber harvest operations (Cline et al., 1980; USDA & USDOI, 1994). Removal also occurs when snags pose safety risks, or are used for firewood and wood chip products (Thomas, Anderson, Maser, & Bull, 1979).

Snags play an integral role in the life history of cavity-nesting birds. Cavity-nesting birds use snags for nesting, roosting, perching, and as food sources and caches. Primary cavity- nesting birds such as woodpeckers, create cavities in snags by drilling into the bark with their powerful bills. They use these cavities often for only one season (Evelyn L Bull et al., 1997). These nest sites are then made available to secondary cavity nesters like swallows and owls, which do not have the ability to create their own.

The focus of my research involves a secondary cavity nester, the Western Purple Martin (*Progne subis arboricola*). Western Purple Martin are a subspecies of the Purple Martin (*Progne subis*), North America’s largest member of the swallow family

(*Hirundinidae*). As neotropical migrants, they arrive in western Washington to breed in early April to May. In late August to September, they return to their wintering grounds in the Amazon Basin in South America. Unlike *P. subis* which is completely dependent on the provision of man-made nest boxes, the Western subspecies continues to nest in natural cavities such as those created by woodpeckers in snags, as well as various nest holes inadvertently created by humans including old buildings, offshore pilings, and the weep holes under bridges (Daniel A. Airola & Kopp, 2009; C.R. Brown & Tarof, 2013).

In the absence of natural cavities, Western Purple Martin will also use man-made houses such as gourds and nest boxes. Though the species is not federally listed, they are currently listed as a Species of Greatest Conservation Need in Washington State by the Washington Department of Fish and Wildlife (Washington Department of Fish and Wildlife, 2015) . Reasons for population declines include loss of habitat (namely natural tree cavities), competition for nest cavities by non-native species such as the European Starling (*Sturnus vulgaris*), nest parasites, and sensitivity to changes in climate (B. Cousens & Lee, 2012). During unfavorable weather conditions, insects are scarce, delivering devastating blows to local populations (B. Cousens, 2010). Population estimates for Washington State as of 2010 total about 700 pairs. Of those pairs, less than 5% are believed to be nesting in natural cavities (B. Cousens & Lee, 2012).

Western Purple Martin currently nest in both man-made and natural nest sites on Joint Base Lewis-McChord (JBLM). Located in western Washington between Olympia and Tacoma, JBLM is the fourth largest military installation in the United States. It spans approximately 91,000 acres and includes late successional forests, wetlands, and prairies. Several locations on base provide ideal habitat for martins, including open areas near water with available snags. Although nest boxes have been placed within this habitat, the locations of natural nest sites on base and accurate population estimates are largely unknown. JBLM Fish and Wildlife biologists are interested in research examining the extent of natural nest site availability and use by Western Purple Martin.

In the literature, little information exists regarding Western Purple Martin nesting in snags. The few papers describing the characteristics of nesting snags are limited to California and Oregon (Horvath, 1999; B. D. C. Williams, 2002). I found no literature specific to the nest site characteristics for these birds within Washington. Studying the Western Purple Martin that nest in snags on JBLM, presents the opportunity to observe and record this information for potentially one of the largest remaining wild nesting populations in Washington.

During the 2017-18 breeding season (April-August), I conducted searches and collected data on snag-nesting Western Purple Martin on JBLM. My research sought to answer the following questions: 1) What are the locations and characteristics of snags used for nesting by Western Purple Martin (*Progne subis arboricola*) on Joint Base Lewis-McChord?, and 2) How much variability in habitat and snag characteristics occurs in snags used for nesting, and how does this compare to unoccupied snags? Knowledge of breeding locations and nest site characteristics will enable biologists and other land managers to make informed land use decisions and protect habitat important not only to Western Purple Martin, but also the numerous species on base that use snags, including 39 species of cavity-nesting birds (JBLM Fish and Wildlife, unpublished data).

LITERATURE REVIEW

The Western Purple Martin (*Progne subis arboricola*), the largest member of the swallow family (*Hirundinidae*), is a subspecies of the Purple Martin (*Progne subis*). The Western Purple Martin is currently listed as a Species of Greatest Conservation Need in Washington State by the Washington Department of Fish and Wildlife (Washington Department of Fish and Wildlife, 2015). Declines have been attributed to several factors. The first is lack of natural nesting habitat, specifically snags. Second, introduced species such as the European Starling (*Sturnus vulgaris*), further these limitations by competing for available nest cavities. Third, high parasite loads present in nesting material negatively impact nestling growth and increase the risk of mortality. Finally, because martins are obligate insectivores, cold wet spring weather increases the risk of starvation. As of 2010, martin populations are estimated at 700 pairs with less than 5% using natural nesting cavities (B. Cousens & Lee, 2012).

The following review summarizes information found in the literature regarding the life history and conservation status of the Western Purple Martin. The first part of this literature review focuses on snags and their significance within forest ecosystems. I introduce cavity-nesting birds and how snags play a particularly important role in their life history. Finally, I address reasons for the limited availability of snags as a resource for wildlife.

The second part of this review introduces the Purple Martin and associated subspecies, giving a general description of their biology, behavior, and distribution. A more detailed account is provided for my focal species, the Western Purple Martin, focusing on Pacific Coast populations within Washington, Oregon, California, and British Columbia. I include historical accounts, current conservation status, and available information on natural nesting. Although nest boxes have been crucial in the recovery of declining populations, I present both the positive and negative implications of their use.

Finally, I describe the theory of habitat selection in birds including its contributions and limitations in the understanding of nest-site selection by cavity-nesting birds.

Snags and Their Significance

Dead standing trees, or snags, provide numerous benefits to forest ecosystems including habitat and forage for nearly 100 species of wildlife as well as numerous invertebrates and fungi (J. Bottorff, 2009; Neitro et al., 1985). Not only do they provide habitat and a food source, their decomposition helps return vital nutrients to the soil (Cline et al., 1980).

Limitations to snag availability can be the result of several factors including stochastic events, forestry practices and urbanization. Snags are created naturally due to disturbances including forest fires, windfall, insect attacks, flooding, and wood decaying fungi (Evelyn L Bull et al., 1997) . Within managed forests, the focus is often on maximum production of wood products, resulting in even-aged, monoculture stands with little understory diversity (Hayes et al., 2005). Snag availability can be limited in these environments due to removal because they present safety concerns, or for use as wood chip products and firewood (Thomas et al., 1979). Snags become even scarcer in densely populated areas where forest habitat is replaced by urban sprawl (Blewett & Marzluff, 2005).

Importance of Snags to Cavity-Nesting Birds

Snags play an integral role in the life histories of cavity-nesting birds. In addition to nesting and foraging, birds use snags during the breeding season as locations for courtship, nesting platforms, and fledging of young. They are also used for perching and communication via singing and drumming. (Neitro et al., 1985).

Cavity-nesting birds are divided into two groups, primary cavity nesters and secondary cavity nesters. Primary cavity nesters such as woodpeckers are the first to begin excavating cavities in snags, and typically use them for only one breeding season. These birds have powerful bills enabling them to drill through the hard-outer layers of bark and sapwood to penetrate the heartwood where the nesting cavity is located. If the tree is sufficiently decayed, smaller birds like chickadees and nuthatches will also create cavities. Unused or subsequently abandoned cavities then become available to secondary cavity nesters such as wrens and bluebirds, which are unable to excavate their own (Evelyn L Bull et al., 1997).

Approximately 85 species of North America birds use snags as nesting habitat (Scott, 1977). Several studies quantifying the importance of these snags to cavity-nesting birds have been published, describing the characteristics of snags and their use by particular species (McClelland & Frissell, 1975; Runde & Capen, 1987). Measurements of these characteristics including height, diameter, and decay stage (hard or soft) are important to their use by wildlife (Thomas et al., 1979).

There are numerous benefits for bird species entirely dependent on snags for nesting habitat. Natural cavities provide protection from excess heat, cold, and moisture and decrease the risk of winter mortality (McComb & Noble, 1981). Snags provide foraging opportunities, and cavity-nesting birds which are primarily insectivores, search for insects on the surface and underneath the bark of decaying wood (Neitro et al., 1985). In addition to foraging, birds use snags as caches enabling them to access food when supplies are low (Brawn, Elder, & Evans, 1982; Neitro et al., 1985). Woodpeckers in particular are voracious predators known to forage on insect pests such as the mountain pine beetle (*Dendroctonus ponderosae*) (Evelyn L Bull, 1983). The foraging of these and other cavity-nesting birds has been shown to be an important factor in the natural control of insect populations (James G Dickson, Conner, Fleet, Jackson, & Kroll, 1979). A study of cavity-nesting birds in pine forests within Arizona found secondary cavity nesters to be a significant part of the overwintering population, and important in removal of insects that might have otherwise hatched the following spring (Balda, 1970).

Limited availability of snags has negative implications for many cavity-nesting birds. Abundance of cavity-nesting birds, as well as species diversity and richness, has been directly correlated with snag abundance (J.G. Dickson, Conner, & Williamson, 1983; Schreiber, 1992; Stribling, 1990). An experimental study in Arizona demonstrated significant increases in breeding densities of secondary cavity nesters when nest boxes were installed within treatment plots. It should not however, be assumed that lack of nest cavities alone limits density. A two year experiment conducted in California, showed no significant decline in secondary cavity nesters when available tree cavities were blocked on treatment plots (Waters, Noon, & Verner, 1990). Results of experimental studies are often more pronounced in certain species, suggesting that cavities are important, but do not always determine breeding density (Brawn & Balda, 1988; Newton, 1994).

Within Washington State, 52 bird species are considered Species of Greatest Conservation Need (Washington Department of Fish and Wildlife, 2015). Included on this list is the Western Purple Martin, the focus of my thesis research.

The Purple Martin

Distribution

The Purple Martin (*Progne subis*) includes three subspecies: *P. s. subis*, *P. s. arboricola*, and *P. s. hesperia* (Chesser et al., 2018). These subspecies are similar in many regards with most pronounced differences in distribution, population numbers, physical size, and nesting habitats. Neotropical migrants, they spend their winters in the Amazon Basin in Brazil as well as northern Bolivia and coastal areas of Argentina (Turner & Rose, 1989), returning to North America in the springtime to breed (Figure 1). Though there is some documentation in the literature regarding the distributions of the subspecies, this is an area in need of more research (C.R. Brown & Tarof, 2013), and the following description should be considered approximate. *P. s. subis* breeds east of the Rocky Mountains and throughout the eastern part of the United States, as far north as southern Canada, with southern limits in Florida and the transvolcanic belt in Mexico (C.R. Brown & Tarof, 2013; Turner & Rose, 1989). *P. s. hesperia* is limited to the deserts of southern Baja, California and Arizona and Tiburon Island (Turner & Rose, 1989). *P. s. arboricola* breeds both within and west of the Rocky Mountains, along the west coast from southern California to southwestern British Columbia and parts of Colorado and

Utah (C.R. Brown & Tarof, 2013). Although there are three recognized subspecies, population numbers cited often reflect the species as a whole. Partners in Flight recently estimated global population size at approximately 9,300,000 (Partners in Flight, 2017).

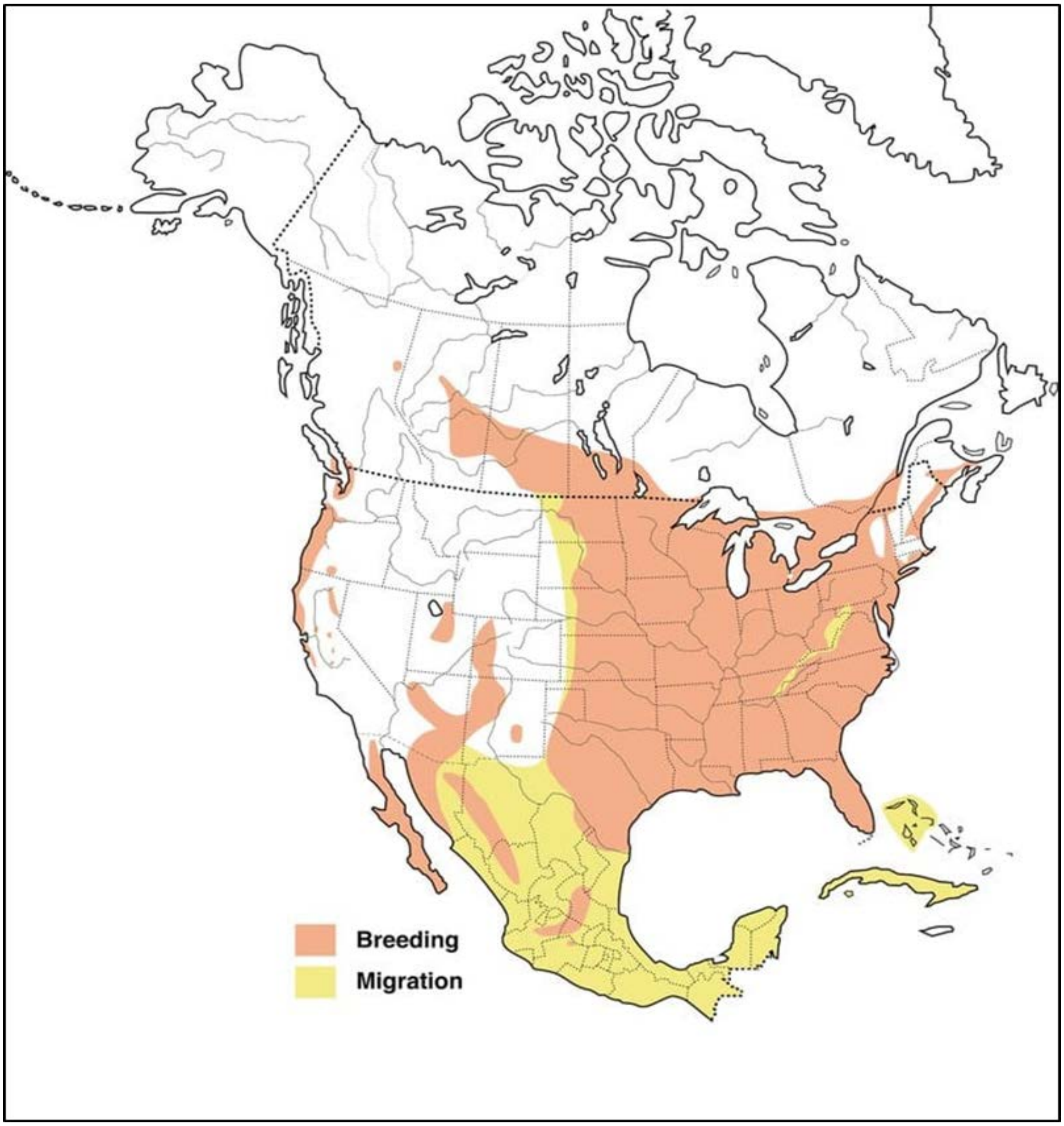

Figure 1. North American breeding distribution of *Progne subis* including all subspecies. Image from: https://www.allaboutbirds.org/guide/Purple_Martin/maps-range

Morphology

All three subspecies are similar in appearance with adult males having iridescent deep blue to purplish-black plumage throughout, and adult females and young much grayer around the throat and breast with a grayish collar around the neck (Figure 2). Sub adult males look strikingly similar to females, but with some dark blue streaking on the breast, with this difference more pronounced in the western species (C.R. Brown & Tarof, 2013) (Figures 2 & 3). Size is the most apparent difference between races and can be determined by measuring the length of the wing chord. For example, the wing chord lengths of the males of the three subspecies *P. s. subis, P. s. hesperia,* and *P. s. arboricola* are >134, >132, >146 respectively (Behle, 1968).

Figure 2. Adult male Western Purple Martin shown on left and adult female on the right. Photos courtesy of Kim Stark.

Figure 3. Sub adult male Western Purple Martin on the left and sub adult male and female (upper right). Photos courtesy of Kim Stark.

Breeding

Purple Martin are asynchronous breeders and timing of return to the breeding grounds differs with sex and age-class (Morton & Derrickson, 1990). Adult male and female birds are the first to arrive, with first-year breeding sub adults arriving about 4-12 weeks later. Males establish territories and pair with females within a few hours to a few days, and defend the nest cavity and surrounding area (Turner & Rose, 1989). Pairs are more commonly monogamous, but instances of polygamy have been reported (C.R. Brown, 1975). Nest building is done primarily by the female and consists of a variety of nesting material including stems, twigs, grasses, leaves, and occasionally mud (C.R. Brown & Tarof, 2013; Stutchbury, 1991). Females typically lay 4-5 white eggs and begin incubation after the last egg is laid. Incubation lasts approximately 15-17 days and birds typically fledge 28 days after hatching (Baicich & Harrison, 1997; Finlay, 1971). In most cases only one brood is produced per season, but reports of two have been documented (C.R. Brown, 1978).

Nesting

The nesting habits of Purple Martin have changed significantly over time. Historically, all subspecies nested in natural cavities such as cliffs and the holes created by woodpeckers in snags and saguaro cactus (C.R. Brown & Tarof, 2013; Stutchbury, 1991). The first accounts of eastern martins using artificial housing began before European settlement, with accounts of Native American tribes creating nesting cavities for martins using hollowed out gourds hung on poles (Bent, 1942). This association with humans continued as forested areas were developed, and natural sites became limited. Eastern martins began utilizing cavities inadvertently created by people in marine pilings and old buildings. This continued throughout the early 1900's as artificial housing was erected for martins including gourds and elaborate nest boxes deemed "martin condominiums". By the end of the nineteenth century, eastern martins had adapted to nesting almost exclusively in man-made nests of which they are now wholly dependent (C.R. Brown & Tarof, 2013). Though the western subspecies also use artificial nest boxes, they still nest in natural cavities, with *P. s. hesperia* nesting in abandoned woodpecker holes of the saguaro cactus, and *P. s. arboricola* in snags. Though the eastern species nests colonially, western martins tend to nest solitarily with typically one to two pairs per site reported (C.R. Brown & Tarof, 2013; Stutchbury, 1991).

Feeding

Martins are insectivores, feeding nearly exclusively on insects taken in flight while foraging alone, in pairs, or small groups. Recent data using altitudinal data loggers recorded martins flying a maximum altitude of 1,945 meters with mean daily altitudes of

119 meters (Dreelin, Shipley, & Winkler, 2018). This is in contrast to previous reports of typical foraging heights of 30-60 meters, with a maximum height of 150 meters (Johnston & Hardy, 1962; Turner & Rose, 1989). Distances traveled from the nest site during foraging can depend on time during breeding season, with birds traveling 5-10 km prior to incubation and 1-2 km when feeding nestlings (B. Cousens & Lee, 2012). Stomach content studies detail the wide variety of insects consumed by Purple Martins which may vary depending on time of year, time of day, and area foraged. Insects include but are not limited to: dragonflies, midges, bees, wasps, grasshoppers, flies, spiders, butterflies, and beetles (Walsh, 1978). In a more recent analysis of prey delivery to nestlings, 83 different species of insects were identified with nearly 79% of those being ants (Helms, Godfrey, Ames, & Bridge, 2016).

Vocalizations

The vocalizations of the Purple Martin are unmistakable and can be heard from long distances, aiding in identification and detection (Lindstrand, 2008; B. D. C. Williams, 2002). Sounds characteristic of the species have been described, with subtle differences detected in eastern and western birds (Charles R. Brown, 1984). In total, Brown (1984) described ten distinct vocalizations. Similarities within species included the “zwrack”, “hee”, “choo”, “zweet” calls, with presumed similarities in “choo” calls. The “zwrack”, an aggressive alarm call used by both males and females, is used when fighting off intruders and potential predators. It is sometimes accompanied with “dive bombing” behavior directed at the target of the attack. While defending territory as well as attracting females, martins give a “hee” call. Juvenile birds give a “choo” call when in the nest, and while in flight. A “choo” call is used mostly by females, likely as a contact call and to direct young back to the roost site in the evening. Mated males use the "zweet" call in territorial disputes and to alert their mate to intruders. Differences between races were noted in the pattern and length of the "chortle" call (signifying excitement), as well as the male specific "croak" song and female "chortle" song. Finally, the dawn song as described by Morton and Derrickson (1990), is sung by male martins presumably to make arriving second-year males and females aware of available nest cavities.

Western Purple Martin

Washington

Within Washington, historical accounts of the distribution of Western Purple Martin are limited and often contradictory. Early records most likely underestimated populations due to the lack of systematic surveys and limited observations. One of the earliest accounts of the Western Purple Martin in Washington describe them as "virtually rare" and uncommon in the summer. They are said to have "adopted the ways of civilization", and limit their breeding to large cities (Dawson & Bowles, 1909). Migration timing in this account is similar to present day, with birds observed arriving in Tacoma, WA April 1, 1905 and departing September 1st. Reports of significant numbers of birds (7,000-12,500) were reported at a pre-migratory roost near Seattle's Green Lake during the 1940's (Kostka & McAllister, 2005; Larrison, 1947). Recounting earlier observations from the early 1950's, Jewett et al. (1953), limits distributions to being "wholly confined to cities and towns of western Washington", with some reports of birds as far north as Bellingham and south to Vancouver. A much later account indicates that they are a “fairly common migrant and summer resident” (Gabrielson & Jewett, 1970). From the years 1960-80, populations were declining, attributed to competition from the European Starling (Tautin, Cousens, Kostka, Kotska, & Airola, 2008). By the late 1980’s they were thought to be uncommon in western Washington with the majority nesting in nest boxes and pilings along the Columbia River (Milner, 1987). Current population estimates within Washington are ~700 pairs (Western Purple Martin Working Group, 2010).

There are few published accounts of Western Purple Martin nesting in natural cavities in Washington, and systematic inventories describing the extent of natural cavity use by martins are lacking (Western Purple Martin Working Group, 2010). Some of the earliest records of snag-nesting martins date back to 1860, where they were observed nesting in the scrub oak areas of the Nisqually Plains (Suckley & Cooper, 1860). In a 1994 systematic survey of 43 sites on Joint Base Lewis-McChord (formerly Ft. Lewis), martins were observed nesting in nest boxes at 14 of those sites but none were found nesting in natural cavities (J. R. Bottorff, Bill; Schroer, Greg, 1994). The lack of snag-nesting martins detected may have been influenced by survey methods. Sites were visited an average of 1-5 times during the season with observation times ranging from 10-30 minutes. Current survey recommendations suggest visiting potential nesting sites for 30-60 minutes, with a minimum 3 visits per site (Bruce Cousens & Airola, 2006). The suggested time of day is critical as well and was not indicated for this survey.

Oregon

Western Purple Martin are currently listed as sensitive, and considered uncommon and rare in Oregon (Marshall, Hunter, & Contreras, 2003), with an estimated 5% of the population still nesting in snags (Horvath, 1999). The first published systematic survey of martins in Oregon estimated the total number of breeding pairs at 784-1000 birds, and martins described as “uncommon and local”. Of those surveyed, 75% nested in martin specific artificial housing and the remaining 25% used a combination of snags, pilings, and other structures. A total of 35 pairs nested in snags, using mostly old woodpecker holes with 3 nesting in rot pockets. The author of the study admits that numbers of snag-nesting birds were likely underestimated, because of the difficulty in accessing certain remote habitats. This study does however, provide useful information on nest snags. Though the sample size is small, conservation recommendations for the long-term include retaining snags >20 meters tall in suitable martin habitat, with distances from the nearest tree canopy ≥10 meters. In the short term, it is suggested that starling-resistant nest boxes be constructed and installed in locations likely to be occupied by martins (Horvath, 1999). A more recent study conducted in the McDonald Dunn Research Forest in Benton County Oregon from 2011-2013, documented 1-2 pairs of martins nesting in a total of nine snags. Descriptions of snags were limited to tree species and number of cavities used.

California

Currently the Western Purple Martin is listed as a Bird Species of Special Concern in California (D.A. Airola & Williams, 2008), with natural nest sites reported in coniferous forest, oak and riparian woodlands, and collapsed lava tubes (B.D.C. Williams, 1998; Yocom & Browning, 1968). In a review of California distributions, Williams (1998) estimated current populations at 800-1000 pairs, with most still nesting in trees. He summarized the nesting status of Western Purple Martin in eleven different regions from the pre-1950 through 1998. The five regions with the largest number of reported nesting martins were northwestern California (250-650 pairs) with 5% using conifer snags, submerged snags, and hollow bridges; central western California (100-200 pairs) 10% in conifer snags and hollow bridges; the Central Valley (70-170 pairs) 10% in conifer snags; southwestern California 50-160 pairs with 90% nesting in conifer snags, and the Tehachapi Range where 100% of the 100-200 pairs nested in oak woodlands. In total, B.D.C. Williams (1998) suggests that >70% of martins continue to use trees for nesting. In his 1998 study, the mean diameter of snags at breast height was 130 cm (n = 17), with nesting pairs significantly greater in larger diameter trees. Nest trees averaged 24 m tall and were either standing alone or in scattered “clusters”.

Within oak woodlands, martins were once considered abundant, with populations extending into at least fifteen counties (D.A. Airola & Williams, 2008). They are now considered “rare and local”, with competition with the European Starling a likely cause of declines (B. D. C. Williams, 2002). A study of snag-nesting martins breeding in the oak woodlands of the Tehachapi Range, described and compared nest snags (n = 46) to unoccupied random snags (*n* = 38). There were significant differences in nesting snag canopy cover at 100 m, slope, number of holes, and diameter at breast height in nest snags. Martins nested in holes an average of 8 m above ground in trees 8.5-24 meters tall. (B.D.C. Williams, 2000). Lindstrand (2008) described martins nesting in snags at Shasta Lake in Shasta County, California. Information included snag location and number of nesting pairs. All nest snags except for one were submerged in the lake and averaged 1-3 nesting pairs. The exception was a ponderosa pine (*Pinus ponderosa*) located on a nearby ridge with two nesting pairs.

British Columbia

British Columbia is the northern most limit of the breeding range of the Western Purple Martin, and they are currently Blue-listed by the British Columbia Ministry of the Environment as a species of concern (B.C., 2019) Prior to the 1800's martins reportedly nested in snags within riparian areas and Garry oak parklands (B. Cousens & Lee, 2012). In the 1890's martins were noted as being common in the summer in Victoria, declining to only 2 to 3 pairs by the early 1920's (Campbell et al., 2011; Kermode, 1923). They nested in city buildings in Vancouver until 1948, and were absent from the mainland by the 1950's (Fraser, Copley, & Finlay, 2000). By the 1970's to early 1980's there were no martins known to nest in the wild (B. Cousens & Lee, 2012). Although the populations have been small historically, by 1985 the number of breeding pairs had declined to approximately 5. A nest box program established by volunteers was instrumental in recovering the population to approximately 200 breeding pairs by 2003 (Darling et al., 2004). Numbers steadily increased to 585 pairs in 2010, and by 2017 there were ~1200 breeding pairs in 112 colonies (Western Purple Martin Working Group, 2017). Nearly all of those birds nest in boxes, and a lack of nesting cavities is cited as the most serious threat to their persistence in the region (B. Cousens & Lee, 2012). Records of snag-nesting martins in the literature are limited, and I was unable to find any detailed descriptions or records of systematic surveys within British Columbia.

Conservation Status

Pacific Coast populations of Western Purple Martin are limited by lack of nesting cavities, interspecific competition, severe weather events, and nest parasites (B. Cousens & Lee, 2012; Kostka & McAllister, 2005). In all western states where the Western Purple Martin breed, population declines have been attributed to lack of available nesting cavities. This is not limited to snags, but includes other sources of cavities like pilings and nest boxes. Martins will nest in the rot pockets and old woodpecker holes of untreated pilings, but this is limited when pilings decay or are replaced with treated ones (B. Cousens & Lee, 2012; Horvath, 1999). Subsequent nest box installations on pilings have been successful in providing nesting holes, but require regular maintenance and replacement (Milner, 1987).

With regard to competition from other cavity-nesting birds, two introduced species, the House Sparrow (*Passer domesticus)* and European Starling (*Sturnus vulgaris*) pose the greatest threat to martins. Both species take over nest sites, destroy eggs, and kill nestlings and adults (C.R. Brown & Tarof, 2013). Early records indicate that House Sparrows were a significant source of competition within city nesting Western Purple Martins before more intensive competition from the European Starling (Bailey, 1917; Dawson & Bowles, 1909). Early concerns over the impact of competition from the

House Sparrow was so great, it was feared that they might force martins out of cities entirely (Dawson & Bowles, 1909).

European Starling were first seen in Puget Sound in 1949, with observers reporting that "The invasion of Puget Sound has begun" (Bennett & Eddy, 1949). This followed reported nesting in Adams County in 1951, and by 1977 they were considered an "abundant resident" in southeastern Washington (Weber & Larrison, 1977). Both starlings and House Sparrows are year round residents occupying similar developed and agricultural habitats that often overlap with martins. When martins arrive to the breeding grounds, these competitors are already established in cavities, leaving martins fewer available options (B. Cousens & Lee, 2012).

Dependency on flying insects makes martins highly susceptible to unfavorable weather. Cold and wet weather increases nestling mortality and chances of severe population crashes (C.R. Brown & Tarof, 2013; Walsh, 1978). In addition, it decreases activity during critical aspects of the breeding cycle including pair formation, nest building, egg laying, incubation, and feeding of nestlings (Finlay, 1976). In contrast, extremely warm temperatures can cause the young to fledge too early, and unable to feed themselves, die prematurely (Allen & Nice, 1952).

Conservation Efforts

With limited funding and resources available for the study of non-listed species, non-profit groups and volunteers have contributed much to the conservation and understanding of the Purple Martin. Here I provide more detail on just two of the many groups dedicated to Purple Martin recovery. In the eastern United States where *P. subis* populations appear to be stable, conservation efforts are led by groups like the Purple

Martin Conservation Association. Founded in 1987 by ornithologist James Hill III, the non-profit group promotes the conservation of the Purple Martin through research and public education. The group is funded through donations, and the sales of martin related products ranging from bumper stickers and earrings to guords and nest boxes of all shapes and sizes. They oversee several citizen science projects, contributing valuable data that cooperating scientists can use to better understand nesting and reproductive success. Funding has also been provided by this group to better understand migration using geolocator data-loggers. This informs scientists on important stopovers areas and migratory routes for martins on their way to wintering grounds in Brazil (Purple Martin Conservation Association, 2017; Tautin et al., 2008).

Although martin populations are smaller and martin hobbiests fewer on the west coast, a dedicated core of individuals are involved in the conservation of the Western Purple Martin. Concerned citizens, hobbiests, and retired professionals among others have volunteered their time and resources to not only increase martin populations, but also to bring isolated populations back from the brink of extinction. In 1998 J. Cam Finlay established the The Western Purple Martin Working Group. The group continues to be active, with approximately 100 members including biologists, state and federal agencies, conservation groups, and concerned citizens. Members contribute valuable research describing Western Purple Martin population distribution, status, and systematics as well as drafting recovery plans (Tautin et al., 2008). The group also works with volunteers to establish and monitor nest boxes. Many nest box birds have been banded as part of a cooperative program within the western states. Each state has its own distinct color band to more easily track birds (Vesely, 2014). These efforts have had a particularly positive impact within British Columbia. When nest boxes were installed in 1985, populations were brought back from an estimated 5 breeding pairs to nearly 200 by 2003 (Darling et al., 2004). Although important information is being collected on the species across North America, research focuses on man-made nest boxes and gourds, with research lacking on naturally nesting martins.

Joint Base Lewis-McChord

Joint Base Lewis-McChord (JBLM) is one of the largest military installations in the world. Located in western Washington, it spans nearly 91,000 acres including diverse habitats such as late successional forests, wetlands, and prairies. Many of these habitats are rare, including nearly 95% of the remaining oak woodlands in Washington and the largest remaining remnant prairie in Puget Sound. Federally listed species on these prairies include the Streaked Horned Lark (*Eremophila alpestris strigata*), Mazama pocket gopher (*Thomomys mazama*), and Taylor's checkerspot butterfly (*Euphydryas editha taylori*). Once federally listed as endangered, species habitat is designated "critical", and restrictions on activities within those areas are put in place. Because these are areas used for military training, restrictions have the potential to interfere with military activities (Anderson, 2011; JBLM, 2014). Therefore, recovery of endangered and threatened populations benefits not only the species concerned, but military operations as well. The Department of Defense collaborates with many partners including JBLM Fish and Wildlife, state and federal agencies, non profits, tribes, and volunteers to effectively manage JBLM lands for these multiple objectives.

The mission statement of JBLM Fish and Wildlife "is to protect, maintain, and enhance the various ecosystems on the installation to promote native biodiversity and support the military mission." This is achieved through habitat restoration projects, invasive species management, and the monitoring of plant and animal populations. Restoration work includes the use of prescribed fire, mowing, herbicide, and planting native species. This requires collaboration with the military in order to avoid conflicts with listed species management within training areas (Army, 2019).

Nest Boxes

The use of nest boxes has contributed significantly to the conservation and understanding of cavity-nesting birds on a global scale. Much of what we know about the Purple Martin can be attributed to studies conducted using nest boxes and gourds (Figure 4). Nest boxes allow easy access to birds for banding purposes, allowing for a wide range of data to be collected including migration timing, life expectancy, productivity, return rate of nestlings, and nest-site fidelity. In addition to bands, birds outfitted with small tracking devices such as geo locators and GPS data-loggers provide information about migration routes and wintering ground distributions (Loon et al., 2017; Tarof, Kramer, Hill, Tautin, & Stutchbury, 2011). This type of accessibility is limited in snag-nesting birds due to nest cavity height and the hazards present when working with decayed trees.

Figure 4. On left, an adult male Western Purple Martin feeding young in a gourd and probable adult female at nest box on right. Photos courtesy of Kim Stark and Gretchen Blatz.

Although much has been learned from nest box studies, it has been argued that results are potentially biased (Møller, 1989). With regard to nest predation, a study comparing the predation rates of five cavity-nesting birds in boxes versus natural cavities, found that Great Tits (*Parus spp*.) nesting in natural cavities were predated nearly 62% more than those in boxes (Nilsson, 1984). Møller (1989) argues this was likely due to the design of nest boxes affording lower predation risk. However, even with good nest box design there are risks. In a review of avian nest box predation on Purple Martin, Ray (2015) described several instances of interspecific predation. He found that 54.5% of the 20 documented nest box predation events involved Barred (*Strix varia*) or Great Horned owls (*Bubo virginianus*). Owls attacked at night, removing birds inside the box or as they tried to escape. Other raptors such as Cooper's (*Accipiter cooperii*) and Sharp-shinned (*Accipiter striatus*) hawks can attack several times during the day, capturing birds as they perch on their nest boxes. These types of predation put smaller colonies at considerable risk. Suggested preventative measures include boxes situated in open areas (to prevent sneak attacks), wire cages, predator resistant cavity depth/design, and decoys.

With regard to nest parasites, results of studies using nest boxes are also potentially biased and cannot be assumed to represent birds that nest in natural cavities (Møller, 1989; Wesolowski & Stańska, 2001). One reason for this is the common practice of replacing nest material in nest boxes during and after the breeding season. This presumably decreases the number of parasites but does not allow for accurate information regarding parasite loads or their negative consequences in nest boxes. Within natural cavities, this is difficult to determine because nesting material is often absent the following breeding season. This is in part, due to the removal of nest material by birds and mammals and the presence of decomposing fungal organisms (Hebda, Pochrzast, Mitrus, & Wesolowski, 2013).

Parasites harbored in nesting material pose risks to parents as well as young. Some of the more common parasites in Purple Martin nest boxes are blowflies, bird lice, ticks, and mites which parasitize the blood, skin, and even the feathers of adults and young. A single nest box can host thousands of parasites representing several species (Hill, 1994). A study comparing two nest box colonies of 12 boxes each, compared the effects of parasites on reproductive success and nestling growth. One colony was treated to remove a significant portion of mites present, and the other was left untreated. Treated colonies had larger broods and increased nestling weights (taken daily for 29 days). During the second year of the study, warm and wet weather led to severe mite infestations in untreated colonies and subsequent abandonment of many of the nest boxes and eggs (Moss & Camin, 1970). A study in the 1980’s, evaluated the fledging success of parasite-free versus infested nest boxes and found a 84% success rate in parasite-free boxes versus 44% in those infested (Kostka & Hill).

Two aspects of the micro-climate within nest cavities important to reproductive success include temperature and humidity. Temperature can be critical in successful embryonic development and hatching. If temperatures are too cold, the embryo stops growing, with extreme heat being lethal (Gill, 2007). Embryo development is also influenced by humidity. For example, in regions with high temperatures and low humidity, an embryo may die from dehydration (Gill, 2007).

In a study comparing the differences in air temperature and humidity in nest boxes and tree cavities, tree cavities were found to provide better insulation with less fluctuation in mean daily temperatures. This was significantly influenced by the thickness of the tree. Temperatures within nest boxes were warmer with significantly greater fluctuations (Maziarz, Broughton, & Wesolowski, 2017). The authors suggest that because of the significant differences found in this and other studies, that the use of nest boxes be a “targeted and temporary intervention”.

Habitat Selection Theory

Birds face many challenges during the breeding season including nest site availability, competition, predation, and prey availability. The location in which a bird breeds is especially important with the potential to influence fitness.

What does “habitat selection” mean? What are the driving factors that determine habitat selection or more specifically, nest-site selection? Do birds consciously “choose” the places in which they breed? These are some of the questions posed by researchers studying habitat selection in birds. Answering these questions is critical in the management of limited resources allocated for wildlife. A long history of ornithological research has revealed the association of birds with particular habitats, and as is the case with many Neotropical migrants, demonstration of nest-site fidelity (Jahn, Sagario, & Cueto, 2016).

Discussing the possible mechanisms that determine habitat selection in birds, Hutto (1985), argues that the use of the term “habitat selection” denotes a conscious “choice” by a species. He suggests “habitat use” as a more appropriate description, because it considers the myriad of macro habitat and microhabitat features that influence use. The features a species uses are decided not by a single choice, but represent what the author describes as a “series of choices”. These range from the geographic location a species uses all the way down to their food choices within that habitat. This was similarly described by Johnson (1980) detailing four orders of habitat selection. First is on the geographic scale, second is based on the home range of a species, third is selection based on the components that make up a habitat, and finally the food that is consumed in that selected site.

Suggesting that nest-site selection is best accounted for by the fourth order, Jones (2001) describes two ways habitat selection is initiated by birds. The first compares used vs. unused habitat and the second, used vs. available. He argues that studies comparing used vs. available habitat more accurately describe habitat use, because a habitat must first be available before it can be used. Availability is defined in terms of not only the amount of habitat available but also the ability of a species to access it. Jones also notes the importance of designing studies so that delineations of available habitat account for differences in the life history of the species being studied. My research is positioned within this habitat-use framework as I will be using comparisons of sites used for nesting to available habitat not used for nesting.

Within habitat studies are what Hutto (1985) calls “intrinsic” factors that determine habitat use by birds that occur at the microhabitat scale. For snag-nesting birds, hole height, location, width and depth have been shown to influence the selection of sites in which birds breed (Nilsson, 1984). These are similar to those I will be looking at in my research (e.g. snag height, cavity orientation, and decay class). This is the framework by which I will be trying to better understand the relationships between nest site characteristics and use of these sites by Western Purple Martin.

Conclusion

Currently no published literature exists describing the nest site characteristics for Western Purple Martin in Washington State. A significant portion of the population now rely on nest boxes, requiring maintenance by volunteers. The unique habitat and martin presence on Joint Base Lewis-McChord provides the opportunity to better understand naturally nesting martins in Washington. This benefits not only Western Purple Martin, but prevents possible interruptions to military activities should population declines lead to federal listing.

My research contributes information useful in determining not only locations of natural nesting sites, but specific characteristics of those sites important to the persistance of the species on base. This also has the potential to inform habitat management for martins within the private and public sector. Although installation of artificial nesting structures are likely to be important to the continued success of the species within

Washington state, it is important to preserve the biodiversity that naturally nesting populations represent.

METHODS

Searches for snag-nesting Western Purple Martin were performed from April to August during 2017 and 2018, coinciding with the arrival of martins in early spring and their departure in late summer. Surveys were confined to training areas within the boundaries of Joint Base Lewis-McChord (JBLM), a large military installation located in Western Washington (Figure 5). Surveys were conducted weekdays from 0630-1730 due to Department of Defense restrictions on training area access. Areas to be surveyed were chosen using information provided by base biologists and by consulting maps of the area. This included areas near wetlands and large open spaces such as prairies, which have greater potential for flying insects, the primary food source for Purple Martin (J. R. Bottorff, Bill; Schroer, Greg, 1994; C.R. Brown & Tarof, 2013).

Survey dates were selected based on a forecast for fair weather with no precipitation, to increase odds of detecting birds. Determination of nesting followed protocols developed by the Western Purple Martin Working Group (Bruce Cousens & Airola, 2006) (Table 1) and deviated from the protocol only in suggested timing of surveys (<2 hours after sunrise or <2 hours before sunset). In 2017, survey activities included ground truthing of historic nest snag locations, searches for potential and probable nesting sites, and point count surveys. Sites were visited a minimum of three times during the survey time frame. Once nesting was either inferred or confirmed (based on protocols), information on nesting snags was recorded. This included tree species, height (m), decay class, diameter at breast height (cm), elevation (ft), total number of visible cavities, canopy cover (0, 25, 50 m), distance to nearest water body (m), nest cavity height (m), degree, and direction. 2018 survey activities included visits to previously probable, inferred, and confirmed nest sites, and searches for new locations. Sites were visited at least three times during the breeding season or until nesting was confirmed. Variables collected were the same for both seasons. Following the 2018 breeding season, data was collected on random non-nesting snags located within 200 m of nest snags. Kayak surveys for potential nesting snags were performed April and May of 2018 in several large marshes and lakes, but discontinued due to difficulty accessing sites.

Ground Truth and Potential Snag Surveys

In 2017, locations of historic Purple Martin nest sites were provided by the Washington Department of Fish and Wildlife. I documented presence or absence of those snags, recorded coordinates, and took a photograph of the site and snag if present. Searches for nest sites involved driving slowly on roads with my windows down, listening for vocalizations and looking for snags that looked like potential nesting sites (e.g. in the open and with visible nesting cavities). I found this method to be effective due to the distinctive vocalizations of Purple Martin and their choice of open habitats. If I heard martin vocalizations or observed potential snags, I stopped my vehicle and investigated the snag or source of the sounds on foot. Any potential snags located were monitored for 15-30 minutes using a scope set up ~60-100 meters away and/or binoculars. If martins were heard or seen in the area, coordinates were recorded, a photograph of the snag/s taken, and any bird species using the snag at the time documented. The original list of ground truth locations I was given included 21 different sites in six different training areas (n = 14) as well as the artillery impact area (AIA) and central impact area (CIA) (n = 7). I visited each site located within the six training areas at least once, and visited four of them twice. No access to sites located in the AIA and CIA's is allowed by non-military personnel and surveying along the road was unsuccessful, due to a lack of visibility.

Nesting Snag Surveys

Surveys for probable nesting snags were similar to the protocol used for potential snags except observations of martin activity were for ≥30 minutes. Snags were deemed occupied with probable nesting, if Purple Martin displayed certain behaviors including pairs perched and entering cavities or flying around a snag for the length of the observation period. Inferred nesting behaviors included food delivery to a cavity during the nestling period, fecal sac removal from a cavity, or dead young observed below an occupied nest cavity. Confirmed nesting behaviors included nestlings observed at nest cavities, food delivery to nestlings, or characteristic begging calls heard from inside a cavity. Only inferred and confirmed nest snags were used for later analysis.

Random Snags

An attempt was made to pair each nesting snag with at least one random non-nesting snag for comparative analysis. Snags were deemed suitable if they were at least 28 cm in diameter with at least one available nest cavity (B. D. C. Williams, 2002). Random snag locations were generated using ArcMap 10.5.1 to create a 200 m buffer around each nest snag. Within each buffer, two random snag locations were generated for each nest snag. The first location that was generated was visited first, and the nearest non-nesting snag within the buffer was chosen as the random snag. The second random location was reserved in the event that I had additional time to survey a second random snag. The same data was collected for random snags and nest snags with the exception of cavity height which was only recorded for nest snags.

Measurements

A Samsung Tablet A with Avenza (v. 3.6.2) mapping software was used to navigate on base as well as to map and photograph nest sites. A laser range finder was used to determine snag and nest cavity height, and iPhone 7C compass application for elevation, nest cavity degree and direction. Decay class followed the protocol from Hunter (1990), and canopy cover was measured using a Model C spherical densiometer. Distance to nearest water body was measured using the ArcMAP measurement tool. Although there are several small areas of standing water on base, for simplification I chose to measure to only named water bodies. Measurements of total tree cavities was determined by facing the nest snag in each cardinal direction and counting cavities that appeared to be suitable for nesting martins. I based this on the size and shape of cavities I had seen martins entering prior to breeding.

Point Counts

In 2017 during my weekly surveys, I performed a total of 26 stationary point counts to detect other bird species present on base. Some of these locations were chosen because of their proximity to ground truth, potential, and probable nesting snags. Others were chosen randomly and performed as time allowed. Upon arrival at a survey site, I waited for at least 5 minutes to pass before beginning the survey. I recorded every bird heard or seen within a ~ 15-20 minute survey window. Species, number, and cue (audible or visual) were recorded as well as weather, wind, and temperature.

Statistical Analysis

Summary statistics and logistic regression were performed using R: A language and environment for statistical computing (R Core Team, 2013). Continuous variables were tested for normality using Shapiro-Wilk tests, and log10 and square root transformations performed on non-normal data. I tested for collinearity among canopy cover at zero and twenty-five meters. For these two variables Pearson's $r = 0.44$ so I used both as independent variables. Using logistic regression, I developed a set of candidate models exploring relationships between nesting and random non-nesting snags, and ranked them using Akaike's Information Criterion (Burnham & Anderson, 2002). For each candidate model I calculated pseudo-R^2 values as a measure of model fit, using the function 'nagelkerke' in the package 'rcompanion' (Mangiafico, 2015). Snags with two trunks were treated as one site for all logistic regression analyses, and separately for cavity number, height, direction, and decay class and diameter at breast height (dbh). I used a $\alpha = 0.05$ for tests of statistical significance.

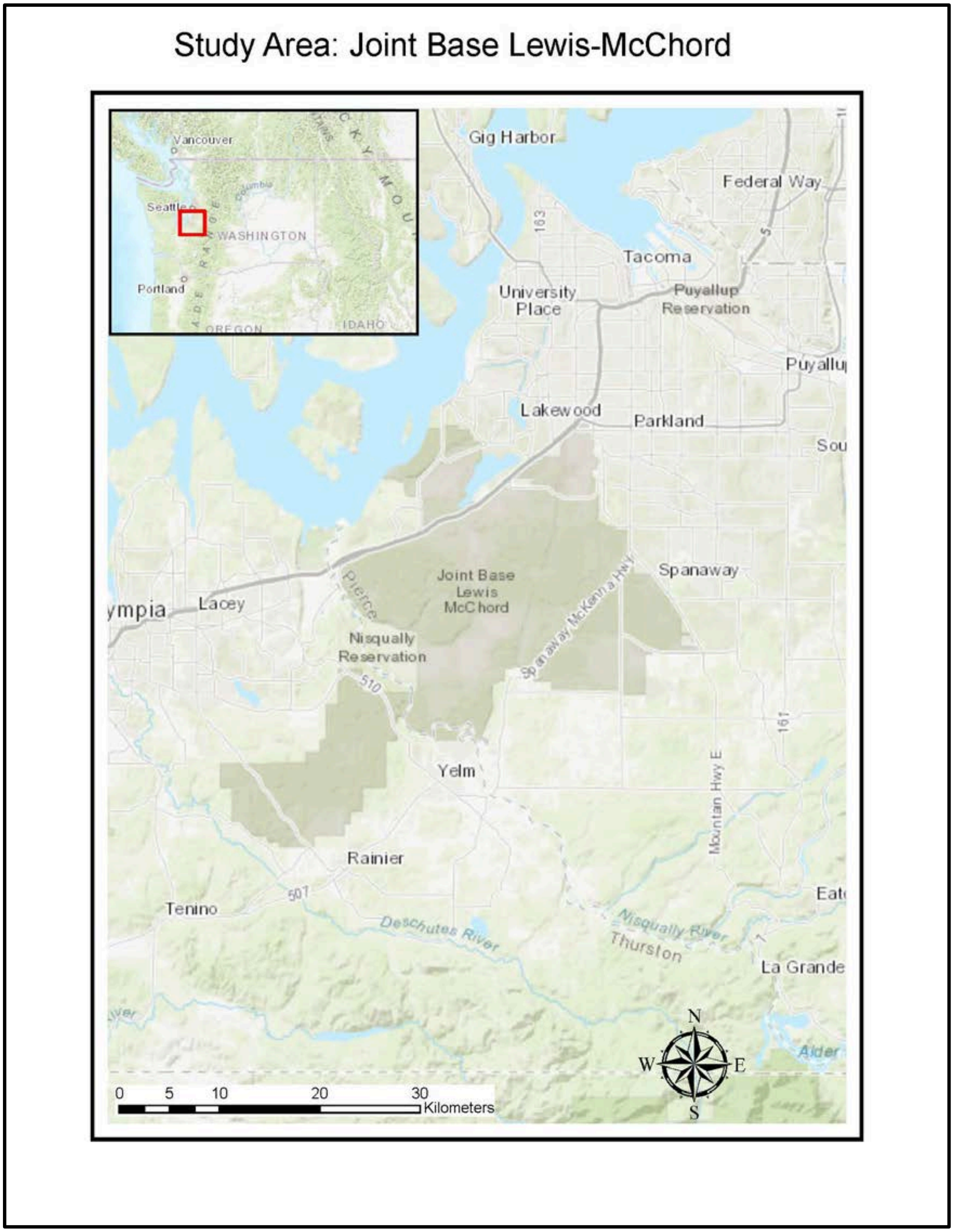

Figure 5. Study area: Joint Base Lewis-McChord, WA.

Table 1

Nest-Site Use Protocols from Cousens & Airola (2006)

Snag/Cavity Status	**Observed Behavior**
Occupied	• Bird(s) seen entering, defending, or guarding a cavity • Adding nest material on one occasion
Probable Nesting	• Frequent visits to a cavity over time • Dead young observed below an occupied or apparently suitable cavity • Nest material repeatedly carried into cavity • Member of pair defending cavity for > 30 minutes • Presumed incubation (female in cavity >30 min)
Inferred Nesting	• Carrying food into cavity or frequent short visits during nestling period • Fecal sac removal from cavity • Dead young below occupied cavity • Newly fledged young at cavity being fed by adults
Confirmed Nesting	• Nestlings observed in nest cavity including being fed at entrance • Dead nestlings observed in cavity • Begging calls heard from within suspected nest cavity

Note. Snag and cavity status determination based on observation of *at least one* of the diagnostic behaviors.

RESULTS

2017 Ground Truth Surveys

During ground truth surveys, six of the fourteen historical nest sites on JBLM had snags that were still standing with available cavities. The other eight had either a snag that had fallen, or no snag present at all. One of these snags with last confirmed nesting dates of 2011 (WDFW unpublished data) was used by martins for nesting during both survey years (2017-2018).

Potential Snags

In 2017, 21 potential nesting snags, within seven different training areas were located. The majority of snags were Douglas-fir (*Pseudotsuga menziesii*; $n = 17$), ponderosa pine (*Pinus ponderosa*; $n = 3$), and one grouping of snags which were unidentifiable due to their charred condition. I surveyed each of these sites twice, with one visit to each during peak breeding season (July-August). Two of these snags had a pair of martins perching near cavity entrances, one of which was later determined to be a probable nesting snag. In mid-April of 2018, kayak surveys were performed and 34 potential nest snags mapped. The majority of these ($n = 22$) were located in Spanaway Marsh which spans nearly 360 acres (Figure 6). Species included Douglas-fir ($n = 22$), ponderosa pine ($n = 1$), and 11 that were too decayed to identify. Kayak surveys were discontinued due to time constraints and accessibility issues. Three other potential snags were located on land in 2018 within training area 12, two of which were later used for nesting by martins.

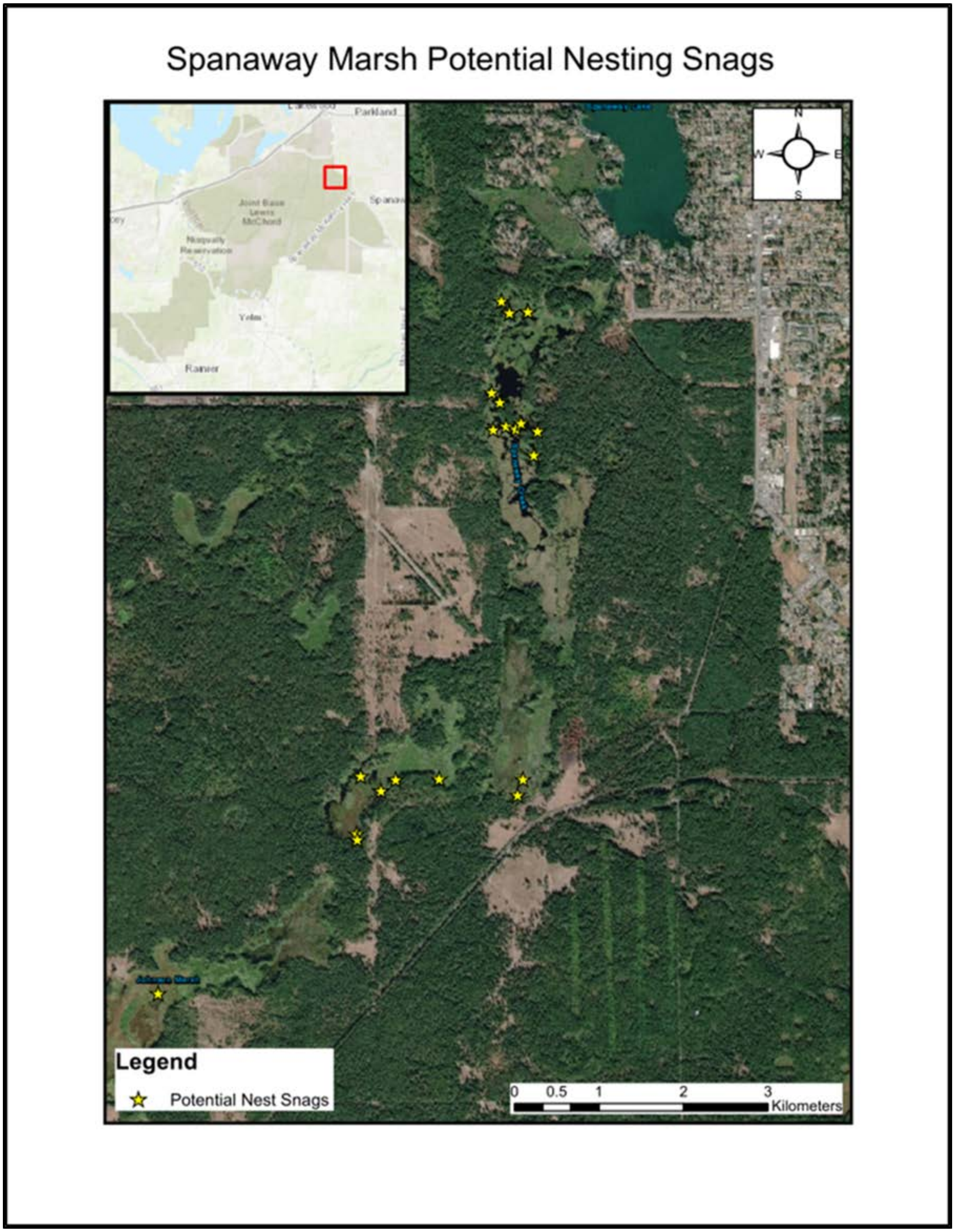

Figure 6. Spanaway Marsh the location of the majority of potential nest snags (n=22) located during 2018 kayak surveys.

Nest Snags

Purple Martin were observed perching and vocalizing on snags as early as April 21st in 2017, and April 19th in 2018. Early nesting behaviors included observations of food delivery to nest cavities and nestlings heard in late June. By July 14th, nestlings were seen peering out of cavities. I located 32 nesting snags during both survey years, including 8 probable, 10 inferred, and 14 confirmed nesting snags. Of the inferred and confirmed nests, martins nested in three species of trees including Douglas-fir (n = 14), ponderosa pine (n = 9), and black cottonwood (*Populus trichocarpa*; n = 1). All nesting snags were located in open habitats near or within water with the majority (33%) located in training area 12 (Figure 7). Results of other snag characteristics (height, dbh, cavity height, cavity number) are reported in Table 2. Nest snags were found in declining and decomposed trees in decay class ranges of 2-7, with 28% of nest snags in both classes 4 and 5 (Figure 8). Nest cavity orientation appeared random, with the majority of nesting cavities oriented to the northeast (27%) and combined northern orientations (N, NE, NW) representing 59% (Figure 9). Sixteen (66%) of nesting sites were occupied by one confirmed nesting pair, four with two nesting pairs, and two with three nesting pairs. Two sites hosted comparatively larger numbers, one with five and the other with nine nesting pairs.

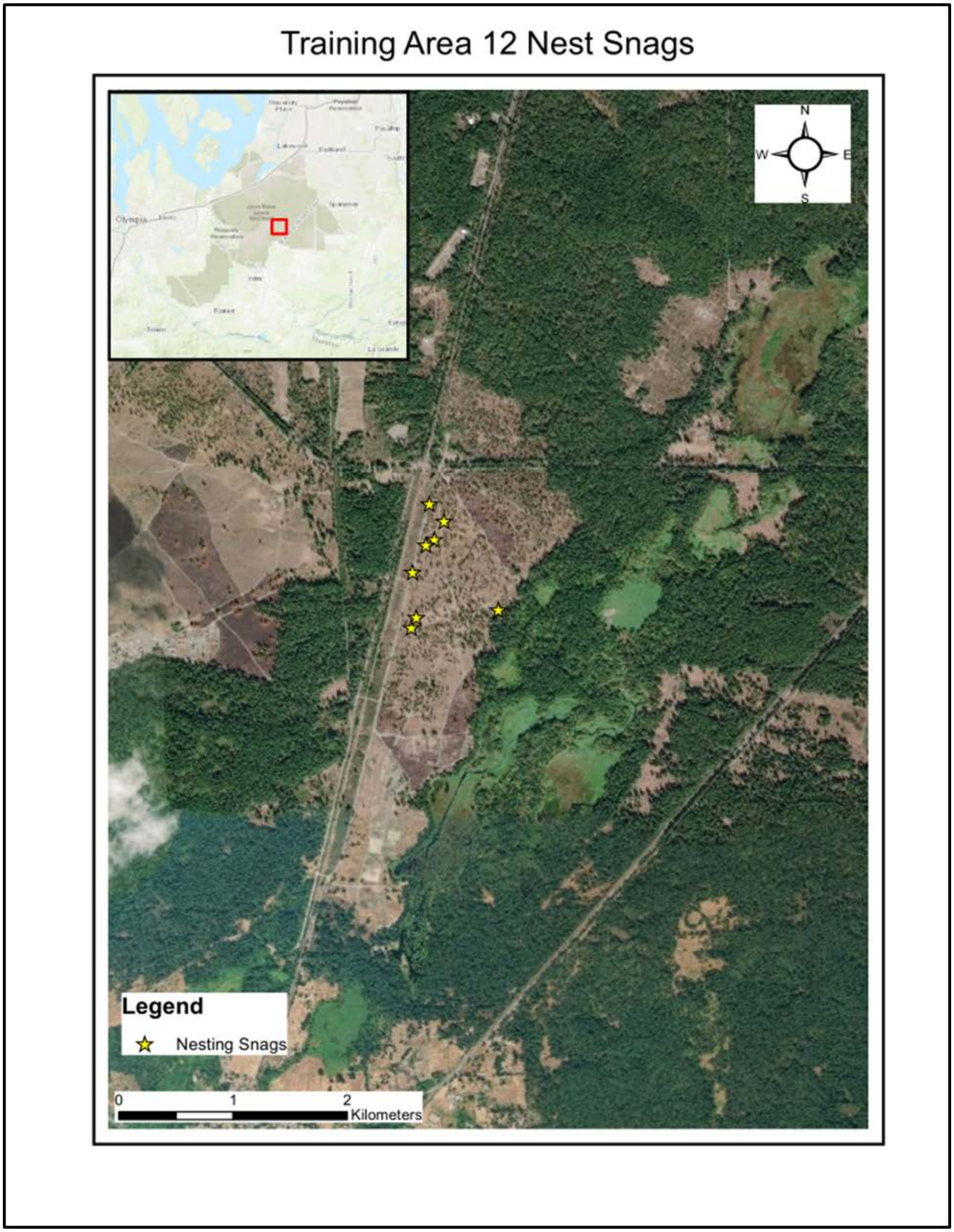

Figure 7. Nesting snags located in ponderosa pine habitat of training area 12 (n = 8).

Table 2

Descriptive Statistics for Nesting and Random Snags

Site	Variable	n	x̄	SD	Min	Max
Nest	Snag Height (m)	29	18.6	8.7	3	33.1
	Snag DBH (cm)	24	75.6	32.9	23.9	153.2
	Cavity Height (m)	48	10.7	6.8	1	25
	Cavity Number	48	9	8.5	1	25
	Mean Elevation (ft)	24	367	73	230	550
	Distance to Water (m)	24	1411	1132	0	3828
Random	Snag Height (m)	22	13.8	9.2	2.2	35.6
	Snag DBH (cm)	22	71.8	31.8	31.8	145.5
	Cavity Number	22	3.7	2.93	1	12
	Mean Elevation (ft)	22	371	66	230	520
	Distance to Water (m)	22	1540	1244	114	4134

Note. There were n = 24 snags used for nesting, with n = 48 total cavities. Five of the snags split into separate trunks and therefore had separate snag height measurements (n = 29). However they separated above the standard measurement for dbh height (1.4 m) so only one dbh was recorded. Cavity height was not recorded for random snags.

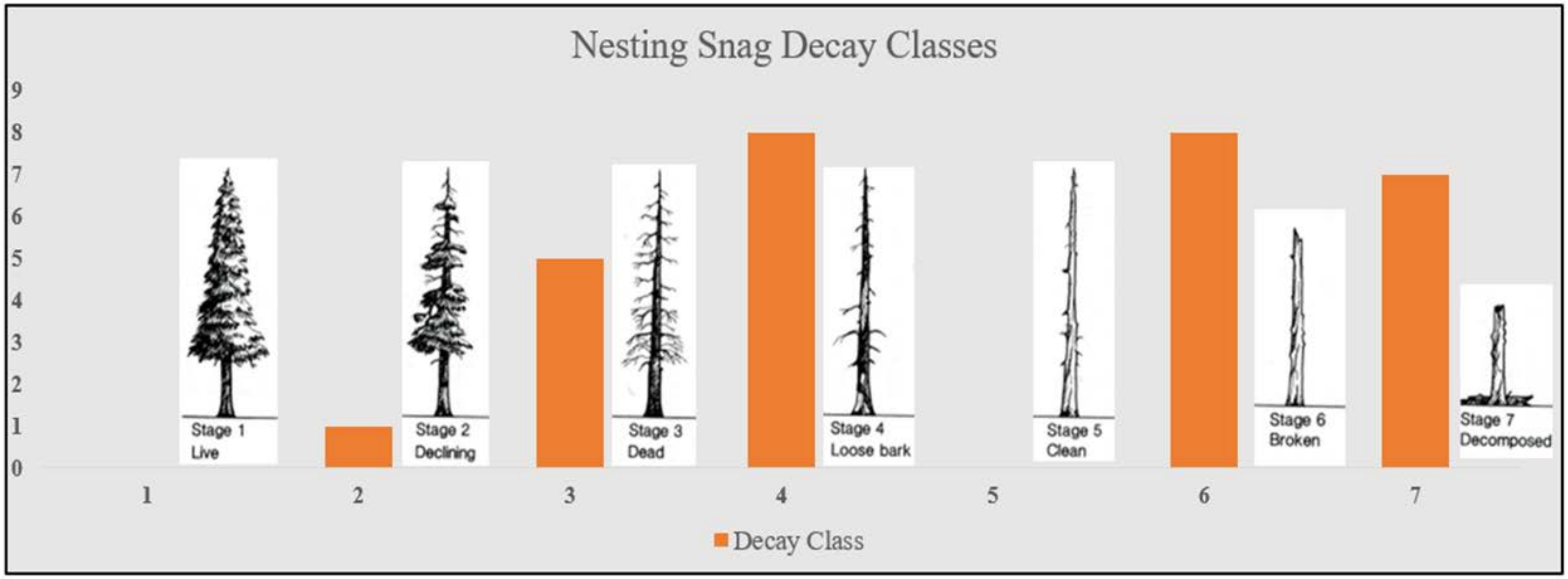

Figure 8. Decay classes of snags used for nesting. Decay class 1 indicates a live tree and 7 a decomposed snag (Hunter 1990).

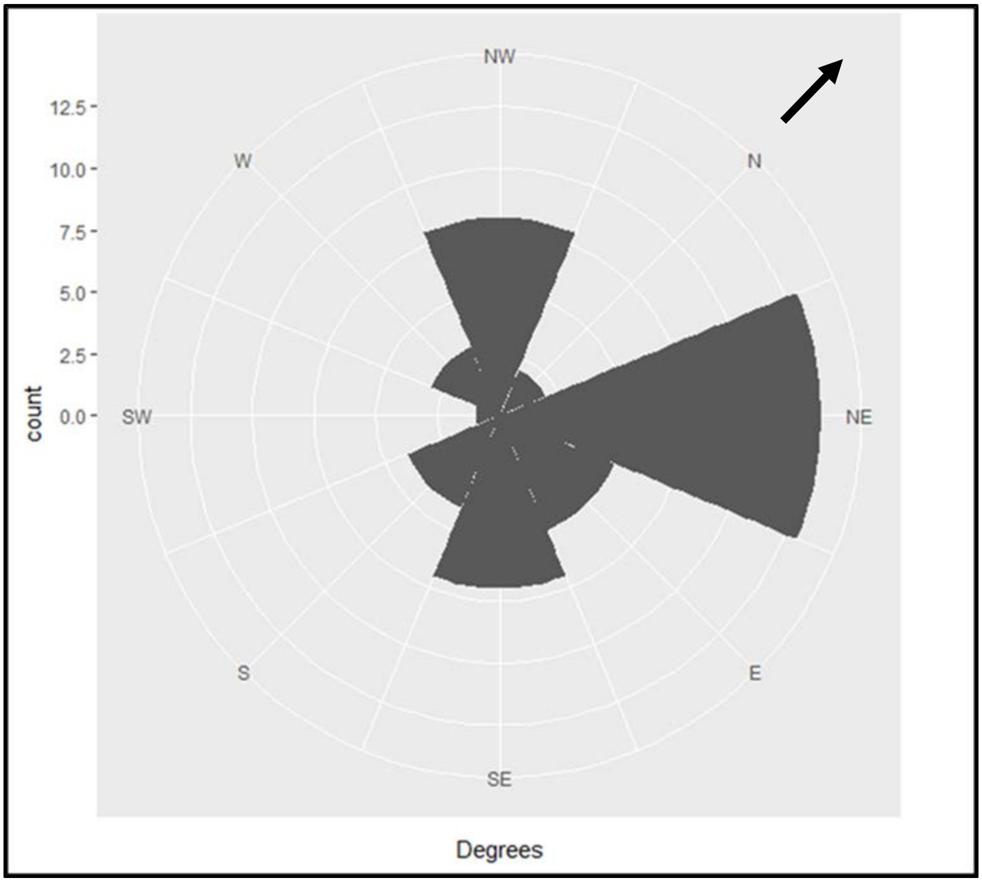

Figure 9. Rose plot illustrating random nest cavity orientation.

Random Snags

I paired twenty-two random non-nesting snags with nesting snags. I was unable to pair two of the nesting snags with a random non-nesting snag, because the 200 m radius they were located in was inside the Artillery Impact Area, and no suitable snags existed outside of that area. Tree species were Douglas-fir (n = 13) and ponderosa pine (n = 9). Results of other snag characteristics (height, dbh, cavity number) are reported in Table 2.

Comparative Analysis

Only two of the nine independent variables hypothesized to influence nesting in snags were significant: canopy cover at 0 m and canopy cover at 25 m (Table 3; logistic regression, Figures 10 & 11. Both variables contributed to 'supported' models using a model selection framework (Table 4).

Table 3

Results of Simple Logistic Regression

Variable	Coefficient Estimate	N	SE	p value
Canopy Cover at 0 m[a]	-3.98	46	1.67	**0.017**
Canopy Cover at 25 m[a]	-4.39	46	1.98	**0.026**
Number of Cavities[b]	0.94	51	0.79	0.236
Canopy Cover at 50 m[a]	-0.72	46	1.63	0.658
Diameter at Breast Height (cm)[b]	0.62	51	1.49	0.679
Distance to Water (m) [b]	-5.32×10^{-5}	46	2.54×10^{-4}	0.834
Height (m)[b]	0.20	51	0.96	0.837
Decay Class	0.03	51	0.18	0.856
Elevation (ft)	-0.001	46	0.004	0.815

Note. In all models, the response variable is whether a nest snag was occupied (1) or a randomly selected unoccupied snag (0). Individual models with $p < 0.05$ are shown in bold. [a] Square root transformation of data for analysis. [b] Log transformation of data for analysis.

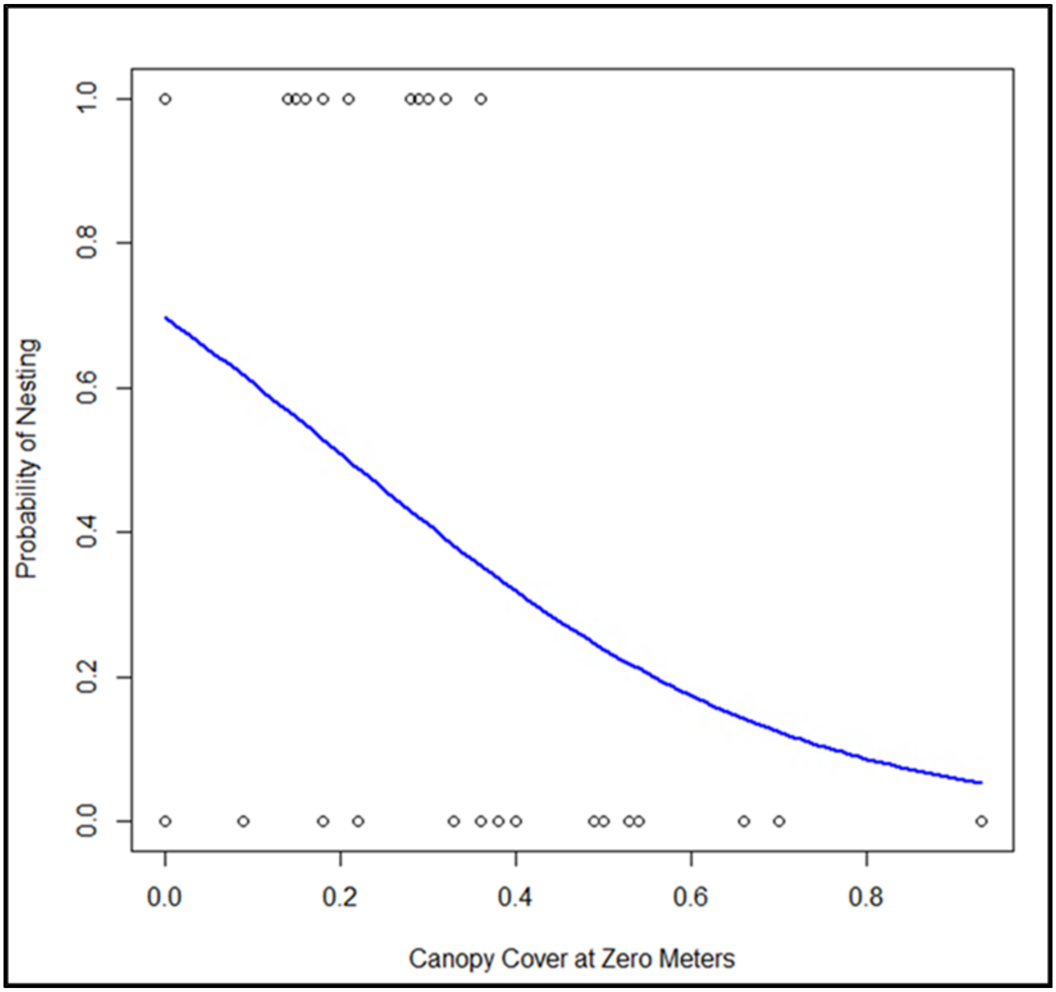

Figure 10. Logistic regression plot demonstrating decrease in nesting probability as canopy cover (at 0 meters) increases.

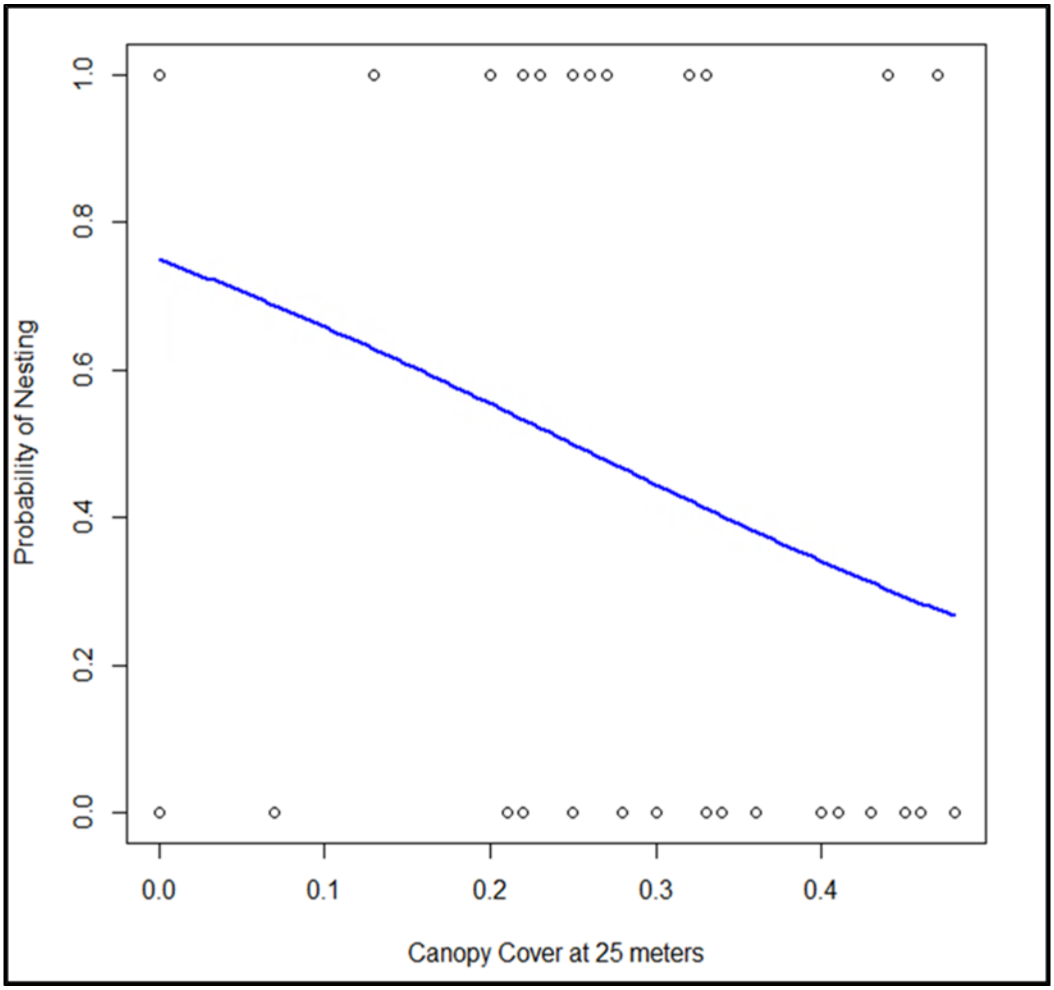

Figure 11. Logistic regression plot demonstrating decrease in nesting probability as canopy cover (at 25 meters) increases.

Table 4

Akaike's Information Criterion (AIC), for Logistic Regression Models

Model: Nest Occupancy ~	AIC	ΔAIC^a	pseudo-R^2
Canopy Cover at 0 m	60.4	0	0.20
Canopy Cover at 0 + Canopy Cover at 25 m	60.5	0.1	0.24
Canopy Cover at 25 m	62.2	1.8	0.15
Canopy Cover at 50 m	67.5	7.1	0.006
Distance to Water (m)	67.6	7.2	0.001
Elevation (ft)	67.6	7.2	0.002
Number of Cavities	72.3	11.9	0.04
Diameter at Breast Height (cm)	73.6	13.2	0.004
Snag Height (m)	73.7	13.3	0.001
Decay Class	73.7	13.3	0.0009

Note. Models exploring the relationship between snag and habitat characteristics and nest selection in used and non-used snags. [a] The difference in AIC scores between the best model and subsequent models.

2017 Bird Surveys

A total of 59 species were detected during stationary point count surveys (Appendix). During these surveys, the total number of Western Purple Martin detected was 37. I detected 114 European Starling, with large groups in the Central Impact Area (n = 53) and training area 4 (n = 28; Figure 12).

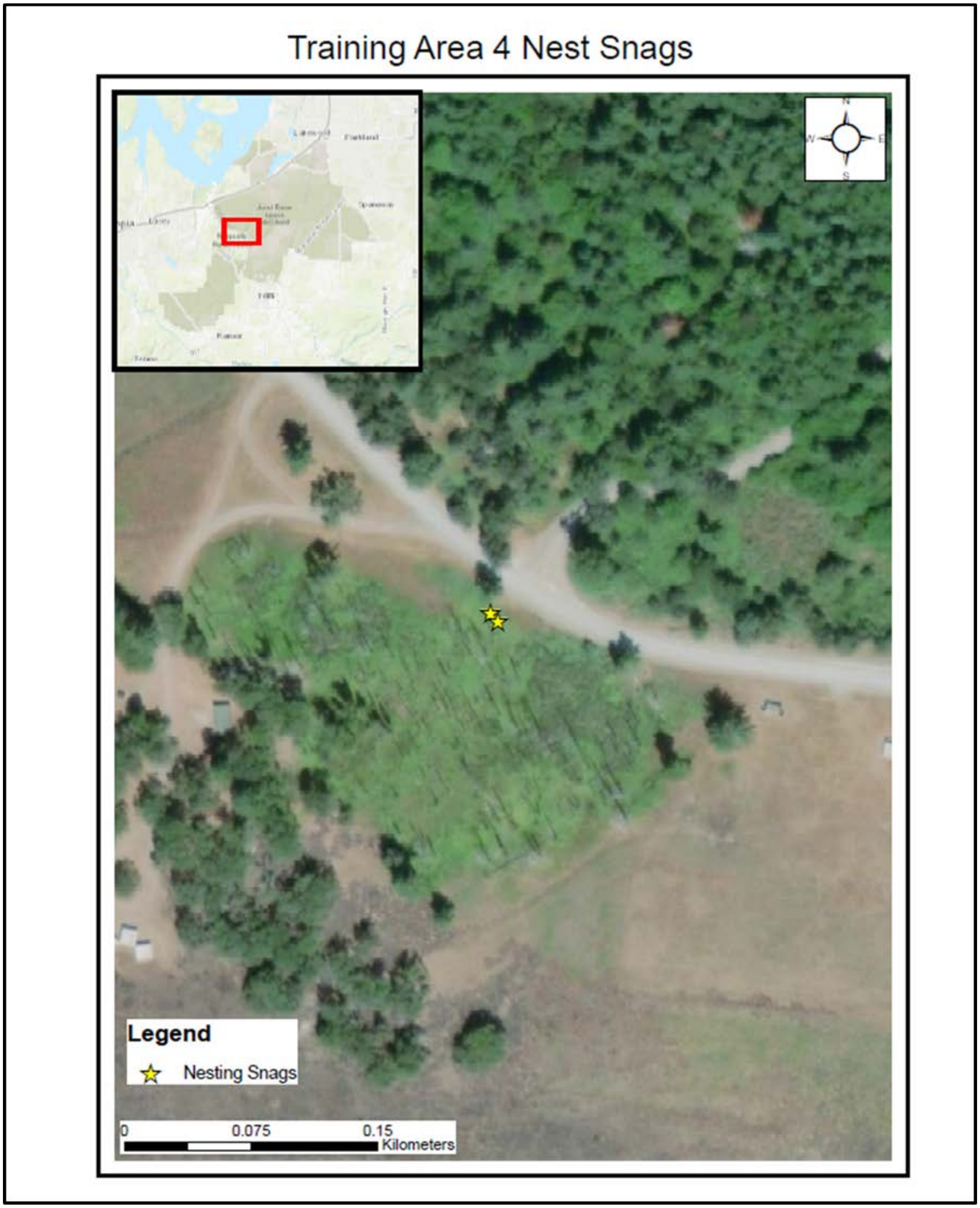

Figure 12. Nesting snags located in the Central Impact Area of training area 4 (n = 2).

DISCUSSION

My results support the findings of other studies on snag-nesting Western Purple Martin (Horvath, 1999; B.D.C. Williams, 1998; B. D. C. Williams, 2002). With regard to the importance of canopy cover in nest selection, two studies in California found canopy cover to be influential in the nest-site selection of martins (B.D.C Williams, 1998, 2002). In 1998, canopy cover in 24 of the 35 snags measured was <10% within a 100 meter radius of the nest tree and no greater than 49% at any given nest snag. In 2002, canopy cover at nest height was significantly lower in nesting verses non-nesting snags but there was no difference in overall canopy cover. It has been suggested that open areas around nesting snags help birds in detecting predators and interspecific competitors (Horvath, 1999) and studies have shown nesting greater distances from forest edges increases reproductive success in other cavity-nesting species (Rendell & Robertson, 1990). This may have contributed to use of the nest snags in my study.

Table 5

Snag Height and Diameter for Four Studies of Snag-Nesting Western Purple Martin

Study	Variable	n	$\bar{x}$	Min	Max
Williams (1998)	Snag Height (m)	17	24	8	45
Williams (2002)		46	15	8.5	24
Horvath (1999)		22	19	6	44
Scalici thesis		29	13.9	3	36
Williams (1998)	Snag DBH (cm)	17	119	36	271
Williams (2002)		42	104.3	57	175
Horvath (1999)		17	120	51	227
Scalici thesis		24	75.6	23.9	153.2

Other studies of Western Purple Martin report sites typically consisting of 1-2 pairs with as many as six (B.D.C. Williams, 1998; Stutchbury, 1991). In my study, the largest number of confirmed nesting pairs at a single nest site was nine, demonstrating that under the right conditions martins will nest colonially in snags. That number was likely greater because during one survey date thirteen cavities were active (e.g. entries into cavity, guarding cavity entrance) but because of limited time, I was unable to confirm nesting in them all. This snag was a two-trunked black cottonwood, had the largest number of available cavities, and was the only snag completely submerged and surrounded by water (Figure 13). Interestingly, I observed a Northern Flicker (*Colaptes auratus*) occupying a cavity in this snag as well as a pair of European Starling which I observed feeding young. Reports of interspecific nesting of Western Purple Martin have been documented in Arizona (Stutchbury, 1991) and are not unusual among other species of cavity-nesting birds. This type of behavior may increase fitness under certain circumstances but this varies (Mouton & Martin, 2018).

Figure 13. Black cottonwood (*P. trichocarpa*) snag with nine confirmed nesting pairs. Adult male martin and Northern Flicker (*Colaptes auratus*) occupying the same snag.

Based on the number of potential nesting sites found over the two years of this study (n = 61) and the similarities between nesting and unused snags, martins do not appear limited by the number of natural nesting sites. It is quite possible I would have located even more active nests had surveys been allowed during peak detection times and I had more time to survey. In addition to these limitations, the most active nesting area was closed for a four-week period in July 2018 for military training, restricting me from surveying several acres of potential nesting habitat. It is possible I missed detecting several nests during this time. There was potential to find even more nesting snags within artillery impact areas where martins have reportedly nested, but this area has restricted access for obvious safety reasons. Even with the seemingly large number of available nesting snags, it is important to note that many of the snags I found were in advanced stages of decay and their use as future nesting sites potentially short-lived. This was evidenced in the loss of two nesting snags during my study. Both had fallen due to unknown causes and were removed from the area.

Selection of nest hole height may afford better protection from predators and is indicated in several studies as the most significant factor in nest failure (Albano, 1992; Nilsson, 1984). Although significant differences in nest hole height preferences exist among species, a study found that nest predation was much higher for nest holes below 2 meters (Nilsson, 1984). My results supported the previous studies of nest hole height selection in snags by martins with the exception of a nest hole located just one meter above the ground. This snag was one of only a few snags with no canopy within the entire 100 meter radius. It also had two trunks with martin pairs occupying each. These factors together may have aided in predator detection and influenced selection of such a short snag.

Competition for nesting cavities by introduced species such as the European Starling and House Sparrow are often cited as limiting nesting opportunities for martins. This did not appear to be the case in most areas on base although this could have been found to be true with more surveys. Most competition observed occurred in open prairie habitats like that found in training area 21 (Figure 14). This area is in close proximity to agricultural fields where starlings are known to congregate in large numbers. It is also the training area with the fewest number of available snags which may have increased competition for limited nesting sites. I did not detect any House Sparrow during surveys or incidentally.

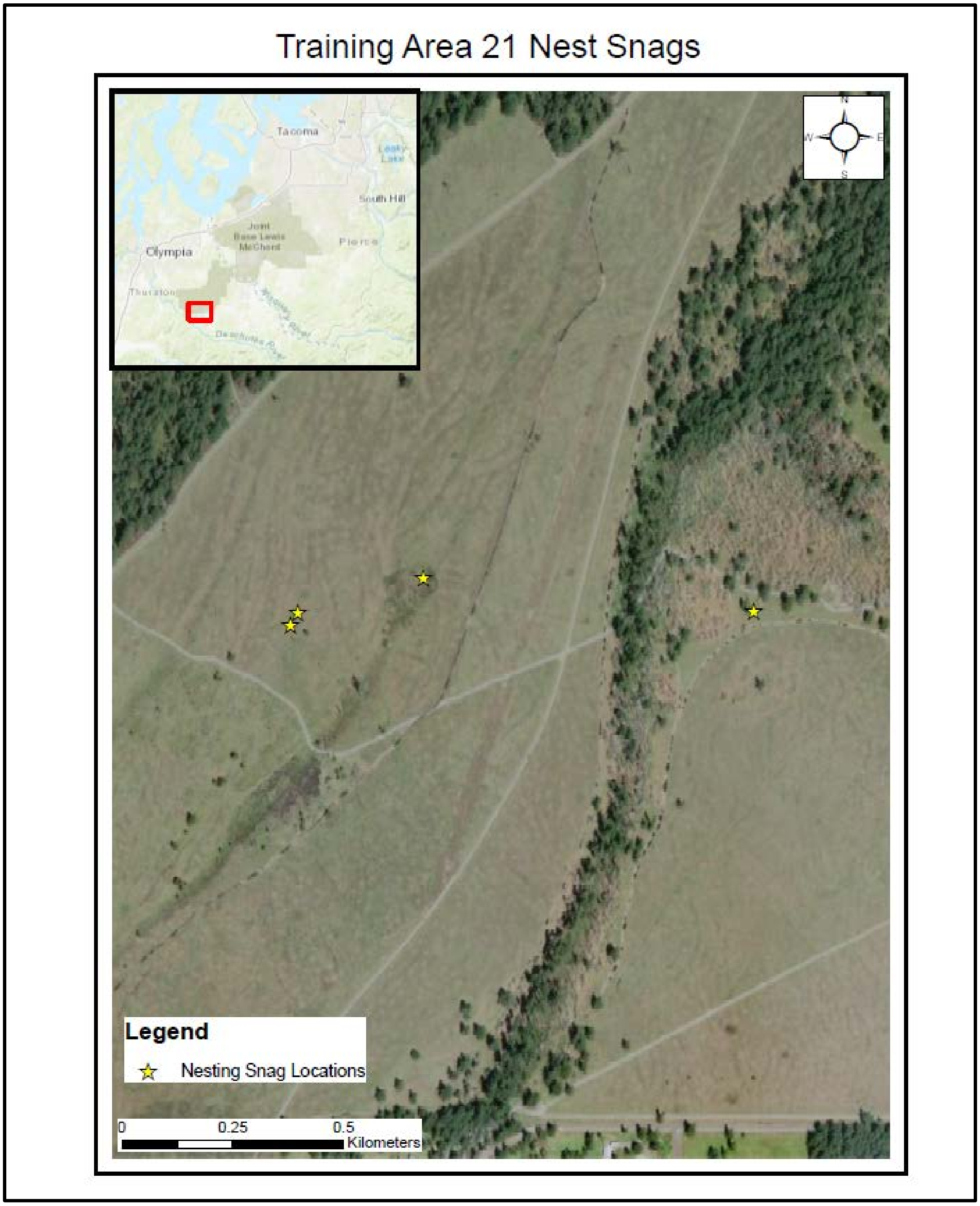

Figure 14. Nesting snags located in training area 21 (*n*=4) where observations of competition with European Starling occurred.

Future Management

The practice of prescribed fires by JBLM land managers has been instrumental in the suppression of encroachment of open habitats by tree species such as Douglas-fir. Although prescribed fire efforts focus on prairies, they are also used in ponderosa pine habitat where the majority of nest snags were located. Continued use of prescribed fire will support the creation of new snags, but these efforts would be best performed before or following nesting season to avoid possible negative effects on breeding and young birds.

In addition to fire, snags can be created through a variety of methods (E. L. Bull & Partridge, 1986). Two of the most common methods shown to produce foraging and nesting habitat for cavity-nesting birds are girdling and topping. Circular girdling is currently being implemented on base (K. Wheeler, personal communication, March 20, 2019). Although girdling is less expensive than topping, the onset of decay can take longer delaying its use by cavity nesting species (Hallett, Lopez, O'Connell, & Borysewicz, 2001). Tree topping studies of ponderosa pine found that over a five year period, topped trees were used more for foraging than girdled trees and were less likely to fall (E. L. Bull & Partridge, 1986). In Douglas-fir, use by cavity-nesting birds was present within just 3 years of creation (Hallett et al., 2001). Since the majority of trees used by martins in this study were Douglas-fir and ponderosa pine, experimental use of tree topping on both tree species would be useful in determining the potential benefits of each method.

Nest Boxes

Over two hundred nest boxes are currently installed on JBLM. Most are located within marshes and lakes, with a small number mounted on poles on land or attached to snags. I made personal observations of martins using several of the boxes within wetlands, often in association with Tree Swallows (*Tachycineta bicolor)*. The installation dates of the boxes range from 2001-2017, with several of the older boxes in disrepair. Surveys of current installation sites are necessary to assess replacement needs. Based on my surveys, areas to prioritize include training area 12 which has several wetlands and small lakes that are relatively easy to access. It may also be beneficial to install boxes within MacKay and Hanner marshes. No nest boxes have been installed in this area and it is the location of the snag with the largest numbers of breeding pairs (Figure 15).

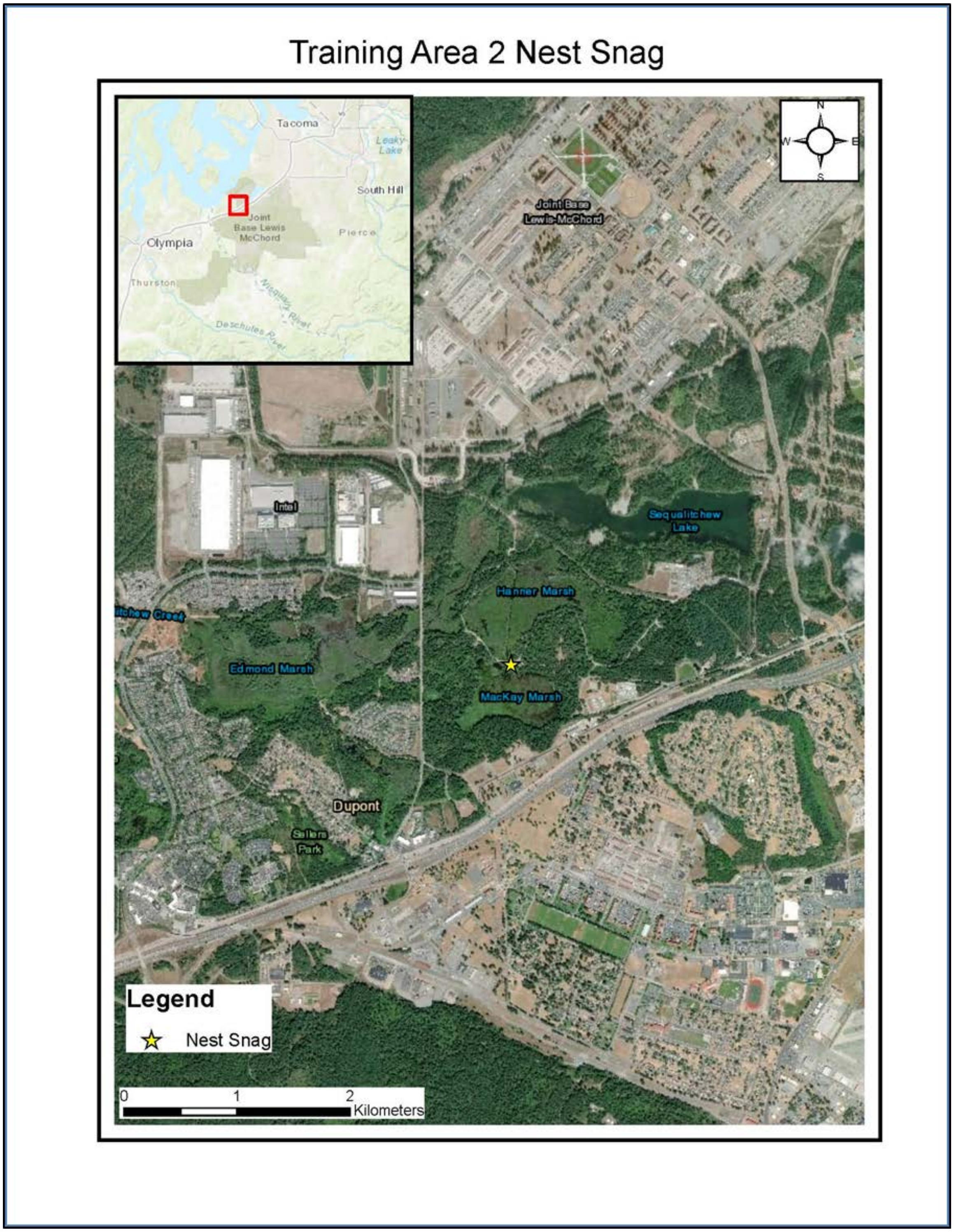

Figure 15. Training Area 2 nest snag and suggested location for future nest box installations.

Suggested specifications for martin nest box designs have evolved over several decades. A recent study of the success of nest box installations at six sites in California had mixed results (D.A. Airola, Kostka, & Elwood, 2018). The authors list several reasons for this and give recommendations based on successes. A nest box design is recommended as well as several characteristics of successful locations. JBLM meets many of the suggested criteria making it worth the effort to continue and enhance their nest box program. These include distances of less than 3 km from source populations (>5 pairs), close proximity to snags, and the ability to maintain the boxes over time with removal of nesting materials “at least every few years”. This is in addition to volunteers to monitor boxes. The need for volunteers could be potentially augmented by the JBLM Fish and Wildlife Environmental Restoration Warriors (ERW) program. This program works with veterans transitioning back into the work force. They volunteer alongside professional biologists as well as college interns to learn skills related to environmental restoration (Hess, 2018).

CONCLUSION

My research sought not only to find locations of snag-nesting Western Purple Martin on JBLM, but to describe the specific characteristics of snags used for nesting. My results are supported in many ways by previous studies in both Oregon and California, with the most significant difference between nesting and non-nesting snags being canopy cover. Although not statistically significant, martins nested in snags that were in close proximity to water and in advanced stages of decay. These are factors to consider when managing areas for martin habitat.

My results confirm the importance of JBLM as an important source of snag nesting habitat for the Western Purple Martin. This habitat has the potential to not only benefit martins but other species of cavity-nesting birds and wildlife on base. Continued preservation of known nest snags and creation of new snags will help to create conditions for these species to persist even as surrounding urban areas continue to grow. Although nest boxes provide a source of nesting habitat for martins they require maintenance and promote dependence as evidenced in eastern populations.

To date there are no accurate population estimates for Western Purple Martin in Washington. Ideally, future efforts should focus on systematic surveys of known (both artificial and natural) nesting areas to give a clearer picture of abundance and distribution. Finally, it would be worthwhile to develop a central database where information can be shared with those involved in conservation, among others, state and federal agencies, tribes, working groups, and concerned citizens.

Appendix

Avian species detected during twenty-six stationary point count surveys.

Common Name	Scientific Name
Canada Goose	*Branta canadensis*
Hooded Merganser	*Lophodytes cucullatus*
Mallard	*Anas platyrynchos*
Ring-necked Pheasant	*Phasianus colchicus*
Mourning Dove	*Zenaida macroura*
Rufous Hummingbird	*Selasphorus rufus*
Osprey	*Pandion haliaetus*
Red-tailed Hawk	*Buteo jamaicensis*
Hairy Woodpecker	*Picoides villosus*
Northern Flicker	*Colaptes auratus*
Pileated Woodpecker	*Dryocopus pileatus*
Red-breasted Sapsucker	*Sphyrapicus ruber*
American Kestral	*Falco sparverius*
Olive-sided Flycatcher	*Contopus cooperi*
Western Wood-Pewee	*Contopus sordidulus*
Pacific-slope Flycatcher	*Empidonax difficilis*
Hutton's Vireo	*Vireo huttoni*
Cassin's Vireo	*Vireo cassinii*
Steller's Jay	*Cyanocitta stelleri*
California Scrub-Jay	*Aphelocoma californica*
American Crow	*Corvus brachyrhynchos*
Common Raven	*Corvus corax*
Purple Martin	*Progne subis*
Tree Swallow	*Tachycineta bicolor*
Violet-green Swallow	*Tachycineta thalassina*
Barn Swallow	*Hirundo rustica*
Black-capped Chickadee	*Poecile atricapillus*
Chestnut-backed Chickadee	*Poecile rufescens*
Red-breasted Nuthatch	*Sitta canadensis*
House Wren	*Troglodytes aedon*
Pacific Wren	*Troglodytes pacificus*
Marsh Wren	*Cistothorus palustris*
Ruby-crowned Kinglet	*Regulus calendula*

Common Name	Scientific Name
Western Bluebird	*Sialia mexicana*
Townsend's Solitaire	*Myadestes townsendi*
Swainson's Thrush	*Catharus ustulatus*
American Robin	*Turdus migratorius*
European Starling	*Sturnus vulgaris*
Cedar Waxwing	*Bombycilla cedrorum*
Purple Finch	*Haemorhous purpureus*
Pine Siskin	*Spinus pinus*
American Goldfinch	*Spinus tristus*
Spotted Towhee	*Pipilo maculatus*
Chipping Sparrow	*Spizella passerina*
Savannah Sparrow	*Passerculus sandwichensis*
Song Sparrow	*Melospiza melodia*
White-crowned Sparrow	*Zonotrichia leucophrys*
Dark-eyed Junco	*Junco hyemalis*
Red-winged Blackbird	*Agelaius phoeniceus*
Brown-headed Cowbird	*Molothrus ater*
Orange-crowned Warbler	*Oreothlypis celata*
Common Yellowthroat	*Geothlypis trichas*
Yellow Warbler	*Setophaga petechia*
Audubon's Warbler	*Setophaga coronata auduboni*
Black-throated Gray Warbler	*Setophaga nigrescens*
Wilson's Warbler	*Cardellina pusilla*
Western Tanager	*Piranga ludoviciana*
Black-headed Grosbeak	*Pheucticus melanocephalus*

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