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RESEARCH ARTICLE

Summer vs. winter: Examining the temporal distribution of avian biodiversity to inform conservation

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ABSTRACT

Winter habitat quality plays a key role in avian population regulation, and conservation of winter habitat is a priority for waterfowl, shorebirds, and Neotropical migrant landbirds. Yet, there has been little discussion of the importance of conserving temperate wintering habitat for landbirds, including the billions of Neotemperate migratory landbirds that winter in the United States. The value and impact of conservation initiatives in the U.S. could be maximized by accommodating the habitat requirements of bird communities throughout the full annual cycle, particularly in the southern and western U.S. where winter species richness is concentrated. To estimate the degree to which winter bird communities should be a conservation priority, we examined the temporal distribution of avian diversity using riparian habitat in the lower Cosumnes River and lower Putah Creek watersheds in California's Central Valley. We used hierarchical multispecies occupancy models to estimate seasonal species richness and phylogenetic diversity in each watershed. We found that total species richness was equally as high in winter as in summer, and that phylogenetic diversity was higher in winter, with a considerable proportion of the winter avian diversity attributable to boreal-breeding Neotemperate migrants. Our results provide evidence that maintaining and restoring high-quality riparian habitat for winter bird communities in California is an important conservation opportunity. Broader recognition of the diversity of temperate winter bird communities and additional research into the factors affecting body condition and survival would facilitate effective conservation of high-quality winter habitat, benefiting Neotemperate migrants and year-round residents during a season that can have important impacts on their population dynamics.

Keywords: biodiversity conservation, phylogenetic diversity, species richness, Neotemperate migrant, winter, riparian, California

Verano vs. invierno: Examinando la distribución temporal de la diversidad de aves para planificar la conservación

RESUMEN

La calidad de los hábitats de invierno juega un rol clave en la regulación de las poblaciones de aves, y la conservación de los hábitats de invierno es una prioridad para las aves acuáticas, las aves playeras y las aves terrestres migratorias neotropicales. A pesar de esto, ha habido poca discusión sobre la importancia de conservar los hábitats templados de invernada para las aves terrestres, incluyendo los miles de millones de aves terrestres migratorias neotempladas que invernan en los Estados Unidos. El valor y el impacto de las iniciativas de conservación en los EEUU podrían maximizarse si se acomodaran los requerimientos de hábitat de las comunidades de aves a lo largo del ciclo anual completo, particularmente en las comunidades del sur y del oeste de EEUU donde se concentra la riqueza de especies de invierno. Para estimar el grado de prioridad de conservación de las comunidades de aves de invierno, examinamos la distribución temporal de la diversidad de aves usando los hábitats ribereños en las cuencas bajas del Río Cosumnes y del Arroyo Putah en el Valle Central de California. Usamos modelos de ocupación jerárquicos multiespecíficos para estimar la riqueza estacional de especies y la diversidad filogenética en cada cuenca. Encontramos que la riqueza total de especies fue igual de alta en invierno que en verano, y que la riqueza filogenética fue más alta en invierno, con una proporción considerable de la diversidad de aves de invierno atribuible a los migrantes neotemplados que crían en el norte. Nuestros resultados ponen en evidencia que mantener y restaurar hábitat ribereño de alta calidad para las comunidades de aves de invierno en California representa una oportunidad importante de conservación. Un mayor reconocimiento de la diversidad de las comunidades de aves de invierno de las áreas templadas e investigación adicional de los factores que afectan la condición corporal y la supervivencia facilitarían la conservación efectiva de los hábitats de invierno de alta calidad, beneficiando a los migrantes neotemplados y a los residentes durante la estación invernal, con potenciales impactos importantes en la dinámica poblacional de estas especies.

Palabras clave: California, conservación de la biodiversidad, diversidad filogenética, invierno, migrante neotemplado, ribereño, riqueza de especies

INTRODUCTION

Winter habitat quality plays a key role in regulating avian populations, affecting body condition, survival rates, migration timing, and reproductive success across taxa (Raveling and Heitmeyer 1989, Holmes et al. 1996, Sherry and Holmes 1996, Saino et al. 2004, Burton et al. 2006, Norris and Marra 2007). Consequently, North American bird conservation plans recognize the importance of conserving and managing temperate wintering habitat for waterfowl and shorebirds (Brown et al. 2000, NAWMP 2012) and tropical wintering habitat for Neotropical migratory landbirds (Berlanga et al. 2010). There has been surprisingly little discussion of the importance of conserving and managing temperate wintering habitat for landbirds, however, including Neotemperate migratory landbirds, which breed in the boreal region and winter in the U.S. and/or southern Canada.

Although the boreal forest has been called a “Neotropical migrant factory” (Rich et al. 2004), more boreal-breeding species winter in temperate latitudes, especially in the U.S. and southern Canada (Blancher and Wells 2005). These Neotemperate migrants represent billions of individual birds that can make up a large proportion of winter bird communities in the U.S. (Robertson et al. 2011). Although they breed in one of the largest and most intact habitats in the world, many of these species are in decline (Berlanga et al. 2010, Wells et al. 2014). For example, Breeding Bird Surveys in the Boreal Hardwood Transition ecoregion indicate significant negative trends for 49% of migratory species between 1966 and 2012 (Sauer et al. 2014). Thus, winter habitat quality and quantity are likely important factors in these declines. Further, accelerating rates of development and climate change in the boreal region increase the likelihood of future declines and are an area of growing conservation concern (Virkkala et al. 2008, Wells et al. 2014). Maintaining and restoring high-quality winter habitat for Neotemperate migratory landbirds is therefore an important research and conservation need.

Research over the full annual cycle of migratory birds has proven a valuable approach for identifying seasonal limiting factors and prioritizing conservation efforts (Faaborg et al. 2010). Similarly, research over the full annual cycle of an individual ecosystem or management area could prove valuable in identifying seasonal habitat needs, prioritizing conservation efforts, and maximizing the impact of a local or regional conservation plan. This approach may be especially important in regions where winter species richness is concentrated, including the southern and western U.S. (Rich et al. 2004). For example, the conservation and restoration of riparian habitat is a high priority in California (Knopf et al. 1988, Rich 2002, RHJV 2004), in part because of its importance to wildlife (Gaines 1977, Knopf et al. 1988) and the high densities of breeding birds found there (Knopf and Samson 1994, Ohmart 1994). Evaluating restoration success by

monitoring the response of the breeding bird community is widely recommended (Rich 2002, Gardali et al. 2006, Ortega-Álvarez and Lindig-Cisneros 2012, Young et al. 2013), yet the responses of winter bird communities to riparian restoration are rarely studied (but see Queheillalt and Morrison 2006, Golet et al. 2011, Latta et al. 2012). Thus, it is unclear to what extent current conservation practices and restoration designs are meeting the needs of winter bird communities, or to what degree the value of these restoration projects could be increased by making the needs of winter bird communities a priority.

We propose that seasonal conservation priorities can be identified by examining the temporal distribution of biodiversity at a site over the full annual cycle. This approach is analogous to setting spatial conservation priorities by identifying areas that support high levels of biodiversity (i.e. biodiversity hotspots; Myers et al. 2000). To identify seasons during which riparian ecosystems support high levels of biodiversity, we used hierarchical multi-species occupancy models to compare the species richness and phylogenetic diversity of the summer and winter bird communities in 2 watersheds in California’s Central Valley. While we expected both measures of diversity to be higher in summer, we also expected to observe considerable levels of both species and phylogenetic diversity in winter, indicating that the value of riparian habitat conservation projects in California could be increased by incorporating the needs of winter bird communities into their designs.

METHODS

Study Site and Data Collection

We conducted strip transect surveys for birds in the lower Cosumnes River and lower Putah Creek watersheds, located in California’s Central Valley (Figure 1). Putah Creek is a heavily impacted riparian system, with 2 dams, a deeply-incised creek channel, and a narrow riparian forest, while the Cosumnes River is the only major free-flowing river remaining in California; it has a much broader riparian forest and is considered to be a relatively intact riparian ecosystem. Surveys were distributed over 14 sites along Putah Creek beginning in 2004 and 10 sites along the Cosumnes River beginning in 2006, continuing through 2012. No surveys were conducted in the Cosumnes River watershed during the breeding season of 2006 due to extreme flooding. During each 45-minute survey, trained observers walked a 500 m transect paralleling the waterway, tallying the number of individuals of each species detected within 30 m of the transect line (Ralph et al. 1993, Bibby et al. 2000). Surveys were not conducted under adverse weather conditions (i.e. rain or high winds). Barring flooding and access constraints, generally one survey was conducted per site in each of the winter (1 January–29 February) and summer seasons

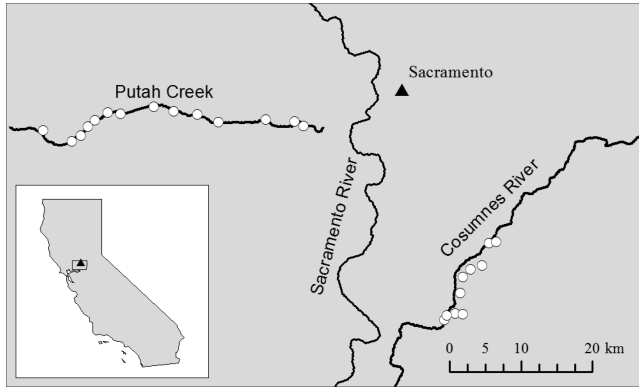


FIGURE 1. Putah Creek and Cosumnes River study areas in the Central Valley of California, showing the 24 study sites.

(1 April–30 June) in each year. To minimize effects of time of day, summer surveys were completed by 0930 hours; however, time of day restrictions were relaxed for winter surveys due to reduced bird activity during cold mornings. For this analysis, we excluded surveys conducted in April to minimize the number of transient individuals detected on spring migration and to make the 2 survey seasons of comparable length.

We assigned each species to 1 of 3 groups: primarily summer visitors, winter visitors, or year-round residents. We also determined the extent to which each winter visitor species was known to breed in the boreal forest (Wells and Blancher 2011) and compiled continent-wide population trends from Breeding Bird Survey data, 1966–2012 (Sauer et al. 2014). Finally, as a measure of phylogenetic diversity, we compiled evolutionary distinctness (ED) scores for each species as reported in Jetz et al. (2014), which represent how isolated a species is on its phylogenetic tree. Species with few close relatives have higher ED scores and may be considered more valuable in that they represent a larger share of avian evolutionary history. Examining variation in phylogenetic diversity provides an alternative method to species richness for identifying biodiversity hotspots (Jetz et al. 2014).

Hierarchical Multispecies Occupancy Modeling

Making use of repeated surveys at each site, occupancy models can be used to estimate the probability of a species' presence at a site while accounting for variation in detection probabilities (Dorazio et al. 2011). In hierarchical multispecies occupancy models, all species are combined into a single model in which detection and occupancy probabilities for each species are assumed to come from a common distribution. Further, they can be used to generate unbiased estimates of species richness for each site or groups of sites, including hypothetical species that have not yet been detected (Dorazio et al. 2011, Iknayan et al. 2014). We fit a hierarchical multispecies occupancy model that allowed occupancy to differ by season and

watershed. Because we were primarily interested in the differences across seasons, we treated the 24 sites in each season as 48 independent sites, allowing the true occupancy status of each species in each site-season to be estimated separately. We also assumed there was no change in the true occupancy status of each species in each site-season across years, and we treated repeated transects in the same site-season across years as our replicate visits.

We used a model structure recently described in detail by Iknayan et al. (2014). The observed presence or absence of each species i in site j on survey replicate k (y_{ijk}) was modeled as resulting from the true occupancy status of each species in each site (Z_{ij}) with imperfect detection (p_i): $y_{ijk} \sim \text{Bernoulli}(p_i Z_{ij})$, where $Z_{ij} = 1$ or 0 if species i in site j is truly present or absent, respectively. True occupancy (Z_{ij}) was modeled as resulting from the probability of occupancy by each species in each site-season (ψ_{ij}) and the existence of the species in the region (w_i): $Z_{ij} \sim \text{Bernoulli}(\psi_{ij} w_i)$, where $w_i = 1$ for all observed species. To account for unobserved species, we augmented the observed data with 100 hypothetical species with all zero encounter histories, which were modeled as existing in the community with probability Ω : $w_i \sim \text{Bernoulli}(\Omega)$. The model can estimate how many of these species are present but never detected on any surveys, analogous to the asymptote of a species-accumulation curve (Yamaura et al. 2011, Iknayan et al. 2014). An arbitrarily large number of hypothetical species must be chosen to ensure that it exceeds the posterior estimate of the number of unobserved species (Dorazio et al. 2006).

We modeled the species-specific probability of occupancy in each site (ψ_{ij}) as a linear function of season and watershed:

$$\text{logit}(\psi_{ij}) = b_{0,i} + b_{1,i} \text{season}_j + b_{2,i} \text{watershed}_j + b_{3,i} \text{season}_j \text{watershed}_j.$$

The indicator variable $\text{season}_j = 1$ if site j was in the summer and $\text{watershed}_j = 1$ if j was in the lower Cosumnes River watershed, and 0 otherwise. Thus b_1 , b_2 , and b_3 represent the seasonal and watershed differences in occupancy probability, and this model structure allowed us to identify species with higher occupancy probabilities during summer in the lower Putah Creek watershed ($b_{1,i} > 0$) or the lower Cosumnes River watershed ($b_{1,i} + b_{3,i} > 0$), or vice versa for winter. Similarly, we modeled the species-specific probability of detection in each site on each survey replicate (p_{ijk}) as a linear function of season and resident status:

$$\text{logit}(p_{ijk}) = a_{0,i} + a_{1,i} \text{resident}_i \text{season}_j.$$

We expected detection probability to vary seasonally for year-round resident species that both breed and overwinter locally due to changes in behavior, but we did not expect detection probability to vary seasonally for winter

visitors that linger into the spring. We also considered all unobserved, hypothetical species to be potential resident species, allowing the detection probability of missed species to vary by season. Thus, the indicator variable $resident_i = 1$ if species i was a year-round resident or hypothetical species, and 0 otherwise. Each a_i and b_i is a species-specific estimate assumed to come from a community-level distribution of occupancy or detection probabilities, equivalent to a random effect of species (Yamaura et al. 2011, Iknayan et al. 2014). Each observed species informs the mean and variance of those community-level distributions, allowing occupancy and detection probabilities of the unobserved, hypothetical species to be estimated (Iknayan et al. 2014).

We also specified in the model several metrics of species richness and phylogenetic diversity derived directly from the species-specific estimates of true occupancy at each site-season (Z_{ij}) in each iteration of the model, allowing incorporation of estimation error. For species richness (subscript s), these metrics included local species richness (α_s), defined as the total number of observed and hypothetical species present at each site, and mean local species richness ($\bar{\alpha}_s$), defined as the mean number of observed and hypothetical species present across sites in each season, overall and within each watershed. Regional species richness (γ_s) was defined as the total number of observed and hypothetical species present overall and within each watershed, and the turnover in species richness (β_s) was defined as the ratio of γ diversity to mean α diversity overall and within each watershed ($\beta_s = \gamma_s / \bar{\alpha}_s$). Similarly, we calculated each of these metrics for phylogenetic diversity (subscript p : α_p , γ_p , and β_p) for each season and watershed based on the total ED of all observed species. We did not include unobserved species in the metrics of phylogenetic diversity because there was no clear way to estimate the ED of unobserved species.

We used JAGS 3.4.0 (Plummer 2003) and the R package R2jags 0.04-01 (R Core Team 2014, Su and Yajima 2014) to fit the model using Markov Chain Monte Carlo (MCMC). We used uninformative priors for the means and variances of the community-level distributions of each a and b in the model. To ensure convergence, even for species with very few detections, we ran 3 chains of 120,000 iterations, discarding the first 100,000 iterations and thinning the remainder by 20, resulting in 3,000 iterations used for inference. We assessed convergence using the Gelman-Rubin diagnostic (\hat{R}), and for all parameters $\hat{R} < 1.1$, indicating convergence (Gelman and Rubin 1992). We considered there to be a significant difference between seasonal community parameters if the 95% credible interval for the difference in the parameters did not overlap zero. All values reported in the Results section are posterior means followed by 95% credible intervals.

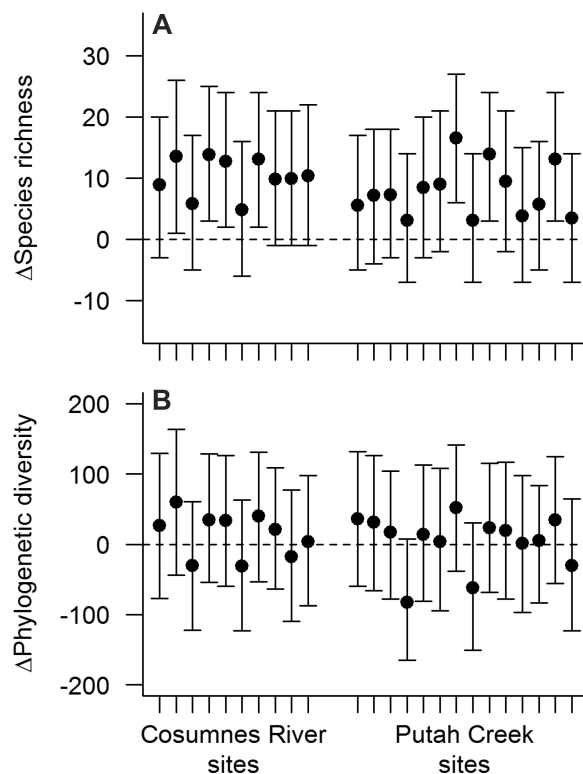


FIGURE 2. Mean and 95% credible intervals for seasonal differences in (A) species richness and (B) phylogenetic diversity at individual sites in the lower Cosumnes River and lower Putah Creek watersheds. A positive difference indicates higher richness or diversity in summer.

RESULTS

The final dataset included 315 surveys, with 41 summer and 66 winter surveys in the lower Cosumnes River watershed and 93 summer and 115 winter surveys in the lower Putah Creek watershed, on which we detected 138 total species (Appendix Table 1). Local species richness (α_s) was significantly higher in summer for 6 of the 10 Cosumnes River sites and 2 of the 14 Putah Creek sites; no sites had higher species richness in winter (Figure 2). Mean species richness across sites ($\bar{\alpha}_s$) was significantly higher in summer (83.8, 74.4–95.1) than winter (74.5, 66.2–84.4) overall and within each watershed (Figure 3), with a mean of 8.8 (1.7–16.4) more species per site. However, we found no significant difference between total species richness (γ_s) in summer (124.1, 115–138) and winter (129.6, 117–146) overall, or within either watershed. Consequently, the ratio of total to local species richness (β_s) was significantly higher in winter (1.74, 1.59–1.90) than summer (1.48, 1.37–1.62), both overall and within each watershed.

Despite significant seasonal differences in species richness at the site level, we found no significant seasonal differences in local phylogenetic diversity (α_p) at any individual site (Figure 2). There were also no significant

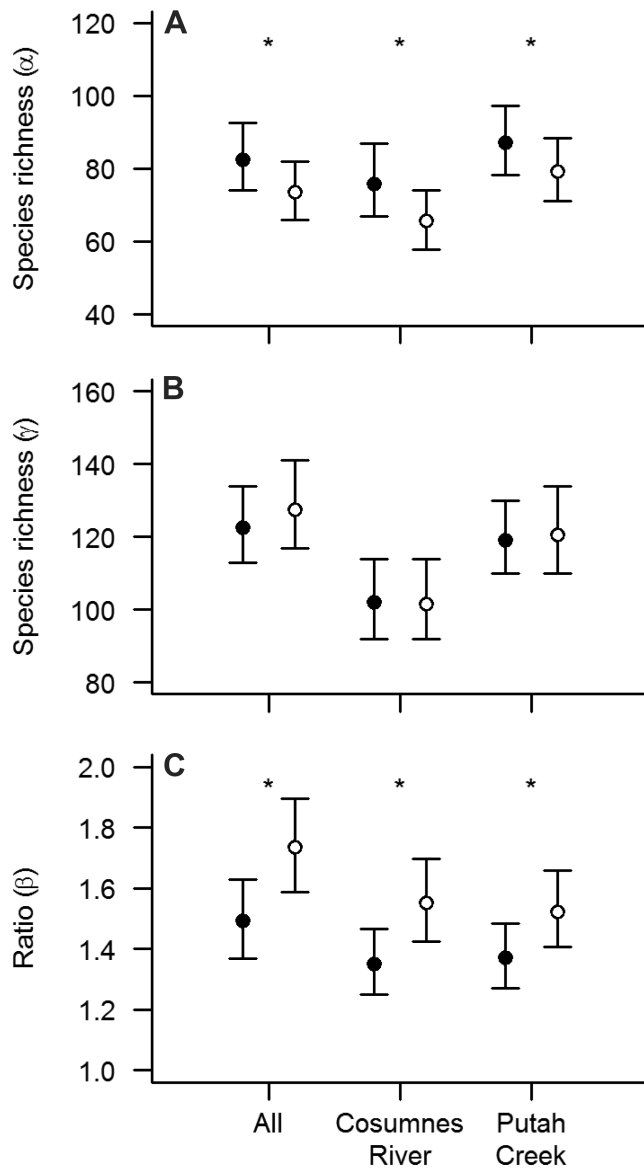


FIGURE 3. Species richness of summer (filled) and winter (open) communities, overall and within each watershed. Mean and 95% credible intervals for each metric are shown. (A) Mean species richness across sites ($\bar{\alpha}_s$). (B) Total species richness across sites (γ_s). (C) Ratio of total to site species richness (β_s). *95% credible intervals for the difference between seasons do not overlap zero.

differences between mean phylogenetic diversity across sites ($\bar{\alpha}_p$) in summer (506.0, 455.9–562.7) and winter (495.5, 447.8–549.2), either overall or within each watershed (Figure 4). However, total phylogenetic diversity (γ_p) across all sites was significantly higher in winter (855.2, 821.9–891.6) than summer (759.7, 724.8–825.5), and the ratio of total to local phylogenetic diversity (β_p) was significantly higher in winter (1.73, 1.55–1.91) than in summer (1.50, 1.37–1.68) overall. Differences in total phylogenetic diversity within each watershed were not significant.

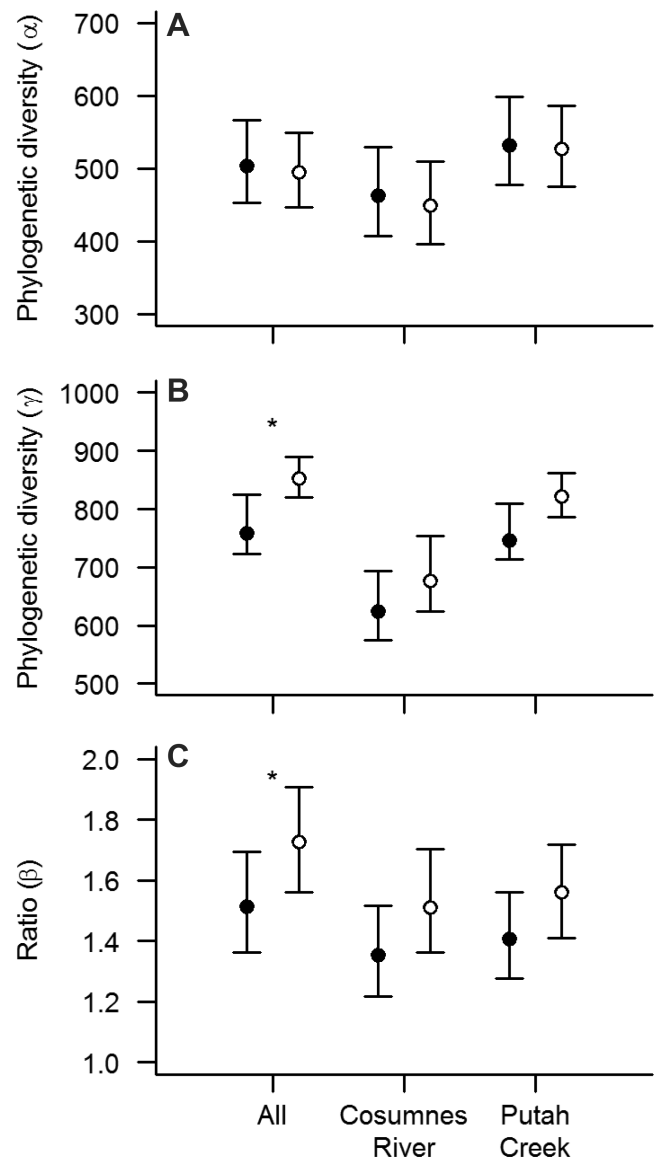


FIGURE 4. Phylogenetic diversity of summer (filled) and winter (open) communities, overall and in each watershed, based on the total evolutionary distinctness of each species present. Mean and 95% credible intervals for each metric are shown. (A) Mean phylogenetic diversity across sites ($\bar{\alpha}_p$). (B) Total phylogenetic diversity across sites (γ_p). (C) Ratio of total to site phylogenetic diversity (β_p). *95% credible intervals for the difference between seasons do not overlap zero.

Individual species contributed differently to seasonal changes in species richness and phylogenetic diversity. Of the 138 species detected, 32 were identified *a priori* as summer visitors, 34 as winter visitors, and 72 as year-round residents (Appendix Table 1). Of the summer and winter visitor groups, 3 species were rare (Cassin's Vireo, Black-throated Gray Warbler, and Pine Siskin; all scientific names provided in Appendix Table 1), with high uncertainties in their occupancy estimates (Appendix Table 2). Of the

remainder, the seasonal occupancy probabilities confirmed our summer and winter visitor groups (Figures 5 and 6), most of which had b_i estimates with credible intervals that did not overlap zero, indicating significant differences in seasonal occupancy probabilities. Several winter visitors had moderate (>0.2) summer occupancy estimates (e.g., Hermit Thrush, Yellow-rumped Warbler, and Golden-crowned Sparrow; Figures 5 and 6; Appendix Table 2), reflecting their late departures from the area and thus their contribution to summer richness and diversity estimates.

Of the 72 year-round residents, 14 were rarely detected, but of the remaining 58 species, nearly half ($n = 27$) had a $<10\%$ difference in seasonal occupancy probabilities in both watersheds (Appendix Table 2), indicating little seasonal variation in their use of riparian habitat. Of the remainder, b_i estimates with credible intervals that did not overlap zero indicated several year-round residents with significant differences in their seasonal occupancy probabilities: 3 that significantly increased in summer (Black-crowned Night-Heron, Brown-headed Cowbird, and American Goldfinch) and 3 that significantly increased in winter (Canada Goose, Anna's Hummingbird, and Northern Mockingbird) in both watersheds, indicating seasonal changes in their local abundance and/or use of riparian habitat. Two additional species (Black Phoebe and Western Scrub-Jay) significantly increased in winter only in the lower Cosumnes River watershed.

Detection probabilities varied widely among species (Appendix Table 1), but there were no significant differences in mean detection probabilities across all observed species between summer (0.137, 0.117–0.159) and winter (0.133, 0.115–0.154), or for year-round residents between summer (0.166, 0.140–0.194) and winter (0.159, 0.140–0.181). These relatively low mean detection probabilities reflect the relatively large number of difficult to detect and/or sparsely distributed species that may be missed on any individual survey. Detection probabilities were significantly higher in summer for 9 year-round resident species and significantly higher in winter for 1 (Northern Flicker; Appendix Table 1). Because detection probabilities were overall similar between seasons, a similar estimated number of species were missed in summer (12.2, 4–24) and winter (14.9, 6–28). Consequently, excluding these hypothetical species had no effect on the results for seasonal differences in α or γ species richness, and only the seasonal difference in β species richness within the lower Putah Creek watershed became nonsignificant (Figure 7).

Of the 34 winter visitors to these 2 watersheds, 33 were species that regularly breed in the boreal forest (Wells and Blancher 2011; Appendix Table 3). As a group they represented an average of 24.4% (21.6–26.9%) of the total winter species richness (γ_s) and 26.4% (25.3–27.5%) of the total winter phylogenetic diversity (γ_p). Of these 33 species, at least 10 have significantly declined on continent-wide Breeding Bird Surveys since 1966 (Sauer et al. 2014;

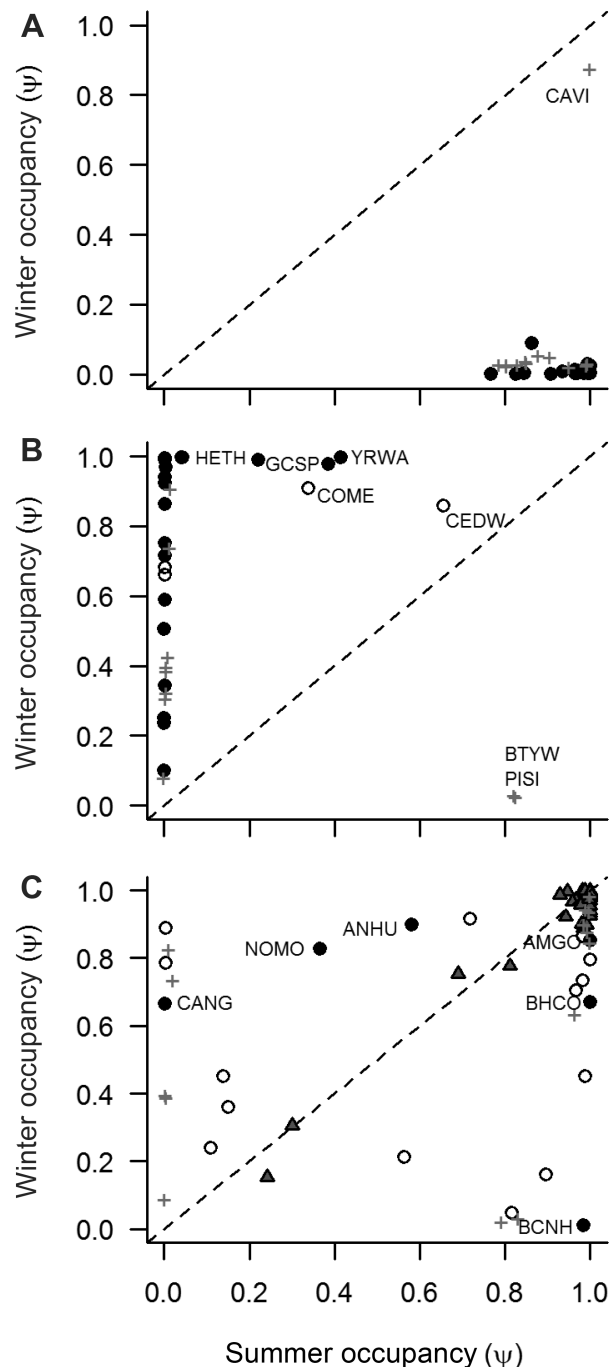


FIGURE 5. Summer and winter occupancy probabilities in the lower Putah Creek watershed for groups of (A) summer visitors, (B) winter visitors, and (C) year-round residents. Filled circles mark species with significant differences in seasonal occupancy probabilities; open circles are not significantly different. Year-round resident species showing little difference ($<10\%$) between summer and winter occupancy probabilities are marked with gray triangles. Rare species with 3 or fewer detections in either season, and thus high uncertainty in occupancy probabilities, are marked with gray crosses. Select species are identified with their 4-letter codes (see Appendix Table 1).

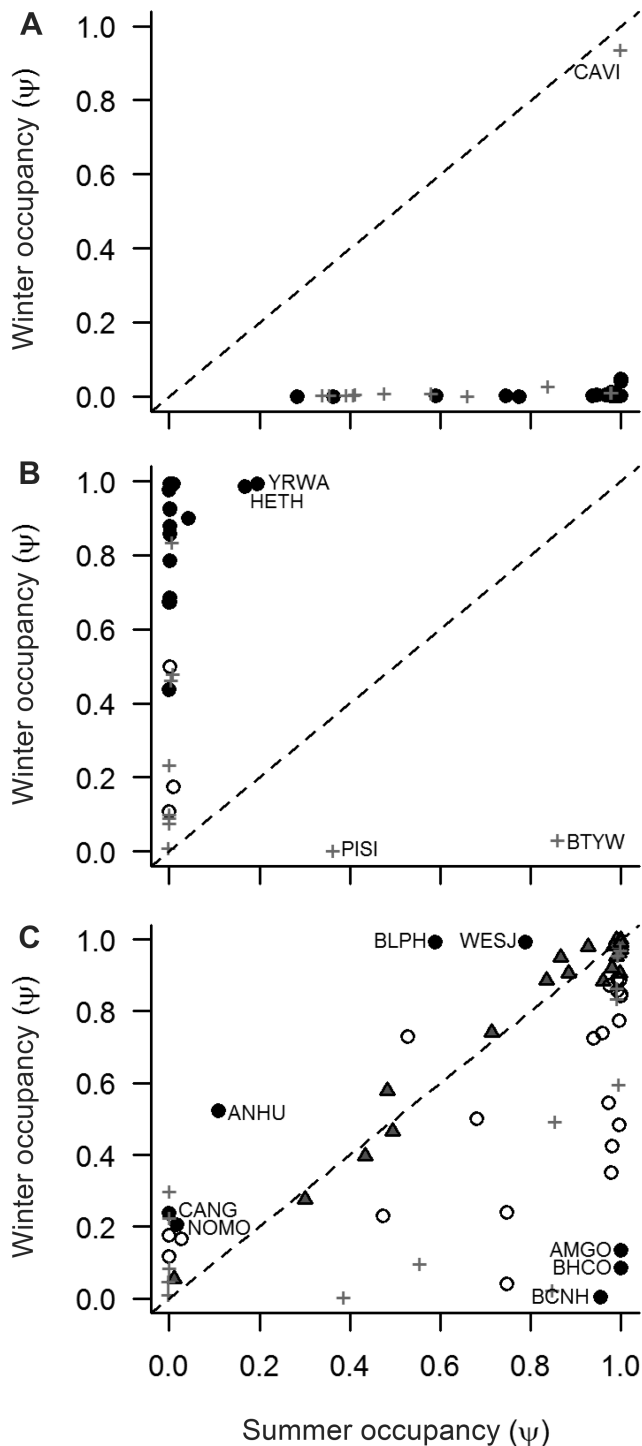


FIGURE 6. Summer and winter occupancy probabilities in the lower Cosumnes River watershed for groups of (A) summer visitors, (B) winter visitors, and (C) year-round residents. Filled circles mark species with significant differences in seasonal occupancy probabilities; open circles are not significantly different. Year-round resident species showing little difference (<10%) between summer and winter occupancy probabilities are marked with gray triangles. Rare species with 3 or fewer detections in either season, and thus high uncertainty in occupancy probabilities, are marked with gray crosses. Select species are identified with their 4-letter codes (see Appendix Table 1).

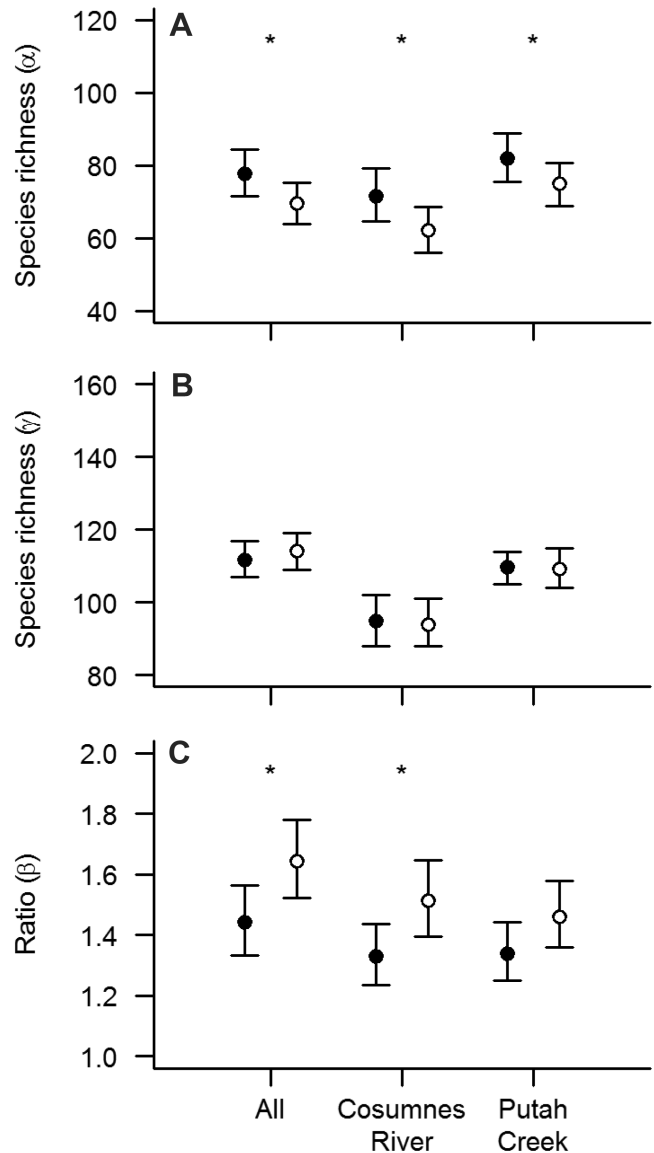


FIGURE 7. Species richness of summer (filled) and winter (open) communities, excluding hypothetical, unobserved species, overall and for each watershed. Mean and 95% credible interval for each metric are shown. (A) Mean species richness across sites ($\bar{\alpha}_s$). (B) Total species richness across sites (γ_s). (C) Ratio of total to site species richness (β_s). *95% credible intervals for the difference between seasons do not overlap zero.

Appendix Table 3), including 5 species with estimated occupancy probabilities >80% in one or both of these watersheds (Dark-eyed Junco, White-crowned Sparrow, Purple Finch, Common Merganser, and Varied Thrush; Appendix Table 2).

DISCUSSION

The riparian habitat in the 2 watersheds we studied in California's Central Valley supported diverse winter bird

communities, as we expected. Contrary to our expectation, however, winter species richness (γ_s) was just as high as summer species richness in both watersheds (Figure 3B), and when the 2 watersheds were pooled, winter phylogenetic diversity (γ_p) was significantly higher (Figure 4B). Thus, riparian habitat supported just as many species and a greater proportion of avian genetic diversity in winter as in summer. The presence of high winter richness and diversity does not necessarily indicate robust and thriving populations, however, and a considerable proportion of the winter species richness and phylogenetic diversity was contributed by boreal-breeding Neotemperate migrants, nearly one-third of which are significantly declining continent-wide (Sauer et al. 2014; Appendix Table 3). Because winter habitat quality plays a key role in avian population regulation (Holmes et al. 1996, Sherry and Holmes 1996, Saino et al. 2004, Norris and Marra 2007) and may be a factor in these declines, our results provide evidence that maintaining and restoring high-quality riparian habitat for Neotemperate migrants and year-round residents in California is an important conservation responsibility.

Wintering birds are often regarded as habitat generalists with relaxed habitat requirements (Yaukey 1996, Queheillalt and Morrison 2006, Golet et al. 2011). While they may not be restricted to a particular habitat type, birds may actively select winter habitat based on food availability, structure, microclimate, or predation risk (Hutto 1985, Carrascal and Diaz 2006, Carrascal et al. 2006, 2011, Seoane et al. 2013). Thus, if riparian vegetation represents relatively high-quality winter habitat in California's Central Valley with a reliable food supply and preferred vegetation structure, then many species may be locally riparian-dependent during the winter. Many of our year-round residents had little difference (<10%) between their summer and winter occupancy probabilities, and 3 species had significantly higher occupancy probabilities in winter in both watersheds (Figures 5 and 6), indicating continued or increased reliance on riparian habitat through the winter. Among Neotemperate migrants, future comparisons of occupancy probabilities between riparian and other habitat types would provide important information about the degree to which species are dependent on riparian habitat during the winter.

Our results also indicate that the value of riparian habitat conservation initiatives could be maximized by accommodating the needs of both breeding and wintering communities. In addition to species turnover within the avian community itself, resource availability, predation risk, habitat structure, and microclimate may all change between the summer and winter seasons. In response, species may use different habitat types (Hutto 1985), expand or specialize their foraging niches (Wagner 1981, Cale 1994, Almeida and Granadeiro 2000), or switch dietary guilds altogether (Lopez de Casenave et al. 2008). Because the

habitat requirements of the wintering bird community are likely to be distinct from those of the breeding bird community, we recommend extra consideration of the needs of the temperate wintering bird community and their responses to restoration and management practices. Here, we found that birds were less evenly distributed in winter, with significantly greater heterogeneity in species composition (β_s) and phylogenetic diversity (β_p) across sites (Figures 3C, 4C), which may reflect aggregation in the highest quality sites and reveal patchiness in required resources and variation in habitat suitability for winter birds that is not apparent among breeding birds. Given limited conservation resources, these winter biodiversity "hotspots" could be targeted for protection, or, alternatively, features missing from the "coldspots" could be identified and restored. Additional research linking specific vegetation structure and composition, food availability, microclimate, and/or predation risk to winter bird distributions, abundance, body condition, or survival rates (e.g., Carrascal and Díaz 2006, Carrascal et al. 2006, Johnson et al. 2011, Latta et al. 2012, Seoane et al. 2013) will contribute to the design of effective restoration strategies and management plans to benefit wintering birds.

Our examination of the temporal distribution of avian biodiversity in 2 California Central Valley watersheds revealed that riparian habitat supports diverse bird communities throughout the year, a pattern that may also hold true in other habitat types and other regions of North America, particularly in the southern and western U.S. where winter species richness is concentrated (Hurlbert and Haskell 2003, Rich et al. 2004). We recommend this approach for setting seasonal conservation priorities, estimating not only seasonal differences in site-level species richness (α_s), but also seasonal differences in heterogeneity among sites (β_s) and in total species richness (γ_s). We recommend the use of occupancy models that allow variation in detection probability among species and seasons (Iknayan et al. 2014). Although here we did not find seasonal differences in mean detection probabilities, detection probabilities did vary among species (Appendix Table 1), and failing to account for variation in detection probability can bias estimates of occupancy and diversity (MacKenzie et al. 2003, Iknayan et al. 2014). Finally, because species richness is not the sole measure of biodiversity, we recommend considering seasonal differences in other measures of diversity, such as diversity metrics that account for relative abundance (Iknayan et al. 2014) or evolutionary distinctness (Jetz et al. 2014). Broader recognition of the diversity and importance of winter bird communities and research into their habitat requirements will facilitate effective conservation of high-quality winter habitat for Neotemperate migrants and year-round residents during a season that can have important impacts on their population dynamics.

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APPENDIX TABLE 1. Seasonal detection probability estimates (medians with 95% credible intervals), grouped by species that are primarily summer visitors, winter visitors, or year-round residents. Also shown are scientific names, species codes and evolutionary distinctness scores (ED; Jetz et al. 2014).

Species	Code	ED	Summer	Winter
Summer visitors				
Swainson's Hawk (<i>Buteo swainsoni</i>)	SWHA	2.20	0.17 (0.11, 0.26)	0.17 (0.11, 0.26)
Black-chinned Hummingbird (<i>Archilochus alexandri</i>)	BCHU	3.83	0.19 (0.12, 0.28)	0.19 (0.12, 0.28)
Olive-sided Flycatcher (<i>Contopus cooperi</i>) [#]	OSFL	4.80	0.02 (0.00, 0.25)	0.02 (0.00, 0.25)
Western Wood-Pewee (<i>Contopus sordidulus</i>)	WEWP	3.78	0.32 (0.21, 0.43)	0.32 (0.21, 0.43)

APPENDIX TABLE 1. Continued.

Species	Code	ED	Summer	Winter
Pacific-slope Flycatcher (<i>Empidonax difficilis</i>)	PSFL	3.21	0.29 (0.22, 0.38)	0.29 (0.22, 0.38)
Willow Flycatcher (<i>Empidonax traillii</i>)	WIFL	4.26	0.03 (0.01, 0.10)	0.03 (0.01, 0.10)
Hammond's Flycatcher (<i>Empidonax hammondi</i>) [#]	HAFI	4.24	0.02 (0.00, 0.26)	0.02 (0.00, 0.26)
Ash-throated Flycatcher (<i>Myiarchus cinerascens</i>)	ATFL	2.61	0.89 (0.83, 0.93)	0.89 (0.83, 0.93)
Western Kingbird (<i>Tyrannus verticalis</i>)	WEKI	3.50	0.45 (0.34, 0.55)	0.45 (0.34, 0.55)
Warbling Vireo (<i>Vireo gilvus</i>)	WAVI	5.32	0.19 (0.13, 0.27)	0.19 (0.13, 0.27)
Bell's Vireo (<i>Vireo bellii</i>) [#]	BEVI	4.69	0.02 (0.00, 0.15)	0.02 (0.00, 0.15)
Cassin's Vireo (<i>Vireo cassinii</i>) [#]	CAVI	3.19	0.02 (0.01, 0.07)	0.02 (0.01, 0.07)
Northern Rough-winged Swallow (<i>Stelgidopteryx serripennis</i>)	NRWS	7.59	0.11 (0.04, 0.24)	0.11 (0.04, 0.24)
Bank Swallow (<i>Riparia riparia</i>) [#]	BANS	10.14	0.02 (0.00, 0.25)	0.02 (0.00, 0.25)
Cliff Swallow (<i>Petrochelidon pyrrhonota</i>)	CLSW	5.96	0.04 (0.01, 0.16)	0.04 (0.01, 0.16)
Barn Swallow (<i>Hirundo rustica</i>)	BARS	3.33	0.08 (0.03, 0.20)	0.08 (0.03, 0.20)
Swainson's Thrush (<i>Catharus ustulatus</i>)	SWTH	8.16	0.32 (0.24, 0.40)	0.32 (0.24, 0.40)
Nashville Warbler (<i>Oreothlypis ruficapilla</i>) [#]	NAWA	2.20	0.02 (0.00, 0.48)	0.02 (0.00, 0.48)
Yellow Warbler (<i>Setophaga petechia</i>)	YEWA	3.02	0.28 (0.20, 0.39)	0.28 (0.20, 0.39)
Townsend's Warbler (<i>Setophaga townsendi</i>)	TOWA	1.45	0.07 (0.03, 0.14)	0.07 (0.03, 0.14)
Hermit Warbler (<i>Setophaga occidentalis</i>) [#]	HEWA	1.45	0.02 (0.00, 0.36)	0.02 (0.00, 0.36)
MacGillivray's Warbler (<i>Geothlypis tolmiei</i>) [#]	MGWA	3.01	0.02 (0.01, 0.12)	0.02 (0.01, 0.12)
Wilson's Warbler (<i>Cardellina pusilla</i>)	WIWA	4.75	0.31 (0.24, 0.39)	0.31 (0.24, 0.39)
Yellow-breasted Chat (<i>Icteria virens</i>) [#]	YBCH	15.23	0.02 (0.01, 0.10)	0.02 (0.01, 0.10)
Black-headed Grosbeak (<i>Pheucticus melanocephalus</i>)	BHGR	5.34	0.56 (0.46, 0.65)	0.56 (0.46, 0.65)
Rose-breasted Grosbeak (<i>Pheucticus ludovicianus</i>) [#]	RBGR	5.36	0.02 (0.00, 0.28)	0.02 (0.00, 0.28)
Blue Grosbeak (<i>Passerina caerulea</i>)	BLGR	6.43	0.13 (0.04, 0.32)	0.13 (0.04, 0.32)
Lazuli Bunting (<i>Passerina amoena</i>)	LAZB	6.43	0.09 (0.04, 0.20)	0.09 (0.04, 0.20)
Western Tanager (<i>Piranga ludoviciana</i>)	WETA	5.29	0.17 (0.12, 0.24)	0.17 (0.12, 0.24)
Bullock's Oriole (<i>Icterus bullockii</i>)	BUOR	2.83	0.63 (0.53, 0.72)	0.63 (0.53, 0.72)
Hooded Oriole (<i>Icterus cucullatus</i>) [#]	HOOR	4.40	0.02 (0.00, 0.25)	0.02 (0.00, 0.25)
Lawrence's Goldfinch (<i>Spinus lawrencei</i>) [#]	LAGO	3.08	0.02 (0.00, 0.25)	0.02 (0.00, 0.25)
Winter visitors				
American Wigeon (<i>Anas americana</i>)	AMWI	2.11	0.05 (0.01, 0.24)	0.05 (0.01, 0.24)
Green-winged Teal (<i>Anas crecca</i>) [#]	GWTE	3.06	0.02 (0.00, 0.27)	0.02 (0.00, 0.27)
Ring-necked Duck (<i>Aythya collaris</i>) [#]	RNDU	1.87	0.02 (0.00, 0.24)	0.02 (0.00, 0.24)
Common Goldeneye (<i>Bucephala clangula</i>)	COGO	4.03	0.33 (0.14, 0.57)	0.33 (0.14, 0.57)
Barrow's Goldeneye (<i>Bucephala islandica</i>) [#]	BAGO	4.03	0.02 (0.00, 0.16)	0.02 (0.00, 0.16)
Bufflehead (<i>Bucephala albeola</i>)	BUFF	5.58	0.34 (0.14, 0.59)	0.34 (0.14, 0.59)
Hooded Merganser (<i>Lophodytes cucullatus</i>)	HOME	5.72	0.18 (0.05, 0.39)	0.18 (0.05, 0.39)
Common Merganser (<i>Mergus merganser</i>)	COME	2.91	0.06 (0.02, 0.14)	0.06 (0.02, 0.14)
Sharp-shinned Hawk (<i>Accipiter striatus</i>)	SSHA	6.10	0.10 (0.03, 0.25)	0.10 (0.03, 0.25)
Wilson's Snipe (<i>Gallinago delicata</i>) [#]	WISN	8.56	0.02 (0.00, 0.28)	0.02 (0.00, 0.28)
Lewis's Woodpecker (<i>Melanerpes lewis</i>) [#]	LEWO	6.95	0.02 (0.00, 0.23)	0.02 (0.00, 0.23)
Red-breasted Sapsucker (<i>Sphyrapicus ruber</i>)	RBSA	4.19	0.13 (0.06, 0.26)	0.13 (0.06, 0.26)
Merlin (<i>Falco columbarius</i>) [#]	MERL	11.30	0.12 (0.01, 0.48)	0.12 (0.01, 0.48)
Eastern Phoebe (<i>Sayornis phoebe</i>) [#]	EAPH	4.74	0.02 (0.00, 0.24)	0.02 (0.00, 0.24)
Say's Phoebe (<i>Sayornis saya</i>)	SAPH	6.78	0.06 (0.02, 0.20)	0.06 (0.02, 0.20)
Brown Creeper (<i>Certhia americana</i>)	BRCR	7.11	0.12 (0.05, 0.23)	0.12 (0.05, 0.23)
Pacific Wren (<i>Troglodytes pacificus</i>)	PAWR	9.67	0.16 (0.07, 0.30)	0.16 (0.07, 0.30)
Golden-crowned Kinglet (<i>Regulus satrapa</i>)	GCKI	32.86	0.16 (0.10, 0.26)	0.16 (0.10, 0.26)
Ruby-crowned Kinglet (<i>Regulus calendula</i>)	RCKI	19.93	0.90 (0.85, 0.93)	0.90 (0.85, 0.93)
Varied Thrush (<i>Ixoreus naevius</i>)	VATH	13.80	0.17 (0.09, 0.28)	0.17 (0.09, 0.28)
Hermit Thrush (<i>Catharus guttatus</i>)	HETH	5.38	0.50 (0.43, 0.57)	0.50 (0.43, 0.57)
American Pipit (<i>Anthus rubescens</i>)	AMPI	5.68	0.11 (0.02, 0.31)	0.11 (0.02, 0.31)
Cedar Waxwing (<i>Bombicilla cedrorum</i>)	CEDW	17.77	0.14 (0.09, 0.23)	0.14 (0.09, 0.23)
Yellow-rumped Warbler (<i>Setophaga coronata</i>)	YRWA	3.91	0.72 (0.66, 0.77)	0.72 (0.66, 0.77)
Black-throated Gray Warbler (<i>Setophaga nigrescens</i>) [#]	BTYW	1.82	0.02 (0.00, 0.30)	0.02 (0.00, 0.30)
Savannah Sparrow (<i>Passerculus sandwichensis</i>)	SAVS	6.56	0.06 (0.02, 0.18)	0.06 (0.02, 0.18)
Golden-crowned Sparrow (<i>Zonotrichia atricapilla</i>)	GCSP	2.63	0.51 (0.44, 0.58)	0.51 (0.44, 0.58)
White-throated Sparrow (<i>Zonotrichia albicollis</i>) [#]	WTSP	3.21	0.02 (0.00, 0.13)	0.02 (0.00, 0.13)
White-crowned Sparrow (<i>Zonotrichia leucophrys</i>)	WCSP	2.63	0.38 (0.30, 0.47)	0.38 (0.30, 0.47)
Fox Sparrow (<i>Passerella iliaca</i>)	FOSP	7.70	0.39 (0.32, 0.46)	0.39 (0.32, 0.46)
Lincoln's Sparrow (<i>Melospiza lincolni</i>)	LISP	3.45	0.57 (0.50, 0.64)	0.57 (0.50, 0.64)

APPENDIX TABLE 1. Continued.

Species	Code	ED	Summer	Winter
Dark-eyed Junco (<i>Junco hyemalis</i>)	DEJU	2.80	0.48 (0.40, 0.55)	0.48 (0.40, 0.55)
Purple Finch (<i>Haemorhous purpureus</i>)	PUFI	5.71	0.05 (0.02, 0.11)	0.05 (0.02, 0.11)
Pine Siskin (<i>Spinus pinus</i>) [#]	PISI	3.64	0.02 (0.00, 0.25)	0.02 (0.00, 0.25)
Year-round residents				
Canada Goose (<i>Branta canadensis</i>)	CANG	3.45	0.10 (0.01, 0.52)	0.11 (0.04, 0.25)
Wood Duck (<i>Aix sponsa</i>)	WODU	6.19	0.22 (0.15, 0.34)	0.16 (0.11, 0.22)
Mallard (<i>Anas platyrhynchos</i>)	MALL	1.18	0.19 (0.12, 0.31)	0.16 (0.11, 0.25)
California Quail (<i>Callipepla californica</i>)	CAQU	5.29	0.51 (0.40, 0.62)	0.24 (0.15, 0.33)*
Ring-necked Pheasant (<i>Phasianus colchicus</i>) [#]	RNEP	5.42	0.01 (0.00, 0.09)	0.01 (0.00, 0.11)
Wild Turkey (<i>Meleagris gallopavo</i>)	WITU	9.19	0.23 (0.14, 0.36)	0.12 (0.03, 0.30)
Pied-billed Grebe (<i>Podilymbus podiceps</i>) [#]	PBGR	36.00	0.02 (0.00, 0.07)	0.02 (0.01, 0.08)
Double-crested Cormorant (<i>Phalacrocorax auritus</i>)	DCCO	6.18	0.05 (0.00, 0.36)	0.06 (0.02, 0.17)
Great Blue Heron (<i>Ardea herodias</i>)	GBHE	6.41	0.10 (0.03, 0.30)	0.15 (0.10, 0.24)
Great Egret (<i>Ardea alba</i>)	GREG	15.14	0.04 (0.01, 0.10)	0.06 (0.02, 0.16)
Snowy Egret (<i>Egretta thula</i>) [#]	SNEG	7.87	0.03 (0.01, 0.16)	0.04 (0.01, 0.21)
Green Heron (<i>Butorides virescens</i>)	GRHE	15.41	0.05 (0.02, 0.17)	0.03 (0.01, 0.16)
Black-crowned Night-Heron (<i>Nycticorax nycticorax</i>)	BCNH	20.20	0.04 (0.02, 0.15)	0.04 (0.01, 0.24)
Turkey Vulture (<i>Cathartes aura</i>)	TUVU	28.79	0.15 (0.04, 0.38)	0.22 (0.12, 0.36)
Northern Harrier (<i>Circus cyaneus</i>) [#]	NOHA	5.22	0.02 (0.00, 0.37)	0.02 (0.00, 0.26)
White-tailed Kite (<i>Elanus leucurus</i>)	WTKI	16.14	0.04 (0.01, 0.22)	0.04 (0.01, 0.17)
Cooper's Hawk (<i>Accipiter cooperii</i>)	COHA	7.42	0.02 (0.01, 0.07)	0.03 (0.01, 0.07)
Red-shouldered Hawk (<i>Buteo lineatus</i>)	RSHA	4.76	0.12 (0.07, 0.20)	0.21 (0.14, 0.29)
Red-tailed Hawk (<i>Buteo jamaicensis</i>)	RTHA	4.56	0.15 (0.08, 0.28)	0.24 (0.16, 0.34)
Osprey (<i>Pandion haliaetus</i>) [#]	OSPR	56.06	0.09 (0.00, 0.63)	0.10 (0.01, 0.45)
Common Gallinule (<i>Gallinula galeata</i>) [#]	COGA	7.19	0.02 (0.00, 0.30)	0.02 (0.00, 0.17)
American Coot (<i>Fulica americana</i>) [#]	AMCO	5.44	0.02 (0.00, 0.31)	0.02 (0.00, 0.34)
Killdeer (<i>Charadrius vociferus</i>)	KILL	18.12	0.04 (0.02, 0.12)	0.04 (0.01, 0.18)
Mourning Dove (<i>Zenaida macroura</i>)	MODO	5.89	0.54 (0.45, 0.62)	0.26 (0.18, 0.35)*
Eurasian Collared-Dove (<i>Streptopelia decaocto</i>) [#]	EUCD	5.15	0.02 (0.00, 0.08)	0.02 (0.00, 0.10)
Barn Owl (<i>Tyto alba</i>)	BANO	14.24	0.07 (0.02, 0.23)	0.19 (0.06, 0.42)
Great Horned Owl (<i>Bubo virginianus</i>)	GHOW	6.48	0.19 (0.10, 0.34)	0.21 (0.14, 0.30)
Anna's Hummingbird (<i>Calypte anna</i>)	ANHU	3.43	0.47 (0.34, 0.60)	0.40 (0.31, 0.49)
Belted Kingfisher (<i>Megasceryle alcyon</i>)	BEKI	11.07	0.17 (0.10, 0.27)	0.26 (0.19, 0.34)
Acorn Woodpecker (<i>Melanerpes formicivorus</i>)	ACWO	5.67	0.31 (0.18, 0.48)	0.37 (0.24, 0.51)
Downy Woodpecker (<i>Picoides pubescens</i>)	DOWO	5.03	0.50 (0.41, 0.58)	0.38 (0.30, 0.46)*
Hairy Woodpecker (<i>Picoides villosus</i>) [#]	HAWO	4.02	0.05 (0.00, 0.47)	0.06 (0.01, 0.27)
Nuttall's Woodpecker (<i>Picoides nuttallii</i>)	NUWO	3.59	0.88 (0.82, 0.92)	0.77 (0.70, 0.83)*
Northern Flicker (<i>Colaptes auratus</i>)	NOFL	5.70	0.34 (0.25, 0.45)	0.72 (0.65, 0.78)*
American Kestrel (<i>Falco sparverius</i>)	AMKE	11.33	0.03 (0.01, 0.13)	0.04 (0.02, 0.11)
Black Phoebe (<i>Sayornis nigricans</i>)	BLPH	4.74	0.70 (0.61, 0.77)	0.70 (0.63, 0.76)
Loggerhead Shrike (<i>Lanius ludovicianus</i>) [#]	LOSH	3.62	0.02 (0.00, 0.25)	0.03 (0.01, 0.14)
Hutton's Vireo (<i>Vireo huttoni</i>)	HUVI	5.89	0.28 (0.16, 0.44)	0.23 (0.15, 0.34)
Western Scrub-Jay (<i>Aphelocoma californica</i>)	WESJ	5.00	0.83 (0.76, 0.88)	0.81 (0.75, 0.86)
Yellow-billed Magpie (<i>Pica nuttalli</i>)	YBMA	5.45	0.10 (0.05, 0.21)	0.12 (0.07, 0.21)
Common Raven (<i>Corvus corax</i>) [#]	CORA	2.75	0.02 (0.00, 0.13)	0.02 (0.00, 0.12)
American Crow (<i>Corvus brachyrhynchos</i>)	AMCR	2.58	0.19 (0.13, 0.28)	0.24 (0.16, 0.34)
Tree Swallow (<i>Tachycineta bicolor</i>)	TRES	8.39	0.67 (0.58, 0.75)	0.18 (0.12, 0.26)*
Oak Titmouse (<i>Baeolophus inornatus</i>)	OATI	6.87	0.60 (0.50, 0.69)	0.58 (0.51, 0.66)
Chestnut-backed Chickadee (<i>Poecile rufescens</i>)	CBCH	5.99	0.05 (0.01, 0.30)	0.06 (0.02, 0.14)
Bush-tit (<i>Psaltriparus minimus</i>)	BUSH	11.67	0.76 (0.68, 0.82)	0.45 (0.38, 0.52)*
White-breasted Nuthatch (<i>Sitta carolinensis</i>)	WBNU	11.54	0.56 (0.47, 0.65)	0.54 (0.46, 0.61)
Bewick's Wren (<i>Thryomanes bewickii</i>)	BEWR	10.52	0.69 (0.60, 0.76)	0.60 (0.52, 0.67)
House Wren (<i>Troglodytes aedon</i>)	HOWR	4.93	0.79 (0.72, 0.85)	0.61 (0.53, 0.68)*
Marsh Wren (<i>Cistothorus palustris</i>) [#]	MAWR	6.83	0.01 (0.00, 0.09)	0.02 (0.00, 0.09)
Wrentit (<i>Chamaea fasciata</i>)	WREN	5.70	0.53 (0.35, 0.69)	0.44 (0.34, 0.55)
Blue-gray Gnatcatcher (<i>Poliophtila caerulea</i>)	BGGN	5.74	0.02 (0.00, 0.18)	0.04 (0.01, 0.12)
Western Bluebird (<i>Sialia mexicana</i>)	WEBL	9.35	0.30 (0.20, 0.42)	0.32 (0.23, 0.40)
American Robin (<i>Turdus migratorius</i>)	AMRO	3.41	0.59 (0.50, 0.67)	0.57 (0.50, 0.64)
Northern Mockingbird (<i>Mimus polyglottos</i>)	NOMO	3.49	0.34 (0.18, 0.52)	0.27 (0.18, 0.37)
California Thrasher (<i>Toxostoma redivivum</i>) [#]	CATH	7.74	0.02 (0.00, 0.30)	0.02 (0.00, 0.32)

APPENDIX TABLE 1. Continued.

Species	Code	ED	Summer	Winter
European Starling (<i>Sturnus vulgaris</i>)	EUST	4.54	0.63 (0.55, 0.71)	0.62 (0.55, 0.69)
Phainopepla (<i>Phainopepla nitens</i>)	PHAI	24.89	0.13 (0.02, 0.46)	0.12 (0.03, 0.30)
Orange-crowned Warbler (<i>Oreothlypis celata</i>)	OCWA	2.57	0.14 (0.09, 0.21)	0.20 (0.14, 0.28)
Common Yellowthroat (<i>Geothlypis trichas</i>)	COYE	1.33	0.24 (0.12, 0.37)	0.18 (0.08, 0.31)
Spotted Towhee (<i>Pipilo maculatus</i>)	SPTO	2.91	0.73 (0.65, 0.80)	0.80 (0.73, 0.85)
California Towhee (<i>Melospiza crissalis</i>)	CALT	3.33	0.44 (0.35, 0.53)	0.42 (0.34, 0.50)
Lark Sparrow (<i>Chondestes grammacus</i>) [#]	LASP	2.90	0.01 (0.00, 0.15)	0.02 (0.00, 0.10)
Song Sparrow (<i>Melospiza melodia</i>)	SOSP	4.00	0.58 (0.48, 0.67)	0.62 (0.54, 0.69)
Western Meadowlark (<i>Sturnella neglecta</i>)	WEME	4.92	0.06 (0.02, 0.22)	0.10 (0.04, 0.23)
Brown-headed Cowbird (<i>Molothrus ater</i>)	BHCO	2.46	0.74 (0.66, 0.81)	0.11 (0.04, 0.25)*
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	RWBL	4.78	0.12 (0.05, 0.24)	0.23 (0.13, 0.35)
Brewer's Blackbird (<i>Euphagus cyanocephalus</i>)	BRBL	4.50	0.08 (0.04, 0.17)	0.05 (0.02, 0.17)
House Finch (<i>Haemorhous mexicanus</i>)	HOFI	7.42	0.68 (0.59, 0.75)	0.46 (0.38, 0.54)*
Lesser Goldfinch (<i>Spinus psaltria</i>)	LEGO	3.09	0.18 (0.10, 0.34)	0.21 (0.12, 0.32)
American Goldfinch (<i>Spinus tristis</i>)	AMGO	3.93	0.42 (0.33, 0.50)	0.42 (0.32, 0.52)
House Sparrow (<i>Passer domesticus</i>)	HOSP	4.03	0.11 (0.06, 0.22)	0.06 (0.03, 0.19)

Note: Summer and winter detection probabilities were set equal for summer and winter visitors.

* Ratio of summer to winter detection estimates significantly different from 1 in both watersheds.

[#] Rare species detected on 3 or fewer surveys in either season.

APPENDIX TABLE 2. Seasonal occupancy estimates for each watershed, grouped by species that are primarily summer visitors, winter visitors, or year-round residents.

	Cosumnes River				Putah Creek			
	Summer		Winter		Summer		Winter	
Summer visitors								
Swainson's Hawk	0.99	(0.52, 1.00)	0.00	(0.00, 0.12)*	0.99	(0.58, 1.00)	0.00	(0.00, 0.13)*
Black-chinned Hummingbird	0.98	(0.37, 1.00)	0.00	(0.00, 0.11)*	1.00	(0.76, 1.00)	0.00	(0.00, 0.13)*
Olive-sided Flycatcher [#]	0.41	(0.00, 1.00)	0.01	(0.00, 1.00)	0.85	(0.01, 1.00)	0.03	(0.00, 1.00)
Western Wood-Pewee	0.97	(0.71, 1.00)	0.00	(0.00, 0.13)*	0.83	(0.41, 1.00)	0.00	(0.00, 0.07)*
Pacific-slope Flycatcher	1.00	(0.59, 1.00)	0.04	(0.00, 0.28)*	1.00	(0.87, 1.00)	0.02	(0.00, 0.19)*
Willow Flycatcher	0.99	(0.22, 1.00)	0.01	(0.00, 0.92)*	0.99	(0.21, 1.00)	0.02	(0.00, 0.94)*
Hammond's Flycatcher [#]	0.34	(0.00, 1.00)	0.00	(0.00, 1.00)	0.80	(0.01, 1.00)	0.03	(0.00, 1.00)
Ash-throated Flycatcher	1.00	(0.89, 1.00)	0.00	(0.00, 0.08)*	1.00	(0.95, 1.00)	0.00	(0.00, 0.11)*
Western Kingbird	0.77	(0.37, 1.00)	0.00	(0.00, 0.04)*	0.97	(0.76, 1.00)	0.00	(0.00, 0.11)*
Warbling Vireo	0.99	(0.53, 1.00)	0.00	(0.00, 0.10)*	1.00	(0.90, 1.00)	0.01	(0.00, 0.13)*
Bell's Vireo [#]	0.66	(0.00, 1.00)	0.00	(0.00, 0.98)	0.95	(0.08, 1.00)	0.02	(0.00, 0.99)
Cassin's Vireo [#]	1.00	(0.29, 1.00)	0.94	(0.12, 1.00)	1.00	(0.22, 1.00)	0.87	(0.01, 1.00)
Northern Rough-winged Swallow	0.09	(0.00, 1.00)	0.00	(0.00, 0.15)	0.86	(0.32, 1.00)	0.09	(0.01, 0.51)*
Bank Swallow [#]	0.48	(0.00, 1.00)	0.01	(0.00, 1.00)	0.88	(0.01, 1.00)	0.05	(0.00, 1.00)
Cliff Swallow	0.59	(0.00, 1.00)	0.00	(0.00, 0.60)*	0.96	(0.24, 1.00)	0.01	(0.00, 0.78)*
Barn Swallow	0.28	(0.00, 1.00)	0.00	(0.00, 0.13)*	0.93	(0.37, 1.00)	0.01	(0.00, 0.35)*
Swainson's Thrush	1.00	(0.76, 1.00)	0.00	(0.00, 0.08)*	1.00	(0.89, 1.00)	0.00	(0.00, 0.12)*
Nashville Warbler [#]	0.84	(0.00, 1.00)	0.03	(0.00, 1.00)	0.79	(0.00, 1.00)	0.03	(0.00, 1.00)
Yellow Warbler	0.36	(0.08, 0.92)	0.00	(0.00, 0.02)*	0.96	(0.71, 1.00)	0.00	(0.00, 0.13)*
Townsend's Warbler	0.99	(0.39, 1.00)	0.00	(0.00, 0.27)*	1.00	(0.51, 1.00)	0.01	(0.00, 0.29)*
Hermit Warbler [#]	0.36	(0.00, 1.00)	0.00	(0.00, 1.00)	0.80	(0.01, 1.00)	0.02	(0.00, 1.00)
MacGillivray's Warbler [#]	0.98	(0.08, 1.00)	0.01	(0.00, 0.99)*	0.99	(0.17, 1.00)	0.03	(0.00, 1.00)*
Wilson's Warbler	1.00	(0.90, 1.00)	0.05	(0.00, 0.29)*	1.00	(0.92, 1.00)	0.02	(0.00, 0.18)*
Yellow-breasted Chat [#]	0.98	(0.06, 1.00)	0.01	(0.00, 0.99)*	0.99	(0.17, 1.00)	0.03	(0.00, 0.99)*
Black-headed Grosbeak	0.94	(0.60, 1.00)	0.00	(0.00, 0.10)*	0.91	(0.67, 0.99)	0.00	(0.00, 0.07)*
Rose-breasted Grosbeak [#]	0.39	(0.00, 1.00)	0.00	(0.00, 1.00)	0.83	(0.01, 1.00)	0.03	(0.00, 1.00)
Blue Grosbeak	0.75	(0.07, 1.00)	0.00	(0.00, 0.15)*	0.84	(0.16, 1.00)	0.00	(0.00, 0.16)*
Lazuli Bunting	0.98	(0.27, 1.00)	0.00	(0.00, 0.21)*	0.98	(0.27, 1.00)	0.00	(0.00, 0.19)*
Western Tanager	1.00	(0.62, 1.00)	0.00	(0.00, 0.10)*	1.00	(0.86, 1.00)	0.01	(0.00, 0.14)*
Bullock's Oriole	0.95	(0.67, 1.00)	0.00	(0.00, 0.12)*	0.77	(0.50, 0.93)	0.00	(0.00, 0.06)*
Hooded Oriole [#]	0.41	(0.00, 1.00)	0.01	(0.00, 1.00)	0.85	(0.01, 1.00)	0.04	(0.00, 1.00)
Lawrence's Goldfinch	0.58	(0.00, 1.00)	0.01	(0.00, 1.00)	0.91	(0.01, 1.00)	0.05	(0.00, 1.00)
Winter visitors								
American Wigeon	0.00	(0.00, 1.00)	0.50	(0.01, 1.00)	0.00	(0.00, 1.00)	0.66	(0.05, 1.00)
Green-winged Teal [#]	0.01	(0.00, 1.00)	0.46	(0.00, 1.00)	0.00	(0.00, 1.00)	0.31	(0.00, 1.00)
Ring-necked Duck [#]	0.00	(0.00, 1.00)	0.08	(0.00, 1.00)	0.00	(0.00, 1.00)	0.39	(0.01, 1.00)
Common Goldeneye	0.00	(0.00, 0.02)	0.01	(0.00, 0.15)	0.00	(0.00, 0.08)	0.10	(0.01, 0.34)*
Barrow's Goldeneye [#]	0.00	(0.00, 1.00)	0.24	(0.00, 1.00)	0.01	(0.00, 1.00)	0.74	(0.05, 1.00)
Bufflehead	0.00	(0.00, 0.02)	0.01	(0.00, 0.15)	0.00	(0.00, 0.08)	0.10	(0.01, 0.34)
Hooded Merganser	0.00	(0.00, 0.02)	0.02	(0.00, 0.28)	0.00	(0.00, 0.13)	0.24	(0.05, 0.71)*
Common Merganser	0.01	(0.00, 1.00)	0.17	(0.00, 1.00)	0.34	(0.01, 1.00)	0.91	(0.48, 1.00)
Sharp-shinned Hawk	0.00	(0.00, 0.24)	0.67	(0.13, 1.00)*	0.00	(0.00, 0.17)	0.59	(0.11, 1.00)*
Wilson's Snipe [#]	0.01	(0.00, 1.00)	0.48	(0.01, 1.00)	0.01	(0.00, 1.00)	0.32	(0.00, 1.00)
Lewis's Woodpecker [#]	0.00	(0.00, 1.00)	0.10	(0.00, 1.00)	0.20	(0.00, 1.00)	0.41	(0.01, 1.00)
Red-breasted Sapsucker	0.00	(0.00, 0.08)	0.44	(0.05, 0.99)*	0.02	(0.00, 0.14)	0.67	(0.28, 1.00)*
Merlin [#]	0.00	(0.00, 0.31)	0.01	(0.00, 0.80)	0.04	(0.00, 0.57)	0.15	(0.00, 0.93)
Eastern Phoebe [#]	0.00	(0.00, 1.00)	0.09	(0.00, 1.00)	0.18	(0.00, 1.00)	0.40	(0.01, 1.00)
Say's Phoebe	0.00	(0.00, 0.63)	0.11	(0.00, 1.00)	0.06	(0.00, 0.94)	0.59	(0.15, 1.00)
Brown Creeper	0.00	(0.00, 0.23)	0.86	(0.32, 1.00)*	0.02	(0.00, 0.13)	0.60	(0.18, 1.00)*
Pacific Wren	0.00	(0.00, 0.20)	0.68	(0.26, 0.98)*	0.01	(0.00, 0.06)	0.27	(0.05, 0.75)*
Golden-crowned Kinglet	0.00	(0.00, 0.15)	0.93	(0.44, 1.00)*	0.01	(0.00, 0.11)	0.83	(0.47, 1.00)*
Ruby-crowned Kinglet	0.01	(0.00, 0.13)	0.99	(0.86, 1.00)*	0.06	(0.00, 0.22)	0.99	(0.94, 1.00)*
Varied Thrush	0.00	(0.00, 0.20)	0.88	(0.48, 1.00)*	0.01	(0.00, 0.06)	0.47	(0.15, 0.98)*
Hermit Thrush	0.17	(0.03, 0.48)	0.98	(0.78, 1.00)*	0.24	(0.07, 0.48)	0.97	(0.88, 1.00)*
American Pipit	0.00	(0.00, 0.08)	0.03	(0.00, 0.88)	0.03	(0.00, 0.27)	0.35	(0.06, 0.98)
Cedar Waxwing	0.01	(0.00, 0.28)	0.04	(0.00, 0.39)	0.59	(0.23, 0.99)	0.81	(0.49, 0.99)

APPENDIX TABLE 2. Continued.

	Cosumnes River				Putah Creek			
	Summer		Winter		Summer		Winter	
Yellow-rumped Warbler	0.20	(0.04, 0.51)	0.99	(0.86, 1.00)*	0.42	(0.19, 0.67)	0.99	(0.93, 1.00)*
Black-throated Gray Warbler [#]	0.86	(0.01, 1.00)	0.03	(0.00, 1.00)	0.51	(0.00, 1.00)	0.21	(0.00, 1.00)
Savannah Sparrow	0.00	(0.00, 0.32)	0.78	(0.10, 1.00)*	0.04	(0.00, 0.33)	0.72	(0.21, 1.00)*
Golden-crowned Sparrow	0.04	(0.00, 0.27)	0.90	(0.62, 0.99)*	0.38	(0.17, 0.65)	0.98	(0.84, 1.00)*
White-throated Sparrow [#]	0.01	(0.00, 1.00)	0.84	(0.04, 1.00)	0.01	(0.00, 1.00)	0.91	(0.11, 1.00)
White-crowned Sparrow	0.00	(0.00, 0.03)	0.67	(0.33, 0.92)*	0.00	(0.00, 0.10)	0.94	(0.73, 1.00)*
Fox Sparrow	0.01	(0.00, 0.16)	0.99	(0.85, 1.00)*	0.04	(0.00, 0.24)	1.00	(0.92, 1.00)*
Lincoln's Sparrow	0.00	(0.00, 0.07)	0.99	(0.85, 1.00)*	0.00	(0.00, 0.08)	1.00	(0.90, 1.00)*
Dark-eyed Junco	0.00	(0.00, 0.06)	0.98	(0.73, 1.00)*	0.00	(0.00, 0.08)	0.99	(0.88, 1.00)*
Purple Finch	0.00	(0.00, 0.61)	0.92	(0.17, 1.00)*	0.00	(0.00, 0.72)	0.97	(0.50, 1.00)*
Pine Siskin [#]	0.36	(0.00, 1.00)	0.00	(0.00, 0.99)	0.82	(0.01, 1.00)	0.02	(0.00, 1.00)
Year-round residents								
Canada Goose	0.00	(0.00, 0.20)	0.24	(0.02, 0.98)*	0.00	(0.00, 0.40)	0.67	(0.21, 0.99)*
Wood Duck	1.00	(0.45, 1.00)	0.99	(0.62, 1.00) [†]	1.00	(0.59, 1.00)	1.00	(0.78, 1.00) [†]
Mallard	0.99	(0.22, 1.00)	0.95	(0.36, 1.00) [†]	1.00	(0.57, 1.00)	0.98	(0.61, 1.00) [†]
California Quail	0.43	(0.16, 0.74)	0.40	(0.13, 0.80) [†]	0.81	(0.57, 0.95)	0.78	(0.47, 0.97) [†]
Ring-necked Pheasant [#]	0.99	(0.00, 1.00)	0.86	(0.02, 1.00)	0.99	(0.03, 1.00)	0.88	(0.01, 1.00)
Wild Turkey	0.98	(0.62, 1.00)	0.42	(0.06, 0.99)	0.90	(0.36, 1.00)	0.16	(0.01, 0.98)
Pied-billed Grebe [#]	1.00	(0.13, 1.00)	0.97	(0.10, 1.00)	1.00	(0.12, 1.00)	0.98	(0.20, 1.00)
Double-crested Cormorant	0.00	(0.00, 0.99)	0.12	(0.00, 0.99)	0.00	(0.00, 1.00)	0.79	(0.25, 1.00)
Great Blue Heron	0.01	(0.00, 0.97)	0.06	(0.00, 0.42) [†]	0.72	(0.10, 1.00)	0.92	(0.63, 0.99)
Great Egret	1.00	(0.26, 1.00)	0.85	(0.05, 1.00)	1.00	(0.30, 1.00)	0.94	(0.23, 1.00) [†]
Snowy Egret [#]	0.56	(0.00, 1.00)	0.10	(0.00, 1.00)	0.96	(0.07, 1.00)	0.63	(0.05, 1.00)
Green Heron	1.00	(0.24, 1.00)	0.48	(0.00, 1.00)	1.00	(0.19, 1.00)	0.80	(0.05, 1.00)
Black-crowned Night-Heron	0.95	(0.06, 1.00)	0.00	(0.00, 0.85)*	0.98	(0.22, 1.00)	0.01	(0.00, 0.90)*
Turkey Vulture	0.48	(0.03, 1.00)	0.58	(0.23, 0.94) [†]	0.30	(0.03, 1.00)	0.31	(0.09, 0.68)
Northern Harrier [#]	0.00	(0.00, 1.00)	0.09	(0.00, 1.00)	0.01	(0.00, 1.00)	0.39	(0.00, 1.00)
White-tailed Kite	0.99	(0.12, 1.00)	0.89	(0.05, 1.00)	0.99	(0.06, 1.00)	0.90	(0.07, 1.00) [†]
Cooper's Hawk	1.00	(0.15, 1.00)	0.97	(0.11, 1.00) [†]	1.00	(0.30, 1.00)	0.99	(0.38, 1.00) [†]
Red-shouldered Hawk	1.00	(0.23, 1.00)	0.91	(0.32, 1.00) [†]	1.00	(0.81, 1.00)	0.98	(0.72, 1.00) [†]
Red-tailed Hawk	0.98	(0.08, 1.00)	0.92	(0.53, 1.00) [†]	0.98	(0.40, 1.00)	0.89	(0.44, 1.00) [†]
Osprey [#]	0.00	(0.00, 0.99)	0.01	(0.00, 0.88)	0.00	(0.00, 1.00)	0.09	(0.00, 0.96)
Common Gallinule [#]	0.00	(0.00, 1.00)	0.23	(0.00, 1.00)	0.02	(0.00, 1.00)	0.73	(0.06, 1.00)
American Coot [#]	0.85	(0.01, 1.00)	0.02	(0.00, 1.00)	0.79	(0.00, 1.00)	0.02	(0.00, 1.00)
Killdeer	0.75	(0.00, 1.00)	0.04	(0.00, 1.00)	0.99	(0.40, 1.00)	0.45	(0.01, 1.00)
Mourning Dove	1.00	(0.85, 1.00)	0.84	(0.31, 1.00)	1.00	(0.92, 1.00)	0.95	(0.63, 1.00) [†]
Eurasian Collared-Dove [#]	0.99	(0.10, 1.00)	0.60	(0.00, 1.00)	1.00	(0.13, 1.00)	0.84	(0.02, 1.00)
Barn Owl	0.98	(0.21, 1.00)	0.35	(0.07, 0.89)	0.81	(0.05, 1.00)	0.05	(0.00, 0.34)
Great Horned Owl	0.87	(0.04, 1.00)	0.95	(0.56, 1.00) [†]	0.96	(0.45, 1.00)	0.97	(0.51, 1.00) [†]
Anna's Hummingbird	0.11	(0.02, 0.38)	0.52	(0.23, 0.82)*	0.58	(0.32, 0.82)	0.90	(0.67, 0.99)*
Belted Kingfisher	0.30	(0.02, 1.00)	0.28	(0.07, 0.66) [†]	0.98	(0.69, 1.00)	0.97	(0.83, 1.00) [†]
Acorn Woodpecker	0.68	(0.30, 0.97)	0.50	(0.22, 0.79)	0.24	(0.07, 0.54)	0.15	(0.04, 0.39) [†]
Downy Woodpecker	1.00	(0.91, 1.00)	0.97	(0.61, 1.00) [†]	1.00	(0.95, 1.00)	0.98	(0.72, 1.00) [†]
Hairy Woodpecker [#]	0.00	(0.00, 1.00)	0.05	(0.00, 0.99)	0.00	(0.00, 1.00)	0.40	(0.03, 1.00)
Nuttall's Woodpecker	1.00	(0.96, 1.00)	1.00	(0.91, 1.00) [†]	1.00	(0.97, 1.00)	1.00	(0.94, 1.00) [†]
Northern Flicker	1.00	(0.66, 1.00)	1.00	(0.90, 1.00) [†]	1.00	(0.74, 1.00)	1.00	(0.93, 1.00) [†]
American Kestrel	0.96	(0.00, 1.00)	0.88	(0.04, 1.00) [†]	0.99	(0.10, 1.00)	0.97	(0.35, 1.00) [†]
Black Phoebe	0.59	(0.28, 0.85)	0.99	(0.83, 1.00)*	0.98	(0.84, 1.00)	1.00	(0.97, 1.00) [†]
Loggerhead Shrike [#]	0.00	(0.00, 1.00)	0.30	(0.00, 1.00)	0.01	(0.00, 1.00)	0.82	(0.14, 1.00)
Hutton's Vireo	0.88	(0.50, 1.00)	0.91	(0.54, 1.00) [†]	0.11	(0.02, 0.38)	0.24	(0.07, 0.54)
Western Scrub-Jay	0.79	(0.48, 0.95)	0.99	(0.84, 1.00)*	0.99	(0.86, 1.00)	1.00	(0.97, 1.00) [†]
Yellow-billed Magpie	0.97	(0.06, 1.00)	0.87	(0.18, 1.00)	1.00	(0.47, 1.00)	0.97	(0.56, 1.00) [†]
Common Raven [#]	0.85	(0.00, 1.00)	0.49	(0.00, 1.00)	0.98	(0.03, 1.00)	0.90	(0.09, 1.00)
American Crow	0.99	(0.29, 1.00)	0.77	(0.27, 1.00)	1.00	(0.75, 1.00)	0.93	(0.58, 1.00) [†]
Tree Swallow	0.99	(0.74, 1.00)	0.86	(0.24, 1.00)	1.00	(0.93, 1.00)	0.98	(0.70, 1.00) [†]
Oak Titmouse	0.98	(0.84, 1.00)	0.98	(0.84, 1.00) [†]	0.69	(0.43, 0.89)	0.75	(0.50, 0.92) [†]
Chestnut-backed Chickadee	0.00	(0.00, 0.97)	0.18	(0.00, 1.00)	0.00	(0.00, 1.00)	0.89	(0.44, 1.00)
Bushtit	1.00	(0.96, 1.00)	1.00	(0.91, 1.00) [†]	1.00	(0.97, 1.00)	1.00	(0.94, 1.00) [†]

APPENDIX TABLE 2. Continued.

	Cosumnes River				Putah Creek			
	Summer		Winter		Summer		Winter	
White-breasted Nuthatch	1.00	(0.87, 1.00)	1.00	(0.93, 1.00) [†]	1.00	(0.74, 1.00)	1.00	(0.92, 1.00) [†]
Bewick's Wren	1.00	(0.88, 1.00)	0.98	(0.74, 1.00) [†]	1.00	(0.97, 1.00)	1.00	(0.90, 1.00) [†]
House Wren	1.00	(0.96, 1.00)	0.99	(0.85, 1.00) [†]	1.00	(0.95, 1.00)	0.98	(0.81, 1.00) [†]
Marsh Wren [#]	0.99	(0.02, 1.00)	0.84	(0.01, 1.00)	1.00	(0.01, 1.00)	0.94	(0.10, 1.00)
Wrentit	0.53	(0.23, 0.82)	0.73	(0.42, 0.92)	0.15	(0.04, 0.39)	0.36	(0.16, 0.63)
Blue-gray Gnatcatcher	0.83	(0.00, 1.00)	0.89	(0.05, 1.00) [†]	0.97	(0.01, 1.00)	0.97	(0.33, 1.00) [†]
Western Bluebird	0.49	(0.12, 0.99)	0.47	(0.17, 0.79) [†]	0.94	(0.64, 1.00)	0.92	(0.69, 0.99) [†]
American Robin	0.99	(0.82, 1.00)	1.00	(0.94, 1.00) [†]	0.95	(0.70, 1.00)	1.00	(0.90, 1.00) [†]
Northern Mockingbird	0.02	(0.00, 0.18)	0.21	(0.04, 0.55)*	0.37	(0.14, 0.66)	0.83	(0.52, 0.98)*
California Thrasher [#]	0.39	(0.00, 1.00)	0.01	(0.00, 1.00)	0.83	(0.01, 1.00)	0.03	(0.00, 1.00)
European Starling	1.00	(0.91, 1.00)	0.99	(0.85, 1.00) [†]	1.00	(0.83, 1.00)	0.97	(0.80, 1.00) [†]
Phainopepla	0.03	(0.00, 1.00)	0.17	(0.01, 0.99)	0.14	(0.00, 1.00)	0.45	(0.09, 1.00)
Orange-crowned Warbler	1.00	(0.53, 1.00)	0.99	(0.68, 1.00) [†]	1.00	(0.86, 1.00)	0.99	(0.66, 1.00) [†]
Common Yellowthroat	0.94	(0.53, 1.00)	0.72	(0.31, 0.98)	0.56	(0.19, 1.00)	0.21	(0.05, 0.60)
Spotted Towhee	1.00	(0.96, 1.00)	1.00	(0.91, 1.00) [†]	1.00	(0.97, 1.00)	1.00	(0.95, 1.00) [†]
California Towhee	0.47	(0.18, 0.80)	0.23	(0.06, 0.54)	0.99	(0.91, 1.00)	0.97	(0.83, 1.00) [†]
Lark Sparrow [#]	0.99	(0.03, 1.00)	0.95	(0.08, 1.00)	0.99	(0.00, 1.00)	0.94	(0.05, 1.00)
Song Sparrow	0.93	(0.59, 1.00)	0.98	(0.76, 1.00) [†]	0.93	(0.70, 1.00)	0.99	(0.85, 1.00) [†]
Western Meadowlark	0.96	(0.03, 1.00)	0.74	(0.08, 1.00)	0.98	(0.09, 1.00)	0.87	(0.25, 1.00)
Brown-headed Cowbird	1.00	(0.88, 1.00)	0.09	(0.00, 0.99)*	1.00	(0.98, 1.00)	0.67	(0.20, 1.00)*
Red-winged Blackbird	0.75	(0.04, 1.00)	0.24	(0.05, 0.65)	0.97	(0.37, 1.00)	0.71	(0.37, 0.96)
Brewer's Blackbird	1.00	(0.12, 1.00)	0.89	(0.08, 1.00)	1.00	(0.52, 1.00)	0.93	(0.12, 1.00) [†]
House Finch	0.99	(0.87, 1.00)	0.96	(0.70, 1.00) [†]	0.98	(0.80, 1.00)	0.90	(0.67, 0.99) [†]
Lesser Goldfinch	0.97	(0.32, 1.00)	0.55	(0.15, 0.99)	0.98	(0.37, 1.00)	0.73	(0.37, 0.99)
American Goldfinch	1.00	(0.86, 1.00)	0.13	(0.02, 0.42)*	1.00	(0.97, 1.00)	0.85	(0.60, 0.97)*
House Sparrow	0.71	(0.01, 1.00)	0.74	(0.05, 1.00) [†]	0.98	(0.49, 1.00)	0.96	(0.21, 1.00) [†]

* Credible interval for the difference in seasonal occupancy estimates does not overlap zero.

[#] Rare species detected on 3 or fewer surveys in either season.

[†] Year-round residents showing small (<10%) increases between summer and winter occupancy estimates.

APPENDIX TABLE 3. Boreal breeding status of winter visitors to Putah Creek and Cosumnes River. Shown are the estimated percent of the North American population breeding in the boreal forest (Wells and Blancher 2011) and continent-wide Breeding Bird Survey trends, 1966-2012 (with 95% credible intervals; Sauer et al. 2014).

Species	% Boreal Breeders	BBS trend
American Wigeon	>50	-2.74 (-4.32, -1.63)*
Green-winged Teal [#]	>50	-0.29 (-5.61, 1.13)
Ring-necked Duck [#]	>50	2.32 (-3.02, 5.41)
Common Goldeneye	>80	1.02 (-1.38, 2.83)
Barrow's Goldeneye [#]	>50	-0.90 (-3.01, 1.17)
Bufflehead	>80	2.72 (-0.35, 4.56)
Hooded Merganser	>50	4.28 (0.72, 6.51) [†]
Common Merganser	>50	-2.10 (-4.98, -0.41)*
Sharp-shinned Hawk	>25	1.05 (-1.73, 1.97) [†]
Wilson's Snipe [#]	>50	0.29 (-0.25, 0.81)
Lewis's Woodpecker [#]	<25	-3.05 (-7.03, -1.09)*
Red-breasted Sapsucker	<25	0.41 (-0.79, 1.53)
Merlin [#]	>50	2.99 (1.28, 4.27) [†]
Eastern Phoebe [#]	>25	0.45 (-0.27, 0.88)
Say's Phoebe	<25	0.75 (-15.69, 1.29) [†]
Brown Creeper	<25	0.63 (-0.40, 1.28)
Pacific Wren	>25 [†]	-0.65 (-1.56, 0.17)
Golden-crowned Kinglet	>25	-0.76 (-2.62, 0.25)
Ruby-crowned Kinglet	>50	0.08 (-0.93, 0.99)
Varied Thrush	>25	-2.36 (-3.14, -1.57)*
Hermit Thrush	>50	0.93 (0.15, 1.64)*
American Pipit	>25	No data
Cedar Waxwing	>25	0.30 (-0.58, 0.86)
Yellow-rumped Warbler	>50	-0.12 (-0.81, 0.35)
Black-throated Gray Warbler [#]	0	-1.45 (-2.34, -0.72)*
Savannah Sparrow	>25	-1.26 (-1.58, -0.97)*
Golden-crowned Sparrow	>50	No data
White-throated Sparrow [#]	>80	-0.51 (-1.03, -0.02)*
White-crowned Sparrow	>50	-0.74 (-1.36, -0.18)*
Fox Sparrow	>50	-0.66 (-2.71, 0.78)
Lincoln's Sparrow	>80	-1.16 (-2.51, 0.05)
Dark-eyed Junco	>80	-1.20 (-1.71, -0.77)*
Purple Finch	>25	-1.34 (-2.06, -0.78)*
Pine Siskin [#]	>25	-2.26 (-4.00, -0.96)*

[#] Rare species detected on 3 or fewer surveys in both seasons

[†] Data available only for Winter Wren, which includes Pacific Wren.

* Credible intervals for population trends do not overlap zero

[‡] High uncertainty in BBS trends