A Multispecies Avian Abundance Analysis in Riparian and Oak Woodland Habitats on the California Central Coast

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Abstract

I investigated the abundance and diversity of riparian and oak woodland birds in a section of the Los Padres National Forest in Coastal Central California. Point counts were conducted in Oak Woodland and Riparian habitats during the summer of 2012. Point counts were replicated in time (2x) and space (25 replicates). The data were analyzed using Program Distance to correct for differing detection probabilities between species and habitat types. The two habitat types showed no significant difference in species richness. For most species, there was no difference in density between riparian and oak woodland habitats. However, the two species with significantly different densities between the habitats showed higher densities in the oak woodland habitats. Other analysis showed that seasonal behavioral changes may affect the detection probability of some, but not all, bird species over the course of the breeding season. The lack of significant differences in the densities of most species between habitats may suggest that that habitat associations in the study area were not strong or that inland birds can survive equally well in either type of habitat. If this is the case, oak woodland habitats may serve as a reservoir to maintain avian diversity in the rapidly declining riparian habitats of California.

Introduction

Little research has investigated the abundance and diversity of the birds of the California Central Coast. In the face of rampant habitat loss and destruction, introduced predators, and other threats to continued avian diversity (Gardali and Holmes, 2011), it is important to maintain a thorough record of the bird species in the area. A base-line record of the abundance and diversity of avian species in the area will allow us to track change over time and create informed and scientifically-backed land management plans in the future.

The dominant habitat types in coastal central California are coastal scrub, chaparral, oak woodland, mixed coniferous forest, and riparian. In this study, we focus on riparian and oak woodland habitats in the Los Padres National Forest. This area is a potentially important bird region since it is made up of large tracts of moderately pristine habitat on public lands (Cooper, 2004). This land is viable habitat for many bird species and may serve as resident, migrant, and wintering habitat for different species.

Riparian habitats are important for the survival and reproduction of species from many taxonomic groups. Areas with restored or undisturbed riparian habitat have been shown to support higher avian diversity than areas without active restoration activities (Gardali &Holmes, 2011). Therefore, declines in riparian habitat extent and quality in California may have a large effect on the populations of the riparian obligates and riparian breeding birds of the state. This study examines relatively intact riparian habitats on the Central Coast. The avian abundance and diversity in these habitats is quantified and compared to that of adjacent oak woodlands. If there is little difference in density of species between the oak woodland and riparian habitats in this area, then the oak woodland habitats might act as a reservoir or overflow habitat for riparian bird species in this area. Elsewhere in California, oak woodland habitat may serve to maintain some of the avian diversity from declining riparian habitats.

We hypothesized that riparian habitats would have higher species richness and diversity (richness weighted by species specific measures of abundance). Due to increased productivity, riparian habitats should have increased biomass, which leads to a more complex vegetative structure. These habitats therefore have an increased amount of microhabitats and thus can support a more diverse assemblage of birds (Khanaposhtani et al, 2012).

We also predicted that detection probability and the effective detection radius would be lower in riparian habitats since larger amounts of vegetation (i.e.: increased cover) decrease an observer's ability to visually and acoustically detect birds (Farnsworth et al 2002). Importantly, we are able ask whether riparian habitats really are more productive and diverse, or whether this impression is an artifact of differential detection probabilities in oak woodland vs. riparian habitats.

The few studies that have investigated avian diversity in California suggest that overall species abundance is declining. One study in central coastal California showed that more than half of the surveyed species had undergone population declines, more so for forest populations in California than for other surveyed locations (Ballard, 2003). Much of the riparian habitat in the state has been lost due to various types of development, resulting in a strong decline or even loss of many riparian obligate species (Gardali and Holmes, 2011). Increased avian abundance after riparian restoration indicates that this type of habitat is vital to the survival or reproduction of many species (Gardali and Holmes, 2011). Previous research indicates that riparian habitat may support more than twice the species diversity as non riparian habitat (Bureau of Land Management, 1998). In the Sacramento Valley, species diversity in riparian habitats is significantly higher than in oak woodland areas, although species richness was only slightly higher (Gaines, 1977).

It is well known that apparent abundance is a poor determinant of the true abundance of a species. Since detection probabilities vary greatly across species, sex, habitat types, season, and time of day, simple point count data do not accurately reflect the total number of individuals present in an area (Wilson and Bart, 1985). Variation in behavior, song, coloration, size, density, and many other factors allow some species to be detected more easily than others (Ralph et al, 1995). Therefore, detection probability needs to be determined for each species in order to accurately determine the density. The singing frequency and breeding behavior of a species may cause variation in detection probability over a season, typically dropping off as the season progresses due to a decrease in vocalizations (Wilson and Bart, 1985). Typically, most survey effort takes place during breeding season to eliminate the seasonal bias (Ralph et al, 1995). In some cases, song phenology is further complicated due to a density dependent response in vocalizations (Wilson and Bard, 1985), so the detection probability within a species may be different between habitat types and populations as well as over seasons. Discrepancies in detection probabilities within and among species reduce the accuracy of a simple point count in determining the abundance and density of bird species.

Program Distance adjusts density estimates by determining detection probabilities for each species. (Meredith, 2009). By using the distance of all observations from the observer, the program fits a probability of detection function to the data for each species. The program then calculates a more accurate density estimate using the detection probabilities at various distances, (Meredith, 2009).

Methods and Materials

The Hi Mountain area in the Los Padres National Forest in California was separated into the three most common vegetation types (See Bohlman, 2003). These vegetation types were riparian, oak woodland (hardwood), and chaparral. Twenty five one-hectare plots were randomly selected within each community to be sampled for representative diversity in each habitat type. Here I focus on avian diversity in 25 one-hectare plots in riparian habitat and 25 one-hectare plots in oak woodland habitat.

Each of the 25 riparian and 25 oak woodland plots were sampled using a variable circular point count approach. Each point count station was surveyed twice between June and August. Songbird surveys began at sunrise and were finished within three hours after sunrise in order to reduce bias in the point count as bird activity declined toward midday (Wilson and Bart, 1985). The day prior to the survey, the observers used a GPS to locate the exact center of each point count station. GPS coordinates for the point count stations are shown in Table 5 and a map of the area is shown in Figure 1. On the day of the survey, the observers quietly approached the survey point and stood silently for at one minute in order to reduce the effects of disturbance on the birds in the area (Ralph et al, 1995). Each point count lasted for five minutes, and every individual of each species detected during the five minutes was recorded (Ralph et al, 1995). Birds were detected visually, by call, and by song. Because the plots were surveyed using a variable distance circular point count method, all birds detected at any distance were recorded. Distance was estimated using a range finder and by the judgment of the observer. Only birds that were actually using the habitat area (to forage, display, mate, etc.) were recorded, although flyovers were also noted (Ralph et al, 1995). Birds detected in the first three minutes were distinguished on the data sheet from birds detected in the last two minutes. Two teams of observers, one team of two people and one team of three, surveyed the plots. During a point count, only one person performed the count. Each plot was surveyed once by each team in order to randomize observer bias.

Diversity was estimated through a species richness analysis for each habitat type. Each species, no matter the number of individuals, contributed equally to the diversity measurement, such that diversity in each habitat type equals the average number of species per plot. The number of species per plot was determined only for the first round of point counts. Species richness was compared between the habitats using a two-tailed T-test.

The program Distance was used to estimate 1) the density of each species 2) the detection probability per habitat and per species and 3) the effective detection radius per habitat and per species. Species with less than 30 observations were excluded from the Distance analysis due to insufficient data, but they were still included in the diversity analysis. Sixteen species had greater than 30 observations and were included. Although the data were collected by surveying 50 plots two times each, the data were analyzed by treating it as 100 separate plots in order to explicitly consider only habitat type in the models.

Two major models were compared for each species. The first model treated all observations as belonging to one population, while the second model distinguished between the observations from the riparian and the oak woodland habitats. The second set of models tested for differences in density, detection probability, and effective detection radius between habitats. Program Distance has 12 combinations of key functions and series expansions for fitting the function to the data. All

12 models were compared for three different species with very different detection patterns: Bushtits, which have soft vocalizations and are generally detected in groups, Anna's Hummingbirds, which are generally detected visually and solitarily or in pairs, and Wrentits, which are almost always detected from their loud song. Four models were selected from the 12 to be compared for all other species to determine the best fit probability of detection function for each species. The four models: half-normal and cosine, hazard-rate and cosine, uniform and cosine, and half-normal and simple polynomial, were chosen because they were the only models that fit the data for any of the trial species. AIC values were used to determine which models fit the data best. A change in AIC greater than or equal to two was regarded as a significantly better fit (Burnham &Anderson, 2002).

In order to determine if variance was increased due to the double sampling across time or seasonal behavioral changes, a model was run for the Ash-Throated Flycatcher and House Wren with only the detections from the first round of point counts. These species were chosen because they were both observed frequently over the sampling time and are primarily vocal during the breeding season, while many of the other species are resident and vocal all year. A sign test also compared the number of detections for each species in the first and second round of point counts to determine if the time element was a directional source of variation.

Results

A total of 43 species were detected over the duration of the point counts. A list of these species can be found in Table 4. Thirty-seven of these species were detected in the riparian plots, and 29 were detected in the oak woodland plots. The riparian plots had an average of 9.04 species per plot and the oak woodland habitat had an average of 8.72 species per plot. The p-value for the T-test was 0.537, indicating that there is no significant difference in species density between habitat types.

Model selection was only attempted on species with greater than 30 observations (see Methods). Only 16 of the 43 species had greater than 30 observations over the entire sampling period, and were therefore included in the Distance analysis.

The Acorn Woodpecker and the Blue-Gray Gnatcatcher were the only species where the stratified model was significantly better than the global model (ΔAIC> 2), indicating that the densities and detection probabilities between the two habitat types were significantly different (Table 2). In riparian habitats, the Acorn Woodpecker had a density of 4.16 individuals per plot and detection probability of 0.161. In oak woodland habitats, this species had density of 3.08 individuals per plot and a detection probability of 0.193. The Blue-Gray Gnatcatcher had a greater density and detection probability in the oak woodland habitat: 6.07 individuals per plot and 0.52 detection probability in oak woodland versus a density of 5.9 individuals per plot and a detection probability of 0.37 in riparian habitat.

Six species had no significant difference in AIC score (ie: ΔAIC<2) between the global and stratified models (Table 1). These species were the Anna's Hummingbird, Bushtit, Pacific Slope Flycatcher, Spotted Towhee, White-breasted Nuthatch, and Western Scrub-Jay. However, all but two of these species had a large confidence interval for the detection probability, density, or both in either the global model or one of the stratified models (the confidence intervals for the White-Breasted Nuthatch and Western Scrub-Jay appeared to be reasonable). Therefore, significant differences may exist between habitat types, but were not detected. Alternatively, variance may actually be high (rather than an artifact) because either there are no differences or no significant differences between habitats.

For eight species, the global model was significantly better than the stratified model (ΔAIC>2), indicating that there was no difference in density between habitat types. These species were the Ash-Throated Flycatcher, House Wren, Lesser Goldfinch, Mourning Dove, Northern Flicker, Nuttal's Woodpecker, Oak Titmouse, and Wrentit.

The three species that were used for model selection, the Anna's Hummingbird, Wrentit, and Bushtit, had very different detection probabilities and densities. The Anna's Hummingbird had the highest density of all species in the region, and the global and stratified models were not significantly different in fit. The density for this species was estimated at 45.4 individuals per plot for the global model or, for the stratified model, 51.92 individuals per plot in the riparian habitat and 37.49 individuals per plot in the oak woodland habitat. The confidence interval for the global model and the riparian model were both extremely large. The effective detection radius was 9.79m for the global model, or 8.25m in riparian habitat and 11.19m in oak woodland habitat. The probability of detection for this species was 0.78 for the global model. The best fit probability of distribution function for this species was the Hazard-rate, Cosine model.

The species with the highest probability of detection was the Bushtit, with values for both the stratified and global models of 1, with a confidence interval of ±0. This species had much lower density than the Anna's Hummingbird, with a global density of 8.75 individuals per plot, and an effective detection radius of 45m. The best fit probability of detection function for this species was the Uniform, Cosine model.

Wrentits were estimated to have a much lower density at 1.46 individuals per plot. This species also had the lowest detection probability of the three (0.378), but a very large effective strip width of 79.98m. The best fit probability of detection curve for this species is the Half-Normal, Simple Polynomial model.

For three species (the Bushtit, Anna's Hummingbird, and Wrentit), all 12 combinations of key functions and series expansions for fitting the function to the data were considered. Out of the 12 models, only four were determined to fit the data best, and therefore were the only combinations tested on the rest of the species. These functions were: half-normal and cosine, hazard-rate and cosine, uniform and cosine, and half-normal and simple polynomial. Five species had significantly different distribution functions when fitting the distance data to a global versus a stratified model. These species were the Northern Flicker, Ash-Throated Flycatcher, House Wren, Mourning Dove, and Pacific Slope Flycatcher. The functions selected for each model (global or stratified) are shown in Table 1. The most common probability distribution function overall was Hazard-Rate, Cosine.

Models were run only using data from the first round of point counts for the Ash-Throated Flycatcher and House Wren. These models were run to determine if the second round of point counts increased the variance for the density or detection probability estimates. These were two species where the global model had been significantly better than the stratified model when all data was included. When the second round of point count data was excluded, the stratified model was significantly better than the global model for both species. This may suggest a differential habitat use in peak breeding versus post breeding.

The sign test comparing the number of detections for each species in the first and second round of point counts showed independence between the number of detections and the time. This suggests that even though sampling occurred June-August, there was no systematic reduction in the detections or detectability of these 16 most common species.

Discussion

Two species (Acorn Woodpecker and Blue-Gray Gnatcatcher) had significantly better fit to the stratified model (different densities/detection probabilities in different habitats) than to the global model (no difference between habitats). Six species (Anna's Hummingbird, Bushtit, Pacific Slope Flycatcher, Spotted Towhee, White-breasted Nuthatch, and Western Scrub-Jay) showed no significant difference in fit between the global and stratified models. Eight species (Ash-Throated Flycatcher, House Wren, Lesser Goldfinch, Mourning Dove, Northern Flicker, Nuttal's Woodpecker, Oak Titmouse, and Wrentit) showed a significantly better fit to the global model (no difference between habitats) than the stratified model. Though one of these species (Ash-Throated

Flycatcher) shows evidence of a shift in density across time. Importantly, the community as a whole showed no directional shift in detection or density over the course of a peak-to-late-season study. The species density results are difficult to interpret due to the high amount of variation in some species, but they suggest that there is no difference in density and abundance between oak woodland and riparian habitats in this area of the Los Padres National Forest.

Overall, more species were detected in riparian habitats, but species density was not significantly different between habitat types. These results were not consistent with previous research in other areas of California, where density was considerably higher in riparian habitats (Gaines, 1977).

The Acorn Woodpecker had a higher density in riparian habitats (4.16 individuals per plot) than in oak woodland (3.08 individuals per plot), and the large number of detections for this species and low variance for the estimates lend credibility to density estimate. The Blue-Gray Gnatcatcher had only 45 detections throughout the entire study, and 69% of the observations were in riparian habitats. Although the stratified model was significantly better, the density estimates were very close between habitats. However, the detection probability and effective detection radius were higher in the oak woodland habitats. The riparian habitat had more observations but lower detection probability and detection radius, resulting in a lower density estimate in this habitat compared to the oak woodland habitat. Due to the low number of detections overall, the density estimates of 6.07 individuals per plot in oak woodland habitat and 5.9 individuals per plot in riparian habitat seems unrealistically high for this species.

For four out of six of the species with no difference in AIC score between the global and stratified models, there were very wide confidence intervals for the detection probability or density estimates. Due to these large confidence intervals, the detection curve in one habitat type fits underneath the detection curve of the other habitat type, even if the means were very different. This causes the samples to not be significantly different between habitat types. The wide range of the intervals could have resulted from large variation in the detection of individuals between plots or from insufficient data (Ralph et al, 1995). The lower limit of 30 detections per species could have been too few to obtain an accurate estimate of density or detection probability via a Distance analysis. All four of the species with no significant difference between models and with large confidence intervals (Anna's Hummingbird, Bushtit, Pacific Slope Flycatcher, and Spotted Towhee) were detected less than 50 times over the sampling period. The other two species, the White-Breasted Nuthatch and Western Scrub-Jay, had approximately 100 detections each. Neither of these species had large confidence intervals for density or detection probability. Therefore, our conclusions regarding the abundance and model selection for White-Breasted Nuthatch and Western Scrub-Jay are probably correct, while our conclusions regarding abundance and model selection for Anna's Hummingbird, Bushtit, Pacific Slope Flycatcher, and Spotted Towhee are likely compromised by sample size.

The time element may have been a source of variation for some of the species. Seasonality and varying life history traits may increase bias if point counts are not performed during breeding season (Ralph et al, 1995). Surveys were performed in the summer (peak to late breeding season), so breeding activity could have dropped off during the second round of point counts. Therefore, models were run for the Ash-Throated Flycatcher and House Wren with data only from the first round of point counts. These models both resulted in significantly better fit to the stratified (two habitat) model. This suggests that both species show differential habitat use at different times of the year. For both species, the oak woodland habitat had higher density estimates for this model. This is opposite of the expected results, since riparian habitat generally has a higher number of species overall and more migratory species (Gaines, 1977). Because of this, we would expect to see higher densities in the riparian habitat during the first round of data, and with the densities becoming more equal later in the season as species start to migrate away from the area (Gaines, 1997). For the Ash-Throated Flycatcher, the confidence intervals for the global, riparian, and oak woodland models were all lower for the model with only the first round of data than for the model with all of the data. In contrast, the confidence intervals for all three models with the first set of data only were all much larger for the House Wren than the model that included all the data. This result does not reflect the typical breeding behavior of House Wrens. Members of this species typically vocalize actively until acquiring a mate, and then drop off during the nesting period (Wilson &Bart, 1985). Therefore, the number of detections should theoretically decrease as the season progresses due to this breeding behavior, and thus the amount of variation in the density estimates should decrease if the second set of data points are excluded from the analysis. The increase in variation could be due to an insufficient amount of observations when data from the second round of point counts is excluded. The different results for the Ash-Throated Flycatcher and House Wren lead to the conclusion that time may be a source of variation for some, but not all, of the species. However, a sign test using data for all 16 species showed no correlation between the time and the number of detections per species. This suggests that the high variance in the data was random, and not due to any form of systematic variance in the data collection.

The density estimate for the Anna's Hummingbird may have been shifted artificially high in the Distance analysis. Since this species was almost always detected visually or by the sound of its flight, both of which require the observer to be close to the bird to detect it, the effective detection radius was very small. This altered the probability of detection function so that the probability of detection is very high at small distances, but drops off dramatically after 10m. This created a very high detection probability for this species, which in turn may have contributed to an overestimate of the density.

The probability of detection for Bushtits also seemed unrealistically high. This may have been due to the flocking behavior of the species. Although Bushtits were only detected at 8 plots, they were always detected in a large group. In effect, this increases the detection probability of individuals, and therefore likely caused an overestimation of the density.

In contrast, Wrentits were detected almost entirely by their distinctive, loud call and song. Unsurprisingly, this species had the highest effective detection radius, since it was easily detected from a distance.

The density and detection probability estimates for the eight species where the global model was best all appear to be robust. The confidence intervals for the density and detection probability estimates for all the species were relatively small, and based on the total number of detections for each species, none of the estimates seem unreasonable.

Several species that are not generally thought of as riparian species were commonly detected in the riparian habitat. For example, the Blue-Gray Gnatcatcher is generally considered a woodland species (Barcelo and Faaborg, 2012), but still had a high density in the riparian habitat. Conversely, the Pacific Slope Flycatcher is thought of as a riparian species (Barcelo & Faaborg, 2012), but was detected frequently in the oak woodland habitats. This species also had a high effective detection radius, suggesting that individuals may have been commonly detected far from the initial point count location. Most species had little or no difference in density between the habitat types. All of these factors suggest that the riparian survey sites may have been imbedded in a diverse matrix of oak woodland forest, so the habitat affiliations may have been weak. Since edges between habitats can create bias in regional estimates and reduce the affiliation between species and habitat (Ralph et al, 1995), the lack of significance differences between the habitat types for many species could have resulted more from high overlap in the habitat rather than species preference for a specific habitat type. To eliminate this bias, further studies could determine edge habitat and separate those areas into a third category (Ralph et al, 1995). Although the region is a matrix of oak woodland and interior riparian habitat, the species list is more typical of oak woodland habitat for both communities. This suggests that either internal riparian communities are inherently different from coastal riparian communities (previous research has detected many riparian obligate species in riparian systems around California (Gardali and Holmes, 2011)), or that habitat associations were weak in the area due to a large amount of overlap of the two habitats.

Overall, the hypothesis that diversity and abundance would be greater in riparian habitats was not supported. Although more species were detected in the riparian plots, the average density was not significantly different between habitat types. As predicted, for the two species where the stratified model was a better fit, both the detection probabilities and effective detection radii were smaller in riparian habitats. However, this was not the case for the two models run for using only data from the first round of point counts.

The lack of significant differences in density between habitat types may suggest that many riparian birds are able to survive and reproduce in oak woodland habitat. Even if there was high overlap between the riparian and oak woodland habitat in this area, many common riparian birds were still detected in the area, suggesting that riparian habitat may not be as important for their survival as previously suggested (Gardali and Holmes, 2011). Since riparian bird abundance can be used as an indicator of the health of the ecosystem (Bureau of Land Management, 1998), the lack or low density of riparian obligates such as warblers, Warbling Vireos, and Song Sparrows may suggest that this section of riparian habitat may not have been optimal habitat for riparian dependent species. Conversely, the area may contain optimal habitat, but may be unoccupied for other reasons, including avian social behavior or population distribution (Ahlering & Faaborg, 2006).

In conclusion, oak woodlands may serve to maintain some of the avian diversity that is generally found in riparian zones as riparian habitat elsewhere in California continues to decline. Therefore, conservation efforts should be directed first toward riparian habitats, but also toward oak woodland habitats in order to maintain high avian diversity in California.

Tables and Figures:

Figure 1: A map of the 25 oak woodland and 25 riparian locations that were surveyed for avian diversity using point count methodology. This map shows a region of the Los Padres National Forest outside of Pozo, CA.

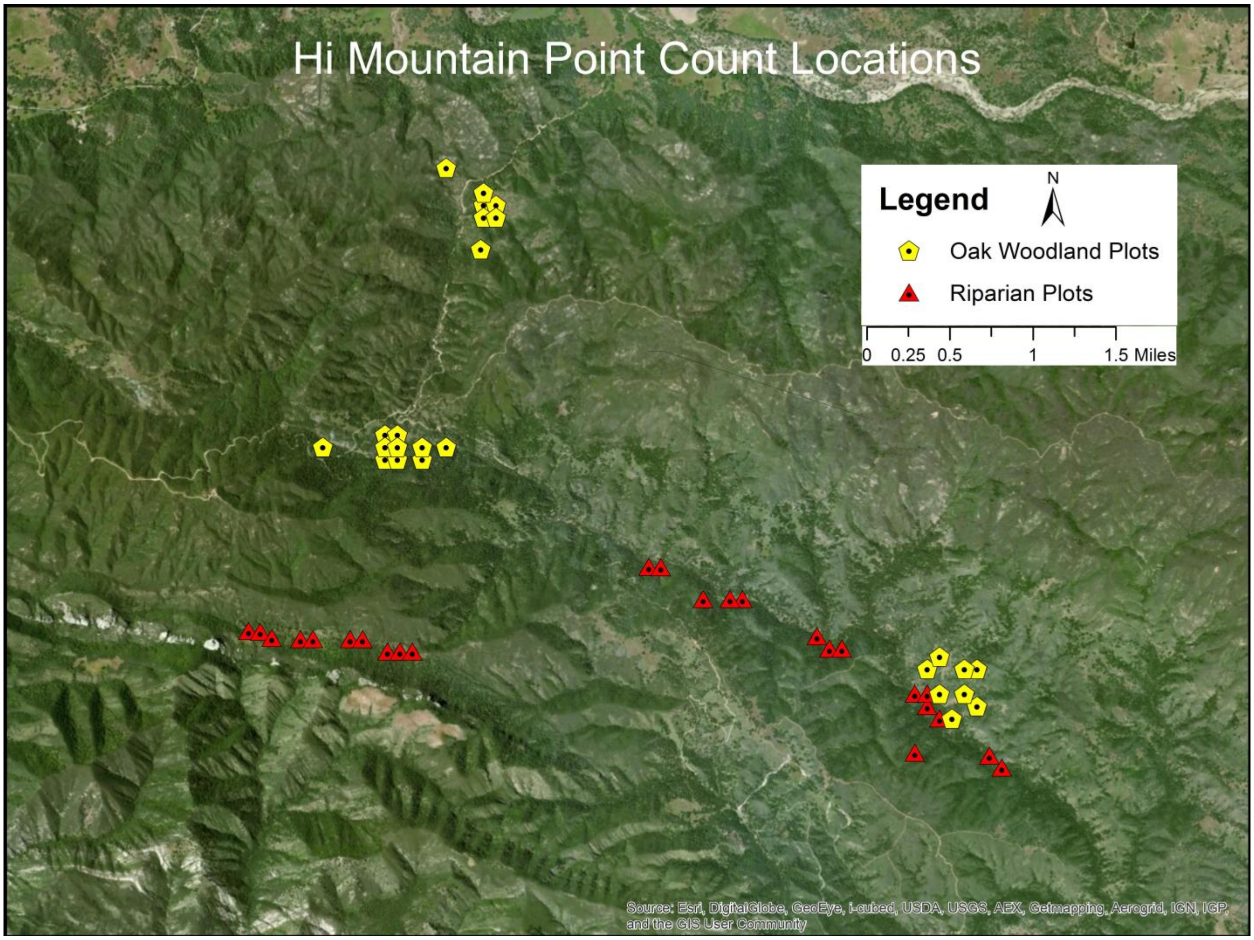

Table 1: The best fit probability of distribution function for each species. Results for all four functions that were tested for each species are shown, with the best fit function in bold. For species where the best fit function differed between the global and stratified models, the results for the four stratified functions are also shown. In cases where there were no significant differences between models, the model with the lowest AIC score was used.

Species	Layer	Model	AIC	Delta AIC
ACWO	Global	Half normal, Simple polynomial	1885.91	
ACWO	Global	Uniform, cosine	1869.58	16.33
ACWO	Global	Half normal, cosine	1862.8	6.78
ACWO	**Global**	**Hazard-rate, cosine**	**1850.3**	12.5

ANHU	Global	Half normal, Simple polynomial	287.35	
ANHU	Global	Half normal, cosine	286.25	1.1
ANHU	Global	Uniform, cosine	285.11	1.14
ANHU	**Global**	**Hazard-rate, cosine**	**278.67**	6.44
ATFL	Global	Half normal, Simple polynomial	1124.16	
ATFL	Global	Half normal, cosine	1119.42	4.74
ATFL	Global	Hazard-rate, cosine	1115.87	3.55
ATFL	**Global**	**Uniform, cosine**	**1115.85**	0.02
BGGN	Global	Half normal, Simple polynomial	322.54	
BGGN	Global	Uniform, cosine	318.89	3.65
BGGN	Global	Half normal, cosine	316.73	2.16
BGGN	**Global**	**Hazard-rate, cosine**	**311.07**	5.66
BUSH	Global	Hazard-rate, cosine	276.12	
BUSH	Global	Half normal, cosine	274.12	2
BUSH	Global	Half normal, Simple polynomial	274.12	0
BUSH	**Global**	**Uniform, cosine**	**272.12**	2
HOWR	Global	Half normal, Simple polynomial	760.88	
HOWR	Global	Hazard-rate, cosine	758.84	2.04
HOWR	Global	Half normal, cosine	758.68	0.16
HOWR	**Global**	**Uniform, cosine**	**756.33**	2.35
HOWR	Stratified	Half normal, Simple polynomial	762.66	
HOWR	Stratified	Hazard-rate, cosine	761.95	0.71
HOWR	Stratified	Half normal, cosine	758.9	3.05
HOWR	**Stratified**	**Uniform, cosine**	**758.33**	0.57
LEGO	Global	Uniform, cosine	1129.24	
LEGO	Global	Half normal, Simple polynomial	1128.34	0.9
LEGO	Global	Half normal, cosine	1113.24	15.1
LEGO	**Global**	**Hazard-rate, cosine**	**1099.87**	13.37
MODO	Global	Half normal, cosine	781.43	
MODO	Global	Hazard-rate, cosine	773.45	7.98
MODO	Global	Uniform, cosine	763.56	9.89
MODO	**Global**	**Half normal, Simple polynomial**	**757.91**	5.65
MODO	Stratified	Half normal, cosine	772.69	
MODO	Stratified	Half normal, Simple polynomial	772.69	0
MODO	Stratified	Hazard-rate, cosine	768.97	3.72
MODO	**Stratified**	**Uniform, cosine**	**762.43**	6.54
NOFL	Global	Half normal, cosine	333.58	
NOFL	Global	Half normal, Simple polynomial	333.58	0
NOFL	Global	Uniform, cosine	326.93	6.65
NOFL	**Global**	**Hazard-rate, cosine**	**325.82**	1.11
NOFL	Stratified	Half normal, cosine	335.49	
NOFL	Stratified	Half normal, Simple polynomial	335.49	0
NOFL	Stratified	Uniform, cosine	330.05	5.44

NOFL	**Stratified**	**Hazard-rate, cosine**	**329.75**	0.3
NUWO	Global	Half normal, Simple polynomial	713.96	
NUWO	Global	Half normal, cosine	708.02	5.94
NUWO	Global	Uniform, cosine	705.78	2.24
NUWO	**Global**	**Hazard-rate, cosine**	**701.01**	4.77
OATI	Global	Half normal, Simple polynomial	1098.63	
OATI	Global	Uniform, cosine	1093.14	5.49
OATI	Global	Half normal, cosine	1092.42	0.72
OATI	**Global**	**Hazard-rate, cosine**	**1076.21**	16.21
PSFL	Global	Half normal, cosine	374.06	
PSFL	Global	Half normal, Simple polynomial	374.06	0
PSFL	Global	Hazard-rate, cosine	372.97	1.09
PSFL	**Global**	**Uniform, cosine**	**372.88**	0.09
PSFL	Stratified	Half normal, cosine	375.33	
PSFL	**Stratified**	Half normal, simple polynomial	375.33	0
PSFL	Stratified	Uniform, cosine	373.97	1.36
PSFL	**Stratified**	**Hazard-rate, cosine**	**372.71**	1.26
SPTO	Global	Half normal, Simple polynomial	326.76	
SPTO	Global	Half normal, cosine	326.64	0.12
SPTO	Global	Uniform, cosine	323.27	3.37
SPTO	**Global**	**Hazard-rate, cosine**	**320.85**	2.42
WBNU	Global	Uniform, cosine	952.29	
WBNU	Global	Half normal, cosine	923.63	28.66
WBNU	Global	Half normal, Simple polynomial	920.02	3.61
WBNU	**Global**	**Hazard-rate, cosine**	**915.37**	4.65
WESJ	Global	Half normal, cosine	958.37	
WESJ	Global	Half normal, Simple polynomial	958.37	0
WESJ	Global	Uniform, cosine	948.13	10.24
WESJ	**Global**	**Hazard-rate, cosine**	**937.74**	10.39
WREN	**Global**	Half normal, cosine	2059.34	
WREN	**Global**	Hazard-rate, cosine	2030.78	28.56
WREN	**Global**	Uniform, cosine	2005.68	25.1
WREN	**Global**	**Half normal, Simple polynomial**	**2003.47**	2.21

Table 2: The detection probability, effective detection radius, and density for each species. For species where the global model was best fit, simple estimates are shown. For species where the stratified model was best fit, result are shown for both riparian and oak woodland types. For species where the global and stratified models were not significantly different, results for both models are shown.

			Detection Probability				**Density**		
Species	**Habitat Type**	**AIC**	**Estimate**	**Lower Critical Limit**	**Upper Critical Limit**	**Effective Detection Radius**	**Estimate**	**Lower Critical Limit**	**Upper Critical Limit**
ATFL	Global	1115.85	0.502	0.31	0.81	44.29	3.159	2.175	5.69
HOWR	Global	756.33	0.312	0.29	0.34	35.08	6.21	5.61	6.87
LEGO	Global	1099.87	0.095	0.079	0.11	40	5.011	4.177	6.012
MODO	Global	757.91	0.28	0.089	0.89	68.8	1.362	0.432	4.294
NOFL	Global	325.82	0.18	0.12	0.27	55.48	1.47	0.99	2.18
NUWO	Global	701.01	0.12	0.088	0.15	44.32	2.373	1.82	3.1
OATI	Global	1076.21	0.26	0.22	0.32	32.47	7.589	6.257	0.9227
WREN	Global	2003.47	0.378	0.199	0.72	79.98	1.459	0.77	2.77
ACWO	Oak woodland	1846.48	0.193	0.14	0.25	57.22	3.08	2.29	4.16
	Riparian		0.161	0.14	0.19	52.26	4.16	3.46	5.01
BGGN	Oak woodland	306.87	0.52	0.33	0.79	32.37	6.07	3.9	9.45
	Riparian		0.37	0.09	1	27.47	5.9	1.47	23.6
ANHU	Global	278.67	0.78	0.018	0.337	9.79	45.4	10.5	195.8
	Oak woodland	277.6	0.102	0.022	0.46	11.19	37.49	8.1	17.2
	Riparian		0.556	0.003	0.96	8.25	51.92	3.01	8.95
BUSH	Global	272.12	1	1	1	45	8.75	6.29	12.18
	Oak woodland	272.12	1	1	1	45	7.33	1.15	46.9
	Riparian		1	1	1	45	9.82	5.2	18.2
PSFL	Global	372.97	0.41	0.32	0.53	40	4.065	3.124	5.289
	Oak woodland	372.71	0.37	0.28	0.49	38.05	4.73	3.55	6.3
	Riparian		0.61	0.04	1	48.84	1.78	0.12	26.1
SPTO	Global	320.85	0.303	0.21	0.43	48.19	1.909	1.35	2.701
	Oak Woodland	322.22	0.22	0.12	0.41	41.27	2.59	1.39	4.8
	Riparian		0.34	0.23	0.52	51.22	1.7	1.12	2.58
WBNU	Global	915.37	0.11	0.086	0.137	42.9	3.33	2.646	4.206
	Oak woodland	915.2	0.12	0.08	0.18	44.31	2.8	1.81	4.31
	Riparian		0.12	0.09	0.15	44.38	3.47	2.71	4.44
WESJ	Global	937.74	0.16	0.13	0.2	52.12	2.55	2.031	3.214
	Oak woodland	939.14	0.21	0.13	0.35	59.75	1.16	0.7	1.92
	Riparian		0.14	0.11	0.18	49.13	3.65	2.79	4.77

Table 3: The density, detection probability, and effective detection radius estimates for Ash-Throated Flycatchers and House Wrens using only data collected during the first round of point counts. The estimates for both species using data for both rounds of point counts are shown for comparison. AIC scores are only comparable between models that use the same data, so the models for first round or both rounds can only be compared via the detection probability, detection radius, and density estimates, and not the AIC scores.

				Detection Probability				Density		
Species	Time	Habitat Type	AIC	Estimate	Lower Critical Limit	Upper Critical Limit	Effective Detection Radius	Estimate	Lower Critical Limit	Upper Critical Limit
ATFL	First round only	Global	555.17	0.27	0.21	0.33	45.07	3.18	2.51	4.028
		Oak woodland	547.05	0.2	0.14	0.28	39.28	4.52	3.15	6.47
		Riparian		0.33	0.22	0.47	49.92	2.26	1.54	3.32
ATFL	Both rounds	Global	1115.85	0.502	0.31	0.81	44.29	3.159	2.175	5.69
HOWR	First round only	Global	277.85	0.54	0.36	0.81	33.3	6.059	3.99	9.19
		Oak Woodland	273.77	0.35	0.11	1	26.63	8.97	2.88	27.94
		Riparian		0.69	0.42	1	37.39	4.93	2.84	8.57
HOWR	Both rounds	Global	756.33	0.312	0.29	0.34	35.08	6.21	5.61	6.87

Table 4: A list of all the species detected in riparian and oak woodland habitats during the surveys.

- Acorn Woodpecker
- American Goldfinch
- American Robin
- Anna's Hummingbird
- Ash-Throated Flycatcher
- Bewick's Wren
- Blue-Gray Gnatcatcher
- Brown-Headed Cowbird
- Black Phoebe
- Bushtit
- California Towhee
- California Quail
- Chestnut-Backed Chickadee
- Cliff Swallow
- Common Raven
- Dark-Eyed Junco
- Hairy Woodpecker
- House Finch
- House Wren
- Hutton's Vireo
- Lawrence's Goldfinch
- Lesser Goldfinch
- Mourning Dove
- Northern Flicker
- Nuttal's Woodpecker
- Oak Titmouse
- Pacific Slope Flycatcher
- Purple Finch
- Red-Shouldered Hawk
- Red-Tailed Hawk
- Song Sparrow
- Spotted Towhee
- Stellar's Jay
- Tree Swallow
- Turkey Vulture
- Warbling Vireo
- White-Breasted Nuthatch
- Western Tanager
- Western Wood Pewee
- Wild Turkey
- Wrentit
- Western Scrub-Jay
- White-Throated Swift

Table 5: The geographic coordinates for the riparian and oak woodland plots.

Riparian Coordinates		Oak Woodland Coordinates	
Latitude	Longitude	Latitude	Longitude
35 15.004	120 25.337	35 14.683	120 21.530
35 15.000	120 25.275	35 14.842	120 21.790
35 14.974	120 25.214	35 14.736	120 21.725
35 15.141	120 22.755	35 14.736	120 21.595
35 15.141	120 22.960	35 14.895	120 21.725
35 15.141	120 22.820	35 14.842	120 21.530
35 14.982	120 22.365	35 14.842	120 21.595
35 14.929	120 22.300	35 14.630	120 21.660
35 14.929	120 22.235	35 16.829	120 24.108
35 15.278	120 23.244	35 16.829	120 24.043
35 15.276	120 23.181	35 16.988	120 24.303
35 14.915	120 24.611	35 16.640	120 24.124
35 14.915	120 24.546	35 16.776	120 24.108
35 14.915	120 24.481	35 16.776	120 24.043
35 14.968	120 25.066	35 16.882	120 24.108
35 14.968	120 25.001	35 15.740	120 24.624
35 14.968	120 24.806	35 15.740	120 24.559
35 14.968	120 24.741	35 15.740	120 24.429
35 14.471	120 21.465	35 15.846	120 24.624
35 14.736	120 21.855	35 15.846	120 24.559
35 14.683	120 21.790	35 15.793	120 24.949
35 14.418	120 21.400	35 15.793	120 24.624
35 14.736	120 21.790	35 15.793	120 24.559
35 14.630	120 21.725	35 15.793	120 24.429
35 14.482	120 21.855	35 15.793	120 24.303

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