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Avian use of restored oak woodland in Northern California

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ABSTRACT Over the course of the last few decades urban development, agriculture, lack of young trees, and sudden oak death have caused a decrease in California's native oak woodlands which are an important habitat for disturbance-dependent bird species (Hunter et al. 2001, Lovio 2004). Restoration in developed areas is an important tool managers can use to protect native species and diversity, but this requires an understanding of what habitat structures best support a diverse ecosystem (Chase and Geupel 2005). I used avian abundance and species richness data as well as vegetation composition data gathered from fifteen-point count locations in a restored oak woodland in Northern California to model which vegetation factors had the most influence on avian abundance, diversity, and species richness. I found that an increase in tree cover may correlate with an increase in avian diversity and abundance, while the number of shrub species or a combination of the number of shrub species and tree cover might have a positive influence on species richness in an oak woodland habitat. However, these findings were largely inconclusive and further studies that examine other vegetation or environmental factors should be conducted.

KEY WORDS birds, California, habitat gradient, oak woodland, restoration

Oak woodlands play an important role in California's ecosystems and are home to many species, but vast sections of California's oak forests have already been lost due to urban development, agriculture, lack of young trees, and sudden oak death (Lovio 2004). Oak woodlands are also an important habitat for disturbance-dependent bird species, which have declined as much as 70% since European colonization of North America (Hunter et al. 2001). However, as of the early 2000s, only thirteen percent of California, or about seven million acres, contained oak forests with over eighty percent on private land mostly used for ranches (CDF 2003). Recent studies have also found that increased competition with conifers, such as Douglas firs (*Pseudotsuga menziesii*) and western juniper (*Juniperus occidentalis*), due to a lack of fire has continued to degrade oak woodland habitat (Das et al. 2020). Along with the increased occurrence of droughts in Oregon and California oak woodlands have faced significant strain in the last few decades (Stephens et al. 2021). As a result of habitat loss and degradation due to these factors, small patches of restored habitat are quickly becoming important safe havens for many species (Tulloch et al. 2015). However, while many restoration attempts have been successful and generalists have done well, fragmentation has taken a toll on specialists that require more specific niches (Leveau et al. 2019, Stephens et al. 2021). Managers need a better understanding of what they can do in managed and restored spaces to promote diversity and help specialists return to areas they previously occupied.

In this study, I wanted to determine how areas with different vegetation structures within a restored area related to avian species richness and diversity in an oak woodland habitat. Due to their mobility, birds are usually able to return to patches quickly, except for interior specialists which may have trouble crossing disturbed areas, and because they are diverse and sensitive to environmental changes, they are excellent indicators of habitat quality and restoration success (Chase and Geupel 2005). In the past, oak woodlands have been found to be dominated by cavity nesting birds, which comprise about 60% of individuals, even though they only make up about

25% of species (Wilson et al. 1991). Cavity nesters rely on large trees, especially oaks (*Quercu*s sp.), which are more likely to provide them with natural cavities for nesting (Wilson et al. 1991). Other important species such as acorn woodpeckers (*Melanerpes formicivorus*) also rely on large trees for granaries, but they prefer certain species over others (Wilson et al. 1991). In areas where white oak (*Quercus alba*) is present, they will select it significantly more than other species, but in areas that are blue oak (*Quercus douglasii*) dominated, they tend to favor other species such as gray pines (*Pinus sabiniana*) (Wilson et al. 1991). While there might be more individuals that rely on large trees, diversity is also important within a habitat. In English moorlands, species were found to possess different preferences when it comes to the composition and structure of vegetation, so heterogeneity of vegetation is important to maintain within a habitat type (Pearce-Higgins and Grant 2006). Since oak woodlands are important for California's wildlife but are being lost and degraded due to multiple factors, it is more important than ever for managers to understand how species richness correlates with vegetation in a managed area. Understanding and promoting diversity is one of the best ways we can keep ecosystems healthy. I hypothesized that there would be a positive correlation between avian species richness and more complex vegetation composition and structure.

STUDY AREA

The study was conducted at the Churn Creek Open Space owned by the McConnell Foundation in Redding, California, USA, which is located at the north end of the California Central Valley. The area is dominated by blue oak (*Quercus douglasii*) woodland which comprises of about 180 acres, but there are also about 30 acres of upland grassland meadow (Young and Gilgert 2014). The dominant tree species are blue oak, interior live oak (*Quercus wislizeni*), and gray pines (*Pinus sabiniana*), and the dominant shrub species are white-leaf manzanita (*Arctostaphylos* *viscida*) and poison oak (*Toxicodendron diversilobum*). The area is open for public use, and there are approximately 4 miles of tails on the property (Young and Gilgert 2014). The area is bordered by Churn Creek on the west side and suburban homes on all other sides. Foliage is the thickest along the creek, while it is thinnest and most disturbed along the suburban edge on the east side; however, some areas around the southern edge of the creek were also disturbed and recently cleared of underbrush. Many different management practices were used to help restore the area including prescribed grazing, disking and planting native grasses, clearing underbrush, and spot spraying herbicides for invasive plants (Young and Gilgert 2014).

METHODS

Sampling Scheme.— I conducted my study from the 23 January to the 11 April 2021 and divided the study area up into three different sections based on the density of the trees and how close they were to the suburban or riparian sides and named them the suburban edge, oak woodland, and riparian woodland areas, respectively. I set up a systematic transect in each of the three sections with five sampling points on each transect for a total of fifteen points. I determined the distance between the points by taking the terrain into consideration and placing points as equidistant as possible with a minimum of 150 m between points. The suburban transect was 700 m in length with points between 150 and 200 m apart, the oak woodland transect was 750 m long with points between 150 and 200 m apart, and the riparian transect was 900 m long with points between 200 and 250 m apart.

Data Collection and Research Design.— I collected avian abundance and species richness data at least once a week by sampling each point with a five minute point count, during which I recorded all of the individuals and species seen or heard (Purcell et al. 2005). Five minute point counts were used because they reduce the probability of double counting a bird while remaining as effective as a longer duration point count (Granholm 1983, Fuller and Langslow 1984). Birds that were farther than 50 meters away or that flew over and did not use the habitat were not counted (Young and Gilgert 2014). In addition to the avian point counts, I recorded the number of people present, other animals, if an area has been recently disturbed, and the weather. Point counts took place in the morning between 700 and 1200 hours, and I rotated which transect I started with and which direction I traveled to minimize the risk of bias related to time of day.

Vegetation sampling was done once during the course of this study, and all points were measured within a one-week period. I estimated the amount of cover by trees, shrubs, and herbaceous plants including grass in a 100 m^2 area around each of the fifteen points. A 100 m^2 plot was used because it is the most flexible standard observation size that works well for small studies (Peet et al. 1998). I identified each tree and shrub to species, and I recorded the height of each tree using the app Arboreal which estimates height using triangulation (Arboreal Version 1.4.3, https://www.arboreal.se/en/, accessed 30 Jan 2020). The diameter of each tree at breast height was also recorded.

Data Analyses.— For this study, my response variables were avian diversity, abundance, and species richness, while my independent variables were habitat type, vegetation coverage, tree size, and plant species. I used the Simpson Diversity Index to calculate the diversity of all my points since there were several species that were present most of the time, while the majority of the species were only recorded once or on a handful of occasions. Because I have several variables, I used AICc modeling to determine which variables had the most impact (Akaike 1974, Burnham and Anderson 2004). I used the models to compare the relative influence each combination of variables had on the abundance and diversity of avian species. I also ran a t-test to determine if the presence of slash piles affected the number of sparrows at a location.

RESULTS

Bird Surveys and Diversity.—I documented a total of 3172 individuals and 52 species across the fifteen plots between the 23 January to the 11 April 2021. There were at least four species present at each point every time I conducted a point count, so there were no points at any time where there were no birds present. The Simpson Diversity Index ranged from 0.8005 to 0.9173 across the different points (Table 1). The riparian woodland transect had the highest species diversity and evenness with a Simpson Diversity Index at 0.9256, while the suburban transect had a score of 0.9180, and the oak woodland transect had the lowest score of 0.8936.

Distribution.—The most common species was the oak titmouse (*Baeolophus inornatus*) which was recorded during 97% of all point count visits and made up 14% of all individuals counted, while the second most common species was the acorn woodpecker (*Melanerpes formicivorus*) which was recorded at 88% of all point counts and made up 14% of all recorded individuals (Table 2). Distribution among the transects varied between species, but most species, including the three most abundant which accounted for 38% of all individuals, the oak titmouse, acorn woodpecker, and dark-eyed junco (*Junco hyemalis*), were spread out among the three transects (Fig 1). However, spotted towhees (*Pipilo maculatus*), bushtits (*Psaltriparus minimus*), and ruby-crowned kinglets (*Regulus calendula*) were most common along the riparian woodland transect (Fig 2), while western bluebirds (*Sialia mexicana*), European starlings (*Sturnus vulgaris*), and white-crowned sparrows (*Zonotrichia leucophrys*) were most common along the suburban edge transect (Fig 3). I observed more white-crowned sparrows and golden-crowned sparrows (*Zonotrichia atricapilla*) at point 5 than any other point likely due to several slash piles located in the area. I counted a total of 121 white-crowned sparrows at point 5, while the second highest number of white-crowned sparrows I counted was 27 at point 9. At point 9, there was a slash pile located there when I first started collecting data, but it was removed about halfway through the study. I recorded a total of 25 white-crowed sparrows before the slash pile was removed and only two after it was removed, but likely due to a lack of data when I ran a t-test this change was insignificant (P=0.07).

Vegetation Relationship Modeling.—Using AICc modeling, there was no model that perfectly explained the diversity, species richness, or abundance of avifauna. The model that best predicted diversity was the null model, which was a model run without any cofactors. However, tree cover was also highly ranked as a potential predictor of diversity (Table 3). For the number of individuals at a site, tree cover had the highest correlation, but the null model was also highly ranked (Table 4). Finally, the number of shrub species best indicated the number of bird species at a site, but the null model and the tree cover/shrub species model were both highly ranked (Table 5).

DISCUSSION

The high Simpson Diversity Index scores across the three transects indicate a healthy and diverse avian population in the surveyed oak woodlands. The most common bird species were spread out across the three transects and did not show a preference for any specific area, nor was their distribution influenced by vegetation structure. However, the riparian woodland transect had a slightly higher diversity score, which means more species preferred the environment of that transect. Spotted towhee, which are associated with dense riparian woodlands, and bushtits, which like dense vegetation for foraging, were most abundant in the riparian woodland (Small et al. 2007). These two species as well as several other species that favored riparian habitat likely increased the diversity of this area. However, western bluebirds, which like open areas for feeding, were most common along the suburban transect where the vegetation was most open (Wightman and Germaine 2006). These results show that areas with different habitat features promote a diverse array of species.

White-crowned sparrows and golden-crowned sparrows were most associated with the two locations where there were slash piles with open areas nearby. Other studies have also found that sparrows readily use slash piles when available since they provide shelter for ground-foraging birds in open areas (Gorenzel et al. 1995). The high abundance of white-crowned sparrows at point 5, where slash piles were present throughout the study, is the reason the species evenness and diversity are much lower at this location than at any other. Slash piles can be an excellent tool for managers to promote an increase of avian use in areas that have been previously cleared of underbrush or thick vegetation, but they can also cause an imbalance in species diversity, so they should be used sparingly.

The highest-ranked model for diversity was the null model, which means that none of the cofactors modeled influenced diversity more than no cofactors at all. However, the change in AICc values between the null model and the tree cover model was less than two, so tree cover still might have an influence on diversity. Tree cover was the highest-ranked model correlated with the number of individuals found at a site, but the null model was still highly ranked with an AICc value change of less than two. This means that an increase in tree cover may have a positive influence on the diversity and abundance of birds. On the other hand, an increase in shrub species might have a positive influence on the number of species in an oak woodland habitat, but the null model and the model that combined tree cover and shrub species were also highly ranked and had a change in AICc value of less than two, so they might also have an influence on the number of species present. While tree cover and shrub species might be predictors of avian diversity, abundance, and species richness, there are likely other factors that contribute more to avian diversity and abundance than the factors I measured. While these findings do not directly support my hypothesis, it does show that tree cover is likely a contributing factor to diversity and abundance, and this is information that could be used in future restoration projects or studies.

APPLICATION OF RESULTS

There has been a large decrease in avian species in oak woodlands over the last 50 years, and areas are becoming more fragmented due to human expansion, so it is important for managers to understand how to promote diversity within restored and fragmented areas (Hunter et al. 2001, Tulloch et al. 2015). Understanding how vegetation composition and structure can support more niches and species is important for fully restoring an area since many specialists have not been able to adapt to smaller fragments of habitat as well as many generalists have been able to adapt (Leveau et al. 2019). Diversity is an important part of the health and future success of an ecosystem, and managers need to be able to successfully promote it.

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TABLES/FIGURES

Table 1. The number of individuals, the number of species, and the Simpson diversity index for each of the fifteen sites

Location	Individuals	Species	Ds
Point 1	218	23	0.9023
Point 2	266	26	0.9079
Point 3	303	24	0.91
Point 4	158	21	0.9131
Point 5	292	27	0.8005
Point 6	210	21	0.8959
Point 7	190	20	0.881
Point 8	199	20	0.8773
Point 9	183	18	0.874
Point 10	216	22	0.8692
Point 11	206	20	0.9149
Point 12	172	24	0.9143
Point 13	208	20	0.9167

Point 14	171	27	0.9173
Point 15	180	27	0.9141

Table 2. The percent occurrence and the percent of individuals recorded for the most common species

Common Name	Scientific Name	Frequency	Percent of Individuals
Oak titmouse	*Baeolophus inornatus*	97%	14%
Acorn woodpecker	*Melanerpes formicivorus*	88%	14%
Anna's hummingbird	*Calypte anna*	59%	4%
Dark-eyed junco	*Junco hyemalis*	55%	10%
California scrub-jay	*Aphelocoma californica*	50%	4%
Ruby-crowned kinglet	*Regulus calendula*	45%	3%
Northern flicker	*Colaptes auratus*	44%	3%

White-crowned sparrow	*Zonotrichia leucophrys*	41%	9%
Lesser goldfinch	*Spinus psaltria*	38%	8%
House finch	*Haemorhous mexicanus*	35%	5%
Spotted towhee	*Pipilo maculatus*	29%	3%
European starling	*Sturnus vulgaris*	29%	4%
White-breasted nuthatch	*Sitta carolinensis*	28%	2%

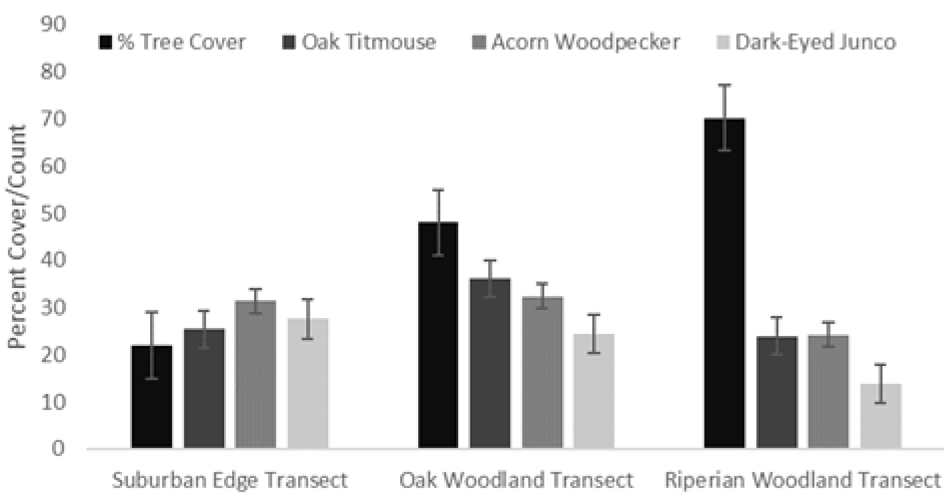

Figure 1. The abundance of the three most common avian species across the three transects compared to tree cover

Figure 2. The abundance of species that occurred most often along the riparian woodland transect compared to the other transects and tree cover

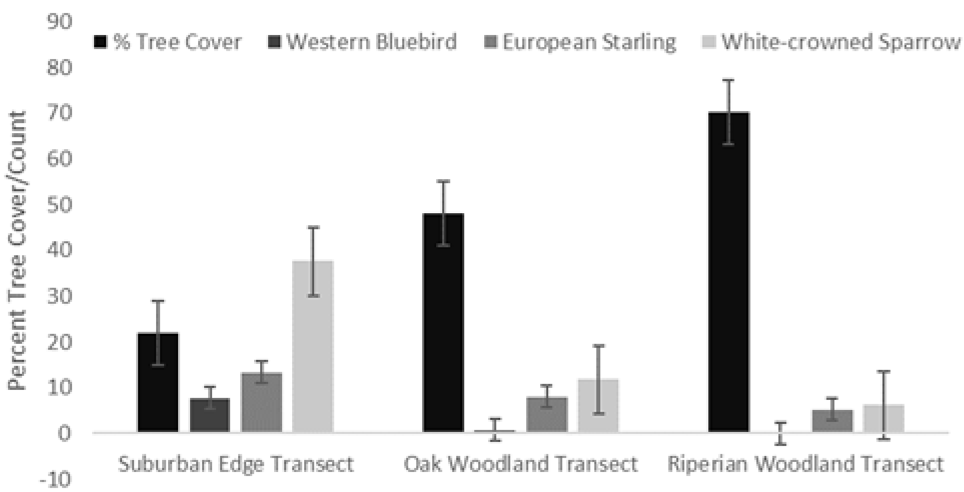

Figure 3. The abundance of species that occurred most often along the suburban edge transect compared to the other transects and tree cover

Table 3. The top four models for diversity

Model	Intercept	df	logLik	AICc	Delta	Weight
Null	0.893	2	31.368	- 57.7	0	0.418
Tree Cover	0.875	3	32.268	- 56.4	1.38	0.209
Shrub Species	0.888	3	31.514	- 54.8	2.89	0.099
Tree Species	0.887	3	31.448	-54.7	3.02	0.092

Table 4. The top four models for number individuals at a site

Model	Intercept	df	logLik	AICc	Delta	Weight
Tree Cover	245.8	3	-75.562	159.3	0	0.321
Null	211.5	2	-77.337	159.7	0.36	0.267
Shrub Cover	225.6	3	-76.644	161.5	2.16	0.109
Shrub Species	226.7	3	-76.906	162.0	2.69	0.084

Table 5. The top four models for species richness

Model	Intercept	df	logLik	AICc	Delta	Weight

Shrub Species	24.894	3	-35.211	78.6	0	0.358
Null	22.667	2	-37.325	79.6	1.05	0.212
Tree Cover and Shrub Species	23.672	4	-33.882	79.8	1.16	0.200
Shrub Cover	23.645	3	-36.642	81.5	2.86	0.085