Occurrence of western scrub-jays (*Aphelocoma californica*) near forest edges in fragmented golden-cheeked warbler (*Setophaga chrysoparia*) habitat

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OCCURRENCE OF WESTERN SCRUB-JAYS (*APHELOCOMA CALIFORNICA*) NEAR FOREST EDGES IN FRAGMENTED GOLDEN-CHEEKED WARBLER (*SETOPHAGA CHRYSOPARIA*) HABITAT

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Abstract—The western scrub-jay (*Aphelocoma californica*) is a common nest predator and has been documented depredating nests of the federally endangered golden-cheeked warbler (*Setophaga chrysoparia*), a woodland songbird, in central Texas. We conducted opportunistic and transect surveys for western scrub-jays across two vegetation classes (woodland and shrub-scrub) to investigate the proximity of scrub-jays to golden-cheeked warblers breeding in a fragmented landscape. We used a chi-square test to compare the number of observed and expected scrub-jay detections for each vegetation class. To investigate if scrub-jays are an edge-occupying species, we compared the distance to nearest vegetation edge of actual scrub-jay detections to a null distribution of mean random distances. We found that scrub-jays occur in areas closer to vegetation class boundaries but do not appear to prefer one vegetation type over the other. Our findings suggest that golden-cheeked warblers may have higher nest predation risk in fragmented areas of their breeding range.

Resumen—La chara azuleja (*Aphelocoma californica*) es un depredador de nido común, y se ha documentado depredando los nidos del chipe mejilla dorada (*Setophaga chrysoparia*), un pájaro cantor del bosque en el centro de Texas que está federalmente amenazado. Realizamos muestreos oportunistas y de transectos de la chara azuleja en dos clases de vegetación (bosque y matorral arbustivo) para investigar la proximidad de la chara azuleja al chipe mejilla dorada reproduciéndose en un paisaje fragmentado. Se utilizó una prueba de chi-cuadrada para comparar el número de encuentros de la chara azuleja observados y esperados para cada clase de vegetación. Para investigar si la chara azuleja es una especie de borde de hábitat, comparamos la distancia al borde de la vegetación de encuentros de la chara a un modelo nulo de puntos generados aleatoriamente. Se encontró que las charas ocurren en áreas cercanas a las orillas de clases de vegetación, pero no parece que prefieran un tipo de vegetación sobre el otro. Nuestros hallazgos sugieren que los chipes pueden tener mayor riesgo de depredación de nidos en áreas fragmentadas de su área de reproducción.

Habitat fragmentation and the associated edge effects are of primary concern to species conservation and habitat preservation. Not only does fragmentation alter species distribution (Porensky, 2011; Reino et al., 2013), but it brings species from adjacent habitats in closer proximity, often with negative effects. Such effects are commonly seen in the increase of nest predation near forest edges (Gardner, 1998; Pangau-Adam et al., 2006; Cox et al., 2012). Edges provide predators with easier visual and physical access to forest species that are usually protected within forest interiors (Poulin and Villard, 2011). Increased predator access can be of particular concern for endangered species.

The western scrub-jay (*Aphelocoma californica*; hereafter scrub-jay) is a common nest predator of songbirds (Small, 2005; Francis et al., 2011; Conkling et al., 2012) and is associated with a wide variety of open habitats throughout the western and southern United States, including juniper (*Juniperus*), oak (*Quercus*), and pinyon (*Pinus*) woodlands as well as open shrub pastures and residential areas (Curry et al., 2002). In central Texas, scrub-jays are known to depredate nests of the federally endangered golden-cheeked warbler (*Setophaga chrysoparia*; hereafter warbler; Petyk, 2004; Stake et al., 2004; Reidy et al., 2008). The warbler breeds exclusively in woodlands comprised of Ashe juniper (*Juniperus ashei*) and mixed-oak species (Pulich, 1976; Kroll, 1980; Magness et al., 2006); however, these woodlands are threatened by the expansion of urban centers and ranching practices (United States Fish and Wildlife Service, 1992).

Increased edge density and habitat fragmentation have previously been linked to increases in warbler nest predation (Peak, 2007; Reidy et al., 2009). Since nest predation by corvids is greater in fragmented landscapes (Rich et al., 1994; Donovan et al., 1997), we hypothesized that scrub-jays would preferentially occupy forest edges of fragmented warbler habitat. To investigate our hypothesis, we examined the occurrence of scrub-jays across juniper-oak woodlands and shrub-scrub vegetation classes and in relation to distance from woodland edges in warbler habitat with patchy distribution.

Materials and Methods—Our study took place 20 April–7 June 2010 within Kickapoo Cavern State Park and surrounding private properties in Edwards and Kinney counties, Texas (29°36′N, 100°26′W). This area is a transition zone between the juniper-oak woodlands of the central Edwards Plateau and the shrub-scrub plains to the south (Griffith et al., 2004). Due to this natural ecoregion shift, as well as fragmentation from ranching practices, the landscape is characterized as a patchy network of Ashe juniper and live oak (*Quercus fusiformis*) woodlands surrounded by open shrub-scrub plains comprised primarily of prickly pear (*Opuntia engelmannii*), blackbrush (*Coleogyne ramosissima*), and honey mesquite (*Prosopis glandulosa*).

We conducted detection surveys for scrub-jays within six study sites (two in Kickapoo Cavern State Park and four on private properties; Fig. 1) previously delineated in Klassen et al. (2012) for their known occupancy of breeding warblers. The study areas were <25 km apart, ranged in area from 137–311 ha, and comprised of patches of juniper-oak woodland in the center surrounded by approximately 200-m buffer of shrub-scrub plains. Using the National Landcover Database (NLCD; Homer et al., 2007), we determined the vegetation class composition of our study area by summing the number of pixels in the ArcMap 10.1 (Environmental Systems Research Institute, Redlands, California) attribute table assigned to each land cover category within each study site boundary. The NLCD provides a land type classification to a 30-m resolution. The resulting composition was approximately 29.7% juniper-oak woodland (comprised of evergreen, deciduous, and mixed-forest vegetation classes) and 70.3% shrub-scrub plains (comprised of shrub-scrub and herbaceous vegetation classes) across all six study sites. We used

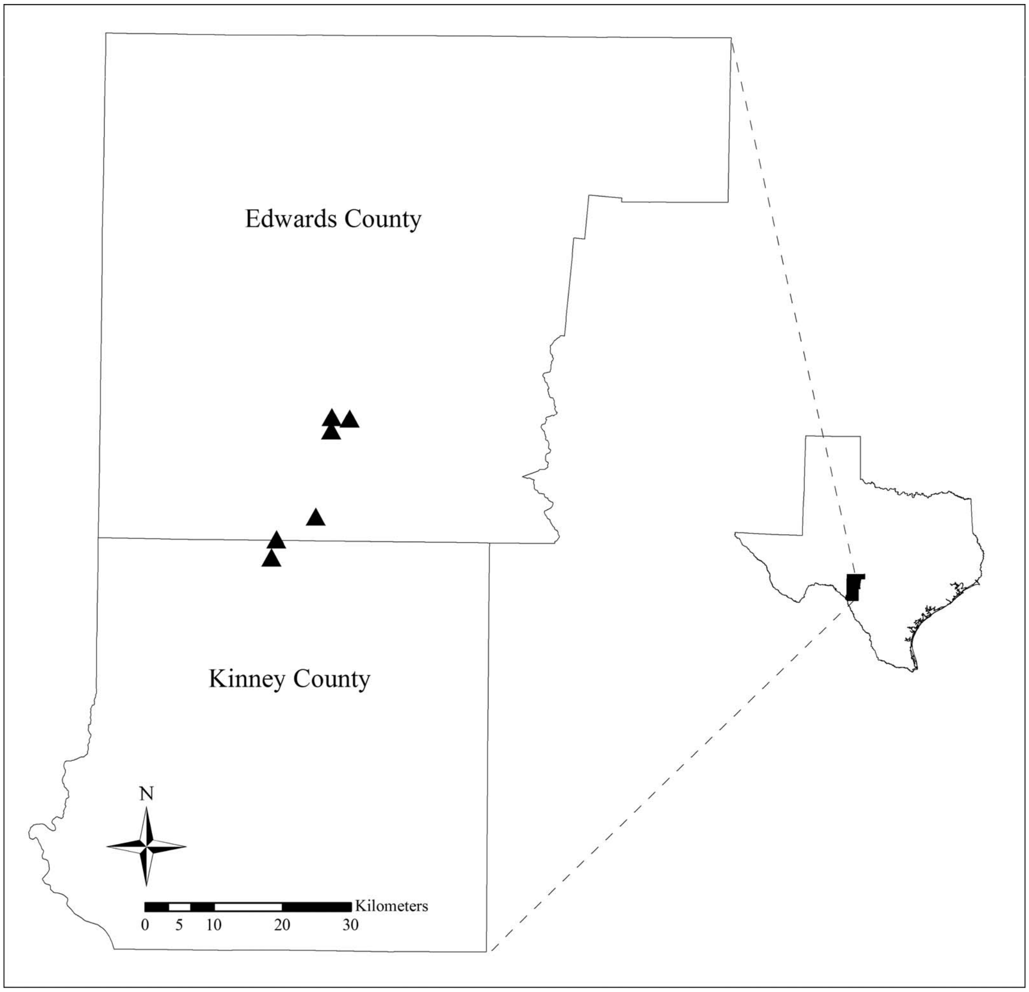

FIG. 1—Location of western scrub-jay (*Aphelocoma californica*) survey sites in Edwards and Kinney counties, Texas, 2010.

two different survey methods to detect scrub-jay locations. The first method, opportunistic surveys, took place 1–2 times a week while we conducted territory mapping and productivity surveys on warbler territories located within each study area. Since warbler territories spanned the majority of the study areas, often expanding into the shrub-scrub plains (Klassen et al., 2012), we were able to survey across both vegetation classes. If we detected a scrub-jay, we recorded its location using a handheld GPS unit. To ensure we surveyed across both vegetation classes without bias, we also conducted transect surveys across the extent of each study site. Each study site had 4–7 transects (1–2.4 km long), with the orientation of the first transect chosen randomly. Transects were spaced 200 m apart to limit detecting the same bird twice. However, since our unit of observation was scrub-jay detection, rather than individual birds, detecting the same individual more than once would not detract from our study. We walked each transect once, looking and listening for scrub-jays. Due to the size of our study areas and the rugged terrain, it often took >1 day to survey a single study site. As such, transect surveys took place on eight separate dates in 2010 (20 and 25 April; 4, 5, 6, 8, 11 May; and 3 June). If we detected a scrub-jay within 30 m of the transect, we walked to the scrub-jay detection point and recorded its location with a handheld GPS unit. If scrub-jay detection was >30 m from the transect, we marked our location on the transect with a GPS unit and estimated the distance and direction to the scrub-jay. Three researchers participated in opportunistic and transect surveys and practiced distance and direction estimates together in the field for 2 weeks prior to data collection to ensure estimations were uniform and accurate. Both survey types took place between local sunrise and 1100h when birds are most active.

We uploaded detection points into ArcMap 10.1 and approximated the locations of detections >30 m from transects based on the distance and direction estimates collected during that survey. To determine the vegetation class for each scrub-jay detection, we overlaid detection points on top of the NLCD raster file and noted the number of detections that fell within juniper-oak woodland and shrub-scrub plains classification. Due to slight locational error in the NLCD, we ground truthed the NLCD vegetation classifications during a co-occurring study (Klassen, 2011) to ensure we assigned correct vegetation type. We used a chi-square test ($\alpha = 0.05$) to determine if scrub-jay detections were located in proportion to vegetation class availability. We calculated the expected number of scrub-jay detections per vegetation class by multiplying the number of detections by the percent coverage of the vegetation classes across all study sites (0.297 for woodland and 0.703 for shrub-scrub plains) for each survey method separately. We could not perform this test for each study site separately due to the small number of scrub-jay detections within each study site.

To calculate the distance of scrub-jay detections from vegetation class boundaries, we converted the NLCD from a raster to a polygon shapefile using the conversion tools in ArcMap 10.1. We delineated boundaries between juniper-oak woodlands and shrub-scrub vegetation classes by creating polygons based on the vegetation classification type of each pixel in the land-use raster file. The result was a polygon layer with a patchy distribution of juniper-oak woodland polygons within a shrub-scrub matrix. We then used the near tool within the proximity analysis toolset in ArcMap 10.1 to calculate the minimum straight-line distance for each scrub-jay detection point to the closest vegetation boundary. We used this calculation method for scrub-jay detection points from both opportunistic and transect detection surveys.

To examine our hypothesis that scrub-jays preferentially occur along edges, we examined the proximity of scrub-jays to vegetation boundaries relative to random locations across our study sites. We generated random points within each study site at an average density of 1 point per 10 ha. We calculated the distance of each random point from nearest vegetation class boundary using the same method as for scrub-jay detections, described above. We created a null model with replacement (Resampling Stats Add-In v. 4.0 for Microsoft Excel, http://statistics.com, LLC, Arlington, Virginia) to resample our data to obtain means and standard deviations for random distances (Efron, 1979; Efron and Tibshirani, 1986). We resampled distance means for each survey method separately with sample sizes equaling the number of scrub-jay detections obtained during each survey method. We repeated this procedure 10,000 times for each survey method to create two null models. We calculated the *P*-values for each test as the proportion of mean random distances less than the observed mean distances of scrub-jay locations for each survey method (Veech, 2012), with $P < 0.05$ indicating scrub-jay detections a significantly shorter distance from edge than randomly possible.

Results—We obtained 58 scrub-jay detections from opportunistic surveys and 31 scrub-jay detections from transect surveys. Due to the small number of scrub-jay detections within each study site (1–7 detections for most sites), we combined all detections for each survey method to examine the scrub-jay occurrence within juniper-oak woodlands and shrub-scrub vegetation. Scrub-jay detections from opportunistic surveys were located in juniper-oak woodlands more than expected, with 32 detections in juniper-oak woodlands and 26 detections in shrub-scrub plains ($\chi^2 = 18.023$, $df = 1$, $P < 0.001$, $n = 58$). Conversely, scrub-jay detections from transect surveys were distributed in proportion to vegetation class availability, with 11 detections in juniper-oak woodlands and 20 detections in shrub-scrub plains ($\chi^2 = 0.497$, $df = 1$, $P = 0.480$, $n = 31$). Distances of scrub-jay detections to nearest vegetation class boundary ranged from 1.5–204.6 m, with a mean distance of 42.2 m for opportunistic surveys. Distances for transect surveys were similar, with a mean distance of 37.1 m and a range of 1.7–236.7 m. Analysis of our null distribution model with actual scrub-jay detections indicated that the mean distance of scrub-jay detections to nearest vegetation class boundary was significantly shorter, by $\geq$11 m, than randomly generated distances for both opportunistic ($P = 0.049$) and transect ($P = 0.034$) surveys.

Discussion—Our study suggests that scrub-jays occupy vegetation edges, or transition zones, irrespective of what vegetation class they occupy. We found support, based on our transect survey method, for scrub-jays as habitat generalists, which is consistent with previous scrub-jay research in this area (Burt, 1996). Conversely, our opportunistic surveys suggested that scrub-jays preferentially occupy woodland habitat. However, this contradiction is probably from an inherent bias in our opportunistic surveys, because we spent more time in woodland habitat while surveying for the warbler.

Our results support our hypothesis that scrub-jays preferentially occupy forest edges of fragmented warbler habitat. Previous research has examined scrub-jay habitat associations based on coarse land-use classifications such as rural, agricultural, and urban (Crosbie et al., 2011) or with tree species and diversity (Koenig et al., 2009), but not at the transition between vegetation types. Knowledge on species distribution at habitat edges is particularly important considering the increased potential to interact with species from adjacent habitats. Our research suggests that fragmented forest edges are key locations for increased scrub-jay and warbler interactions. Since nest predation from corvids tends to increase at edge habitats (Hannon and Cotterill, 1998), it would be reasonable to expect an increase in warbler nest predation by scrub-jays.

As ranching practices expand in South Texas, so does the potential for scrub-jay and warbler habitat overlap. Not only does ranching tend to cut down and fragment existing juniper-oak stands, but Goguen and Mathews (1998) found that scrub-jays prefer nongrazed areas, which, in the portion of Texas where this study occurred, is remaining warbler habitat. Additionally, juniper-oak fragmentation can lead to additional stresses on scrub-jays for resources. Oak tree masting events are an important part of scrub-jay diet and reproductive success (Burt, 1996; Monahan and Koenig, 2006; Koenig et al., 2009). A decrease in oak trees, and the subsequent acorns, may require the scrub-jay to rely more heavily on alternative food sources such as nest contents. In terms of golden-cheeked warbler management, minimizing edge habitat by maintaining large, contiguous stands of juniper-oak woodlands should remain a priority.

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