BIRDS OF A FEATHER: SPATIAL RELATIONSHIPS OF AVIFAUNA IN HAZELNUT ORCHARDS

By

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THESIS ABSTRACT

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This thesis investigates how hazelnut orchard age and landscape variability influence wild bird communities on farms, with a focus on adjacent habitat and establishing a biodiversity baseline. I conducted field studies within the Willamette Valley, OR to assess avifaunal diversity across hazelnut farms of increasing matrix quality; and across orchard ages within the farm with the highest matrix quality, Dorris Ranch. My findings show that landscape heterogeneity has a significant impact on bird communities, with adjacent habitat being a key factor for functional community traits such as diet guild. Due to its proximity to large habitat areas and distributed wildlands, Dorris Ranch has high species richness – particularly near restored oak habitats. Although younger orchards supported a higher species diversity on average at this site, older orchards supported key species of conservation and service-provisioning value, highlighting the importance of landscape diversity and ecologically intensive practices in management plans.

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To Nana, from who my love of birds was found

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I. INTRODUCTION

Agricultural systems are embedded in a larger landscape, and the interplay between agricultural and surrounding habitat can alter both regional biodiversity and on-farm ecosystem services. At times, farmlands can share structural components to the surrounding habitat (Brambilla et al. 2015); for example, tree crops share structural characteristics with woodlands, generating resources for wildlife and facilitating movement between agricultural and non-agricultural areas (Bailey et al. 2010, Peisley et al. 2016). Due to competing objectives and/or trajectories, maintaining natural habitat elements is one of the more significant issues that agroecosystems have to navigate (Gonthier et al. 2019). Many agricultural pests are known to have sink-source dynamics across the landscape, with remnant patches of habitat, or wildlands, often being removed to mitigate the loss of production on farms (Penkauskas et al. 2021, Saunders et al. 2016). The movement of species between adjacent habitat and agricultural lands, and the utilization within these systems, is still an active area of research (Olimpi et al. 2020). Fortunately, some wildlife can benefit farms by eating pest insects, however these species are adversely affected by habitat removals (Peisley et al. 2016).

The movement of non-agricultural species, such as birds, from wildlands to agricultural land is shaped by heterogeneity at both the farm and landscape scales (Gove et al. 2013, Kontsiotis et al. 2019, Martínez-Núñez et al. 2020), and species with wide ranges are more likely to utilize both wildland and farm habitats across space and time (Ikin et al. 2014). A growing body of evidence is demonstrating the benefits of managing habitat elements for providing ecosystem services for farms in Mediterranean and tropical systems (Gove et al. 2013, Kontsiotis et al. 2019, Perfecto et al. 2003), suggesting that more ecologically intensive practices can be good for both production and biodiversity. Furthermore, synergies between agricultural management and wildland habitat are poorly understood in many places (Sharps et al. 2023), such as the Pacific Northwest of the United States (PNW), yet their function across spatial and ecological scales is increasingly relevant for biodiversity conservation within private lands (Reynolds et al. 2017, Smith et al. 2022). The role of conservation in agroecosystems requires thinking about agricultural context to wildlands, and how the movement of species function with agricultural production and cultural practices.

Understanding how and why species interact within agroecosystems, especially those able to disperse easily within the landscape, is fundamental to pragmatic management and conservation within the agricultural-wildland matrix. For example, birds are known to be highly mobile within home ranges (Ikin et al. 2014) and have classically been studied in ecology for their ability to both partition resources spatially and temporally. However, bird populations are declining worldwide due to habitat loss (García et al. 2021) and decreased insect populations (Perfecto et al. 2003). As such, bird species, or avifauna, are often used as indicators since they are highly responsive to changes in habitat elements and matrix-quality, with landscape factors like habitat heterogeneity, composition, and structure influencing their diversity and abundance (Olimpi et al. 2020, Reynolds et al. 2017, Stirnemann et al. 2015). This is important because emerging systems within agro-ecological landscapes consist of novel interactions of legacy practices, historical and ongoing land-cover change (Reynolds et al. 2017), and economic pressures which present unique decision making challenges and courses of action for biodiversity conservation (Smith et al. 2021).

Bird communities, through their functional and cultural roles, are of increasing interest for farmers and the public, while regional conservation efforts mainly focus on species of strategic value due to the limited amount of conserved habitat (dos Santos et al. 2021). Moreover, the frequent and intensive disturbance of agricultural farms by operations often constrain the structure and composition of habitat elements within crops (Brambilla et al. 2015, Martínez-Núñez et al. 2020), with management practices often not being favorable to many species. Fortunately, woody perennial crops – such as apples, almonds, and hazelnuts – generate vertical complexity to the landscape, and add to the heterogeneity of habitat elements across agroecosystems throughout their different life stages (Morelli et al. 2018). This is particularly important in the PNW because Oregon produces almost all of the country's hazelnuts and is currently undergoing exceptional growth (Penkauskas et al. 2021). The shift in canopy structure and vertical complexity across spatial scales, in some ways, could serve a functional role for avifauna in conjunction with nearby wildland. However, it is highly likely that contributing factors like orchard age, type and size of adjacent habitat, and overall landscape matrix quality contributes to the diversity and density of birds in Oregon's agroecosystems.

As they age, orchards create a closed canopy and have significant edge effects on the presence of birds across adjacent crops, developed space, and wildlands (Bailey et al. 2010, Kontsiotis et al. 2019, Maestas et al. 2003). Likewise, the composition of habitats and variability of canopy structures are known to increase the quality of the wildland-agricultural matrix (Martínez-Núñez et al. 2020). Depending on the heterogeneity and connectedness of habitat, farms with a variety of orchard ages and higher heterogeneity may be a hybridization of both historical and novel ecosystems, acting across scales in respect to type of habitat, and distance to large patches (dos Santos et al. 2021, Martínez-Núñez et al. 2020). As matrix quality increases across scales, bird diversity and density is expected to increase as well. Therefore, highly heterogeneous farms that retain a variety of habitat elements and habitat types increase the matrix quality for wild birds. These dynamics between the age structure of hazelnut farms and habitat composistion in the landscape may alter the functional variety of bird communities, which may influence hazelnut farms to adopt conservation methods rather than more intensive ones.

To investigate this knowledge gap, I conducted a survey of avifauna communities throughout 2022 at three similar-size hazelnut farms in the Willamette Valley, OR. I asked: (**Q1**) how does landscape heterogeneity affect wild bird communities across hazelnut farms? Then focusing on the farm with the highest matrix quality, I asked: (**Q2**) how do different adjacent wildland habitat types affect species diversity; and, (**Q3**) how does stand age affect bird diversity? I predicted that: (**P1**) farms of greater matrix quality will have a higher diversity of birds – and at the farm scale: (**P2**) orchards adjacent to oak habitat will have higher diversity compared to other habitat types; and, (**P3**) older orchards will have higher diversity compared to younger orchards.

II. METHODS

First, I did a cross-farm comparison of low, medium, and high landscape matrix-quality, followed by a within-farm comparison of habitat edge and orchard age at the site with the highest heterogeneity. I assessed functional groups of birds and categorized them into four main diet guilds that are agriculturally important (Cornell 2019, Saunders et al. 2016), and identified species of conservational value for the region (Altman & Stephens 2012). Observations in this study may also include qualitative accounts of bird communities alongside bird behavior including foraging, hunting, and/or nest building.

Spatial Analysis

To characterize habitat heterogeneity and overall matrix quality, I used a spatial analyses of percent cover conducted in ArcGIS Pro (Version 3.0.3) utilizing the CropScape raster layer (USDA 2022) and a 3-km buffer around each farm. Pixel values of major land-covers across farms were selected and passed through a generalization of classified raster imagery workflow to decrease misidentification of pixels (Peter & Weibel 1999) and then calculated for percent cover. Since this dataset does not include a hazelnut classification per se, hazelnut orchards are classified as Other Tree Nut and may be an underestimation of land cover of hazelnut orchards. I then categorized common wildland habitats in the region into one general category – such as wooded wetlands, conifer, and oak woodlands. Likewise, I aggregated other agricultural crops into their own category; although it should be noted that there are potential spatial and temporal dynamics that can arise from adjacency to various other crops (Martínez-Núñez et al. 2020). Furthermore, low, medium, and high developed land-covers were aggregated into a Developed category with similar caveats. Lastly, both Grassland/Pasture and Sod/Grass

Seed categories are significant in the region and were left un-aggregated for the analysis (**Figure 1a**).

After calculating the landscape land-use composition and proportion surrounding each farm, I classified the sites by the amount of land-cover into three categories: low, medium, and high matrix quality. Farms that had a significant amount of contextual agricultural crops resulted in lower matrix quality, with a percent edge of adjacent wildland and contextual wildland contributing to a higher quality. In addition, the general

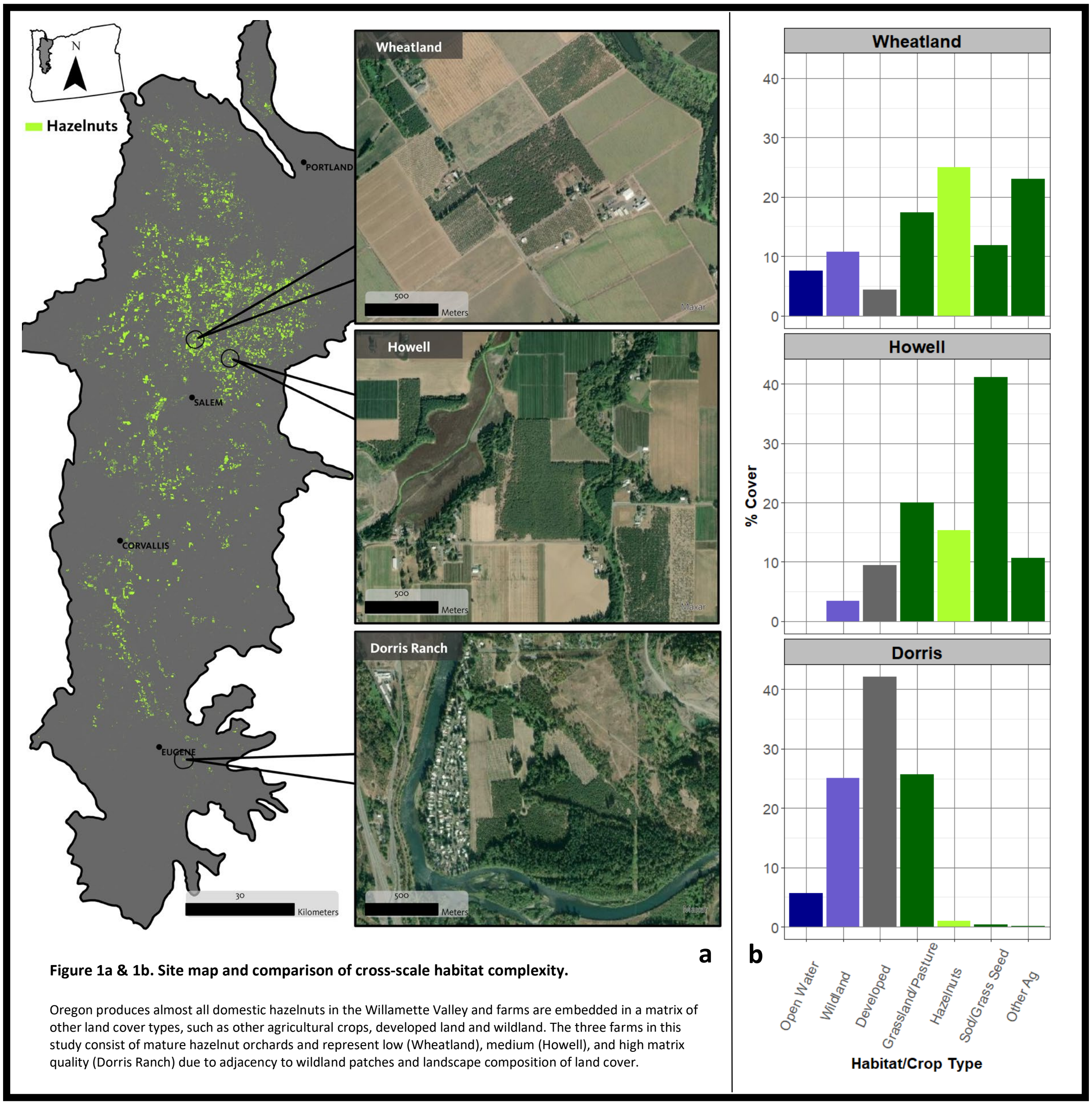

Figure 1a & 1b. Site map and comparison of cross-scale habitat complexity.

Oregon produces almost all domestic hazelnuts in the Willamette Valley and farms are embedded in a matrix of other land cover types, such as other agricultural crops, developed land and wildland. The three farms in this study consist of mature hazelnut orchards and represent low (Wheatland), medium (Howell), and high matrix quality (Dorris Ranch) due to adjacency to wildland patches and landscape composition of land cover.

landscape's composition of land-use influences how connected farms are and their degree of heterogeneity, which results in improved matrix quality.

Site Descriptions

Lane-Massee Farms – Medium and Low Matrix Quality

Lane-Massee Farms consists of two hazelnut farms (~20 hectare orchards at 10 km apart) near Keizer, Oregon. The medium matrix quality orchard, North Howell, has a higher degree of adjacent wildland habitat and lower abundance of hazelnuts in the surrounding landscape compared to the Wheatland farm. North Howell is directly adjacent to marionberries, a Douglas-fir plantation, wooded wetland, and mixed hardwood woodland. In contrast, the low matrix quality farm, Wheatland, is directly adjacent to mature hazelnuts, hops, and has two homesteads at the site. However, the Wheatland farm is a little over 2 km from the Willamette River and a quarter of a mile from a remnant oxbow lake, which is within the home range of most birds (Gregory et al. 2004). Both farms are adjacent to young hazelnut orchards, with North Howell coming in at 45 years and Wheatland at 60 years old. Although management practices are the same, North Howell has a low degree of eastern filbert blight infection compared to extensive infection at Wheatland – which can be a factor of age and abundance of the pathogen in the landscape (AliNiazee 1998).

Dorris Ranch – High Matrix Quality

Dorris Ranch is the oldest operating hazelnut farm in the U.S. and pioneered the industry in Oregon (Willamalane 2019). Today, it is a public park, a national heritage site, and a living museum that actively manages both wildland habitat and hazelnut production (Willamalane 2019). Dorris Ranch is located in Springfield, Oregon, and

Willamalane Parks and Recreation District is past the second phase of replanting the aging orchards suffering from extensive eastern filbert blight infection – including some over 90 years old. In late February 2022, approximately 6 hectares of hazelnut trees were replaced along the parks urban edge. Similarly, approximately 5.5 hectares were replaced back in 2016 and have since been moved into production. The remaining 14.5 or so hectares are scheduled to be replanted as early as 2024 (with roughly 2 hectares being conserved for heritage). This high degree of habitat heterogeneity and proximity to large habitat patches, including an ex-urban development, substantially increases Dorris Ranch's matrix quality. This is in contrast with most of the agricultural-wildland matrix in the Willamette Valley, in which orchards are associated with habitat homogeneity due to increasing land conversion and farmland consolidation (Penkauskas et al. 2021).

Avifauna Survey Design

Utilizing stratified point counts of birds is a common practice for ecological monitoring (Ralph et al. 1993) and can be generalized for various habitat types (Buckland et al. 2008). To properly capture the variability of habitats at each hazelnut farm, I established point count stations at a density of approximately 1 per 4 hectares of farmland; following protocols published by Smith et al. 2022. Stations were positioned just within the orchard, along the edge, to optimize species detection with the interface of habitat unless otherwise able to fit in the core of a hazelnut orchard. Stations were positioned at least 200 meters from each other and were selected to capture each sites' spatial heterogeneity and habitat composition. Each farm surveyed in this study consisted of mature orchards of similar size, comparable adjacent habitat types, and performs similar, contemporary, management practices for pest control and nut harvesting.

Surveys were then repeated at least every month throughout the breeding season at each hazelnut farm, with Dorris Ranch including surveys approximately every two weeks and extra point count stations in the ex-urban development and upland oak-prairie (**Supplemental 1**). Across Dorris Ranch, there are a number of wildland habitats, including: wooded wetlands, mixed hardwood woodlands, oak woodlands, mixed conifers, and an extensive restored oak habitat. Likewise, two stations along old orchards edges were included to have more direct pairwise comparisons with Lane-Massee Farms, since both farms are of only old hazelnut trees. This allowed me to not only more accurately describe what bird communities are present within these large adjacent habitat types, but also to disentangle the movement of birds between wildland and orchards both across-farms, and within Dorris Ranch itself.

Field Methods

Bird species and abundance were recorded within 100 meters of each station (**Supplemental 2**) for 5-minute intervals during good weather and within the first 4 hours of sunrise (Ralph et al. 1993) from March – September 2022. To maximize species detection probability and minimize temporal sampling error, I conducted point count surveys twice within each week, in alternating orders, and averaged across days to mitigate pseudo-replication of observations (Buckland et al. 2008, Gregory et al. 2004, Thompson et al. 2002). I replicated surveys at least every month throughout the breeding season at each hazelnut farm. Birds that were not actively utilizing the space within the point count, such as fly-overs, were recorded for presence but not density. Density of bird observations was determined by methods put forth by Buckland et al. 2008 ($\widehat{D} = \frac{n}{k\pi w^2}$) in which the abundance of birds, equal to the number of observations summed across all points, is divided by the multiple of the radius. Across all farms, 5 point count stations were selected from each farm ($k = 5;\ k\pi w^2 = 15.708\ ha$). For within Dorris Ranch, the 8 point count stations in the hazelnut orchards were selected ($k = 8;\ k\pi w^2 = 25.133\ ha$). To add in the accuracy of bird identifications I used field guides and placed observations within 50 meter bands extending from the station, using Google My Maps (Google a & b 2022), binoculars, and a laser rangefinder to insure distance approximations.

Diversity and Functional Diet Guilds

To assess the degree to which bird diversity differs across farms, orchard ages, and habitat types, I utilized the following metrics: Simpson's Reciprocal Index (**D**), Species Richness (**S**), and density– which was calculated in R (Version 4.0.2) using the "simpson_e" function in the *abdiv* package. I chose the Simpson's Reciprocal as my main metric of avifauna diversity due to the indices' ability to detect both richness and evenness of communities while taking into account the relative abundance of species (Buckland et al. 2008, Ralph et al. 1993). Similarly, it is also important to look at the composition of communities for associated species and diet guilds for both service provisioning and conservation, since these are some of the main motivating factors for the thesis (Gove et al. 2013). Therefore, I categorized insectivore bird species into four relevant diet guilds based off of their foraging behavior (aerial, bark, foliage, and ground; Cornell 2019). Moreover, each of these guilds provision different levels of ecosystem service, with bark and foliage gleaners having the most direct effect of aphids in orchards. Similarly, aerial and ground foragers may affect some pests as well, yet theses direct ecosystem services are yet to be quantified for hazelnut production in the Willamette Valley (AliNiazee 1998).

Statistical Analysis

All statistical analyses were conducted in R (Version 4.0.2). To test (**Q1**) how landscape heterogeneity affects bird community diversity and composition, I first compared species diversity (**D**) by farm, treating farm as an ordinated factor (low, medium, high matrix quality). I chose five point-count stations of similar orchard age and adjacent habitat at each farm (three farms x 5 points = 15 locations), each sampled monthly over a five-month period (75 total observations). To compare how bird community composition differed among farms with different levels of matrix quality I performed a cluster analysis using the Analysis of Similarity (ANOSIM) function "anosim" in R-package *indicspecies* (Version 1.7.13) where I grouped both abundance and diversity over time, and then defined farm as a fixed factor and point as a random effect, resulting in an output of significant indicator species across farms over the entire breading season.

Qualitative Analysis

To compare how bird community composition differed among orchard ages with different types of habitat at the farm-scale (Dorris), I pooled observations and averaged within weeks by point, and then calculated the effort for each point (*Effort* = 13.3 hrs., Buckland et al. 2008). Across all points at Dorris Ranch, including the Urban and Upland habitat patches (n=14), a total of ten 2-week periods served as repeated surveys (N=140). To investigate (**Q2**) how different adjunct habitat types and (**Q3**) orchard ages affect bird density (birds/ha) and species richness (**S**), I calculated the density and richness of birds paralleling the stratified point count design with adjacent habitat type (urban/new orchard, mixed hardwood, and oak) and orchard age (young vs. old). Due to pseudo-replication and the substantial underestimation of variance within Dorris Ranch, direct comparisons of species density and richness are not able to be statistically tested – rather, a qualitative assessment of metrics are performed for pooled data between habitats over time.

III. RESULTS

Landscape Heterogeneity and Composition

The landscape composition that surrounds the Wheatland farm consists of 25% Hazelnut, 23% Other Ag, 17% Grassland/Pasture, 12% Sod/Grass Seed, 11% Wildland, 8% Open Water, 4% Other, and 4% Developed (**Figure 1b**). Similarly, the farm at Howell is situated with a context of 41% Sod/Grass Seed, 20% Grassland/Pasture, 16% Hazelnut, 11% Other Ag, 9% Developed, 3 % Other, and no Open Water cover. Meanwhile, the landscape composition surrounding Dorris Ranch is 42% Developed, 25.5% Grassland/Pasture, 24.5% Wildland, 5.5% Open Water, 2% Hazelnuts, and less than 1% of Sod/Grass Seed and Other cover.

Cross-farm Diversity and Composition

Visual confirmation of bird species accounted for less than half of identifications, with auditory confirmation comprising the bulk of observations. In total, my team performed over 2700 observations across 7 months. The highest habitat matrix quality (Dorris Ranch), on average, was found to have a higher diversity scores on the Simpson's Reciprocal Index and species richness (D =0.98; S = 14.90) compared to the moderate matrix quality (Howell) (D = 0.93; S = 10.96) and low matrix quality farms (Wheatland) (D = 0.90; S = 9.28). Lastly, the high matrix quality (Dorris Ranch) has the highest number of associated species at 7, with Howell and Wheatland having 4 each (**Figure 2**).

(**P1**) When comparing bird communities across farms, there is some notable degree of grouping among habitats within Dorris Ranch, sharing little similarity from Lane-Massee Farms – with a higher density of bark foragers and foliage gleaners found within higher quality matrices (**Figure 3**). The ANOSIM of avifauna richness across all farms was found to be highly statistically different ($p < 0.01$), with a high degree of dissimilarity ($R = 1$) with adjacent habitat demonstrating to be a significant driver of evenness across farms.

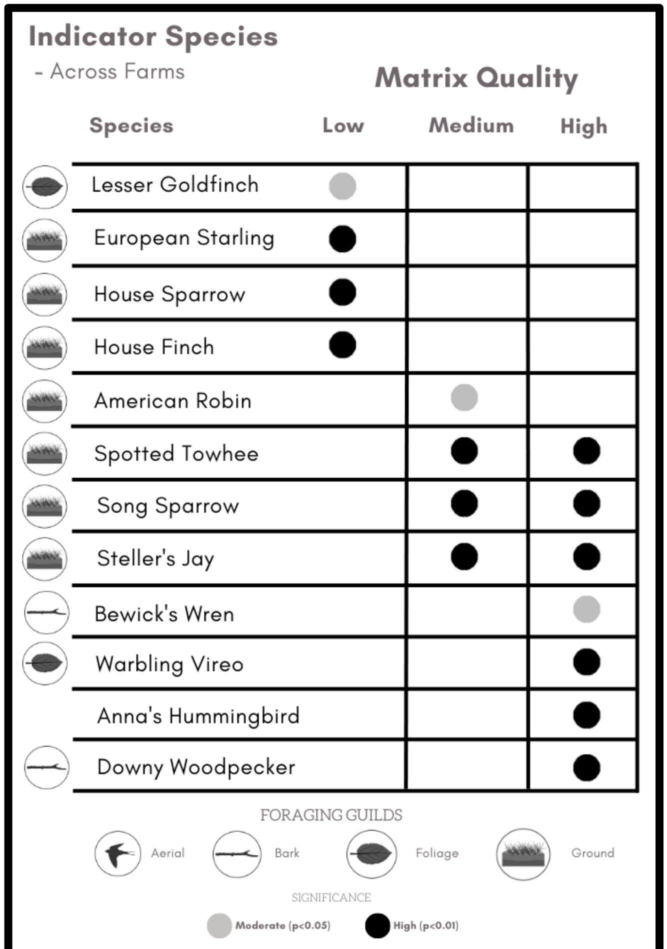

Figure 2. Cross-farm indicator species and functional diet guilds. High matrix quality supports more species and higher guild diversity.

Within-farm Diversity and Composition

Likewise, when comparing within-farm habitats at the highest heterogeneity farm (Dorris Ranch), there is some observable emerging trends from the data. Points near oak ($S = 16.15$) and mixed hardwood habitat ($S = 14.65$) had the highest richness of species of birds at Dorris Ranch (**Supplemental 3**). This pattern holds true across other habitat types, as younger orchards, on average, had a higher species richness compared to older orchards. To investigate the comparison of orchard age and habitat I then excluded the ex-urban, oak-prairie, conifer, and maple points. (**P2**) Young orchards typically had higher richness and density than old orchards, especially in the oak habitat (**Figure 4**), with young orchards driving richness and density of birds. In particular, (**P3**) the oak points have on average higher richness and density. However, the young-oak point was almost solely responsible for driving this phenomenon.

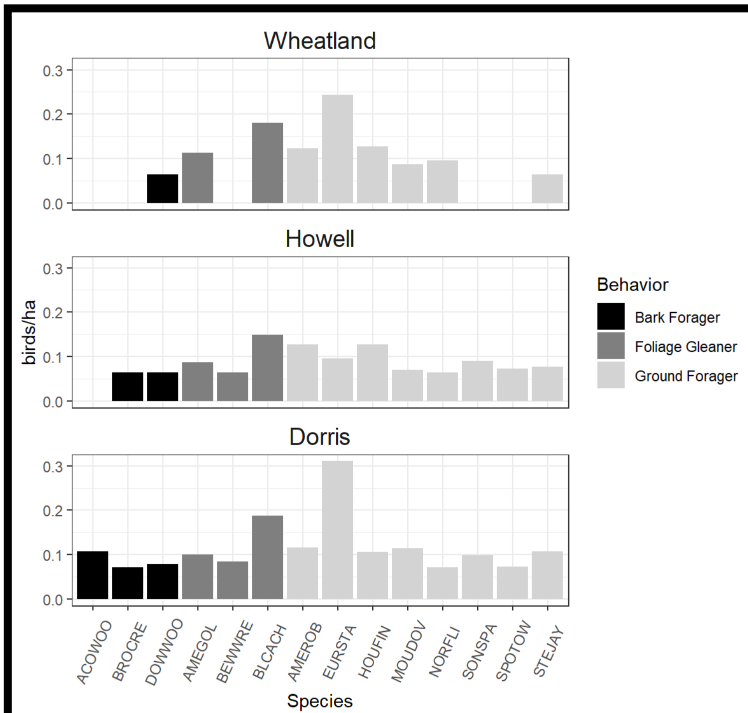

Figure 3. Density of cross-farm indicator species; including black-capped chickadees (BLCACH). Services provisioned by bark and foliage diet guilds may be higher in higher quality matrices due to their increased abundance.

Functional Diet Guilds

Aerial foragers were found exclusively in young orchards, with the density of ground foragers being higher on average than older orchards (**Figure 5**), while the density of both bark foragers and foliage gleaners were found to be higher on average in old orchards. Acorn woodpeckers were found, on occasion, utilizing the young orchard directly adjacent to oaks. On the other hand, western bluebirds were observed in the young orchard on the urban/new orchard side of Dorris Ranch. Chipping sparrows were most abundant in old orchards and were mostly observed along habitat edges. Likewise, the density of white-breasted nuthatches was highest in older orchards and were observed actively excavating cavities.

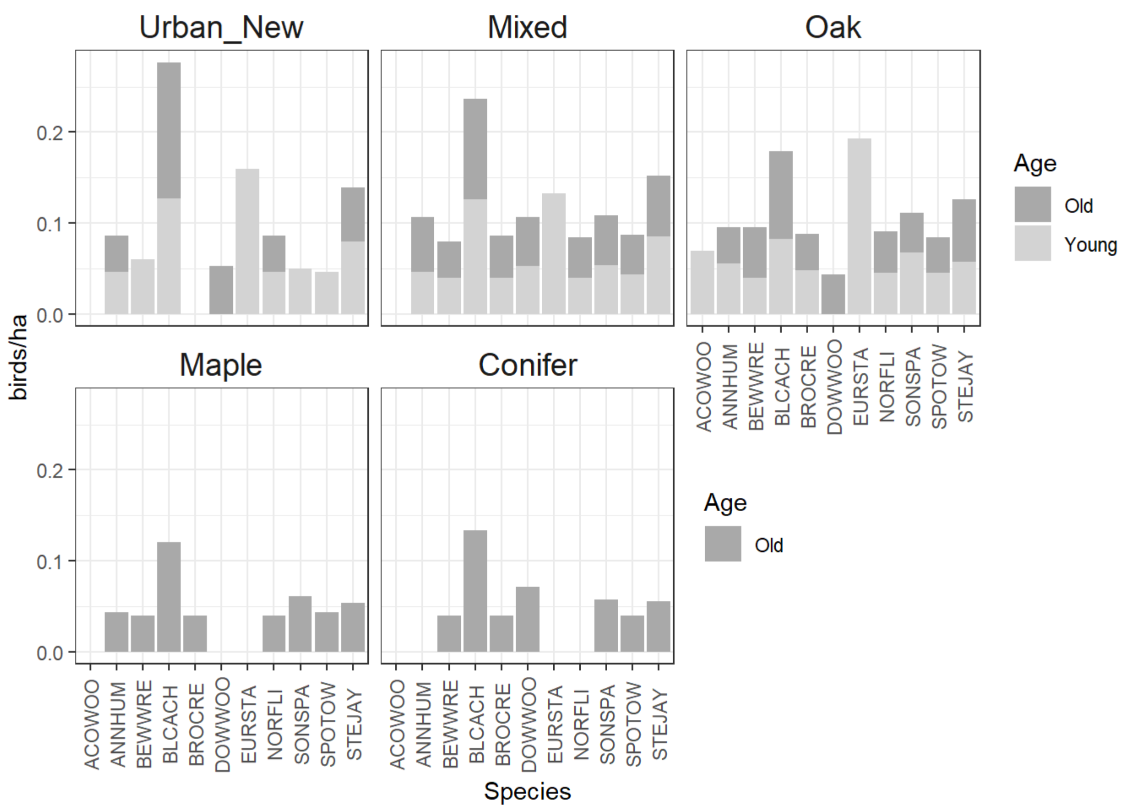

Figure 4. Density of abundant species across habitat and orchard age at Dorris Ranch. Both of the young orchards near the mixed hardwood and oak habitats have more diverse bird communities, with black-capped chickadees favoring the older orchard near the urban extent.

IV. DISCUSSION

Here, I found orchard structure to greatly affect the matrix quality of agricultural land and wildlands through variation in canopy structure of hazelnut orchards and adjacent habitat. The availability of suitable habitats for bird species is affected by changes in habitat complexity across scales, and this was found to be one of the determining factors in the presence of ecosystem service-providing bird communities in this study. These results are in line with literature surrounding matrix quality and agricultural land in a variety of systems (Gove et al. 2013, Kontsiotis et al. 2019, Lomba et al. 2020, Morelli et al. 2018, Perfecto et al. 2003, Tscharntke et al. 2008) and further demonstrates the importance of using avifauna as indicators for biodiversity conservation

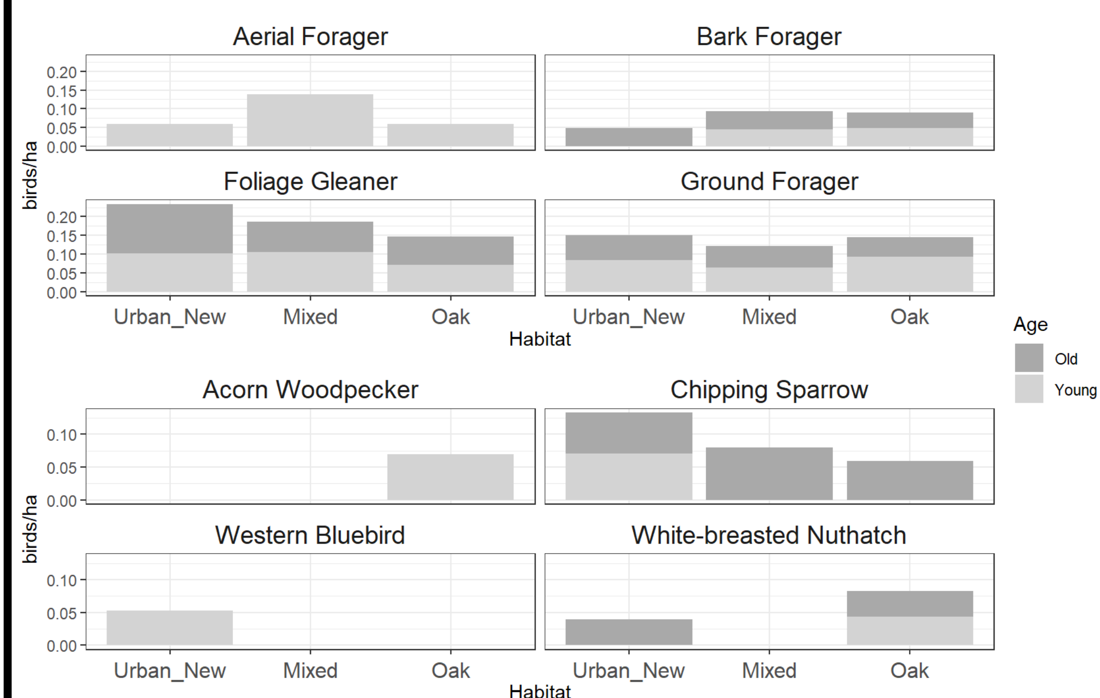

Figure 5. Density of relevant ecosystem service provisioning farm bird diet-guilds and species of strategic conservation value. Older orchards support a higher abundance of species within diet guilds beneficial to hazelnut farms. Similarly, some species of conservational value utilize orchards of different ages – highlighting the important role hazelnut orchards play in managing for biodiversity conservation.

and ecosystem services. The novelty of this study then lies in being based in Oregon's hazelnut agroecosystem and serves as a baseline for conservation and future work.

According to my findings, landscape heterogeneity has a large impact on bird community composition at all hazelnut farms. Between farms, (**P1**) there were considerable differences in the number of bird species present, with the highest matrix quality farm, Dorris Ranch, having the highest species diversity and Simpson's Reciprocal Index score. The moderate degree of variation in bird communities among farms suggests variations in the species composition of birds may be due to habitat elements within the surrounding landscape and the similar agricultural context among the less heterogeneous Lane-Massee farms.

The findings from this study have important implications for conservation efforts within farms as well. The observed similarity of bird groups near urban development and upland oak-prairie highlights the need to incorporate these areas into habitat management plans. These observations may be due to both the vertical complexity of these habitats and the unique resources associated with them (Gove et al. 2013). Preservation and enhancement of these habitats can support diverse bird populations (Maestas et al. 2003, Pejchar 2018) and the high bird diversity throughout Dorris Ranch exemplifies the presence biodiversity hotspots have in agricultural land. (**P2**) The ex-urban, urban/new orchard, and oak habitats showed the highest average number of associated species and there were different species in each habitat, emphasizing the importance of directed conservation actions in these areas as well. This study also demonstrates the significance of orchard age, (**P3**) as younger orchards exhibited greater species richness compared to older orchards. Therefore, maintaining a mix of orchard ages within hazelnut farms is crucial for supporting a broader range of species of strategic conservation value. Protecting oak habitats is particularly important, given the notable differences in diversity between oak points and urban/new orchard points. Conservation efforts therefore should aim to balance both abundance, and functional diversity, of bird populations; ensuring a healthy ecological balance within hazelnut orchards.

The presence of specific bird species in hazelnut farms, such as acorn woodpeckers and western bluebirds, emphasizes the significance of habitat connectedness (Reynolds et al. 2017, Smith et al. 2022). Young orchards next to oak trees were used by acorn woodpeckers in which I observed them gleaning insects from the trees themselves and potentially caching hazelnuts in their granary, highlighting the necessity of linking ecosystems that supply vital resources. On the urban/new orchard side of Dorris Ranch, western bluebirds were also seen in young orchards, demonstrating their capacity to use the open canopy for foraging and perhaps benefit from diverse habitats at the farm-scale (Bailey et al. 2010, Brambilla et al. 2015). These observations of foraging behavior and orchard utilization show how interrelated various habitats are and how crucial it is to preserve a mosaic of ecosystem components within hazelnut farms.

Some bird species, such as chipping sparrows and white-breasted nuthatches, may find old orchards to be ideal locations for foraging or even nesting. Both black-capped chickadees and white-breasted nuthatches were actively observed excavating in older orchards, possibly due to not only the vertical complexity of mature trees, but the high presence of eastern filbert blight and decayed wood – conditions suitable for excavation and bark gleaning (Kontsiotis et al. 2019). As such, hazelnut farms that preserve historic orchards with decay can improve nesting and foraging possibilities for these species and aid in their conservation, potentially resulting in a trade-off between the presence of blight within farms and the ecosystem services they provide. Thus, the retention of old orchards, which provides appropriate nesting habitat for cavity-nesting birds, should be balanced with the requirement to manage orchard age diversity and preserve suitable feeding supplies in conservation initiatives. Similarly, having a mixture of young and old hazelnut trees within farms may be favorable for chipping sparrows due to the explicit ecotones that are created at their interface (Brambilla et al. 2015, Ikin et al. 2014, Stirnemann et al. 2015).

A wide variety of bird species are supported by highly heterogeneous hazelnut farms, like Dorris Ranch, that exhibit high nature-value traits because of their even distribution of wildlands and proximity to major habitat patches, including urban development and upland oak prairies. In contrast, the less heterogeneous Lane-Massee facilities may only offer a limited variety of habitats for birds because they are located in a more homogeneous agricultural region dominated by monoculture crops such as hazelnuts, hops, and sod/grass seed. My results suggest that maintaining habitat variability within hazelnut farms encourages the presence of various bird guilds and helps create an agricultural-wildland matrix that is more biodiverse.

Depending on the maturity of the orchard and the availability of resources at the farm-scale, I found hazelnut farms have different bird guild densities and compositions. Due to the greater availability of resources, young orchards with open canopies and thick ground cover attract aerial foragers and have a higher population of ground foragers (Gonthier et al. 2019, Ikin et al. 2014). On the other hand, old orchards with closed canopies and epiphyte protection offer ideal circumstances for gleaners of leaf and twigs (Bailey et al. 2010). These guilds are more common in older orchards and directly support hazelnut businesses by offering pest management services such as aphid treatment. For the benefit of a diverse bird community that can aid in sustainable pest management, it is essential to maintain an assortment of young and old orchards.

Decision-making should take into account the relationships and trade-offs between cultural services, environmental function, and biodiversity to effectively conserve birds in hazelnut farm (Martínez-Núñez et al. 2020, Morelli et al. 2018, Peisley et al. 2016). Farmers' attitudes about birds and conservation goals can be more closely matched by adopting high nature value farms and implementing more ecologically intensive measures for orchards. Incorporating biodiversity-focused farming practices and matching incentive programs with consumer preferences might also encourage the preservation of bird habitats within hazelnut farms (Reynolds et al. 2017). It is crucial to understand that managing agroecosystems for bird conservation necessitates a socioecological systems approach incorporating public incentives and regulations to stimulate conservation actions and advance planning at the landscape scale (Peisley et al. 2016). It is possible then that hazelnut farms may contribute to curbing biodiversity loss in the coming years by promoting sustainable agricultural practices that benefit both farmers and bird conservation groups through promoting the value of preserving orchard variation and habitat elements.

In conclusion, my results largely supported my predictions that heterogeneous matrices help wild bird communities utilizing hazelnut orchards. In particular, compared to other habitat types at the farm scale, orchards near oak habitats showed greater diversity. In addition, older orchards showed greater abundance of insectivore species and species of conservational value than younger orchards. These findings highlight the significance of taking into account orchard age and landscape elements when planning for hazelnut production and species conservation in Oregon’s agroecosystems. Therefore, hazelnut farms are likely in a position, today, to aid in the preservation of bird communities and lessen the loss of biodiversity in agricultural lands by maintaining a variety of orchard ages and wildland components within the landscape.

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