

Ecology

Don't count your eggs before they hatch: differential survival of artificial bird nests in an anthropogenically modified landscape in western Mexico

No cuentes los huevos antes de que eclosionen: supervivencia diferencial de nidos artificiales de aves en un paisaje antropogénicamente modificado en el oeste de México

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Abstract

Native habitat conversion to urban and agricultural areas represents conservation concerns for habitat quality and the breeding success of birds. In tropical areas facing regular deforestation of at-risk habitats, changes may occur to bird and nest predator communities that influence contradictory trends in breeding success. To assess the value of working lands for birds, we placed 100 artificial nests in 5 habitat types of varying human footprint, including a tropical dry forest reserve, a biological research station, croplands, and 2 urban towns. We report a clear decline in survival from the forest to urban towns. Habitat type explained the variation in nest survival probabilities over nest height, elevation, or time of nest exposure. Reducing the structural and compositional contrast of habitat and landscape vegetation between tropical dry forest and working lands represent valuable conservation actions for increasing habitat quality for birds.

Keywords: Croplands; Bird nest predation; Habitat quality; Jalisco; Plasticine eggs; Tropical dry forest; Urbanization

Resumen

La conversión de hábitats nativos en áreas urbanas y campos agrícolas representa problemas de conservación para la calidad del hábitat y el éxito reproductivo de las aves. La deforestación constante de hábitats en riesgo puede cambiar las comunidades de aves y los depredadores de los nidos, lo que puede influir en su éxito reproductivo. Para

evaluar el valor de los hábitats dentro de un paisaje antropogénicamente modificado en el éxito reproductivo de las aves, colocamos 100 nidos artificiales en 5 hábitats con diferentes niveles de actividades humanas, incluyendo una reserva de bosque tropical caducifolio, una estación de investigación biológica, campos agrícolas y 2 pueblos urbanos. Encontramos una clara disminución en la supervivencia de nidos artificiales desde el bosque tropical caducifolio hasta los pueblos urbanos. El tipo de hábitat fue la variable que mejor explicó la variación en las probabilidades de supervivencia de los nidos artificiales en comparación con la altura del nido, la elevación y el tiempo de exposición del nido. Reducir el contraste dentro del paisaje en la estructura de la vegetación entre la reserva y los hábitats dentro del paisaje modificado representan acciones de conservación importantes para aumentar la calidad del hábitat para las aves.

Palabras clave: Campos agrícolas; Depredación de nidos de aves; Calidad de hábitat; Jalisco; Huevos de plastilina; Selva seca tropical; Urbanización

Introduction

Urbanization and the conversion of native habitat to agricultural land represent key factors in the long-term conservation of bird biodiversity (Aronson et al., 2014; Kehoe et al., 2017). In the tropics, urbanization and agriculture have led to the degradation and destruction of native vegetation and the reconfiguration of landscapes, causing stark contrast in habitat complexity between remnant vegetation and agricultural and urban areas that pose risks to bird biodiversity (Filloy et al., 2019; Fischer et al., 2015; Maas et al., 2016). Biodiverse tropical regions suffer some of the highest rates of urbanization and native habitat transformation (Estrada et al., 2020), which represent pressing challenges for the conservation of bird populations.

A key component of bird biodiversity and population monitoring in tropical landscapes with high rates of natural habitat transformation includes the evaluation of breeding ecology (DeGregorio et al., 2016). Reduced vegetative complexity and the exchange of native plants with non-native plants, both common attributes of agricultural and urban areas (Chace & Walsh, 2006), tend to negatively impact bird species with highly sensitive breeding requirements tied to native vegetation (Maas et al., 2016). Vegetation change in the tropics alters biotic—e.g., nest predation pressure and reduction of nest locations—and abiotic conditions—e.g., increased nest exposure, higher temperatures, and brighter conditions—, leading to potential direct and indirect influences on avian breeding ecology in species that depend on native plants and vegetation structure for nesting (Estrada et al., 2002; Rivera-López & MacGregor-Fors, 2016; Tellería & Díaz, 1995; Zúñiga-Palacios et al., 2021). Meanwhile, certain bird species may be positively impacted by or able to acclimate to novel conditions (DeGregorio et al., 2016; Kurucz et al., 2021; Latif et al., 2012), underlining the semi-permeable ecological filter that is applied to nesting birds in human-modified tropical landscapes and the importance

of evaluating bird breeding ecology in different types of transformed land (MacGregor-Fors, 2010; MacGregor-Fors et al., 2022).

Nest predation represents a powerful force on bird breeding success and population dynamics (DeGregorio et al., 2016). A consequence of native habitat conversion to more urban or agricultural areas includes changes to nest predator communities, and the ability of bird species to adapt to these changes will ultimately determine whether disturbed areas offer viable habitat for native levels of biodiversity (DeGregorio et al., 2016; Latif et al., 2012). Urban and agricultural areas tend to have lower vegetation cover as forested habitats, leading to different natural predator abundance and nest visibility to predators, representing powerful determinants of breeding success for bird species that use transformed land (López-Flores et al., 2009; Martin, 1993; Zúñiga-Palacios et al., 2021). More disturbed areas may lead to a reduction of nest predation pressure due to the absence of native nest predators that have a low tolerance for human activity (Kurucz et al., 2021; Pretelli et al., 2023). A possible caveat to lower predation pressure from typical native predators in urban areas include birds that are habitat and foraging generalists (Estrada et al., 2002; Martin, 1995; Rivera-López & MacGregor-Fors, 2016), mammals that are attracted to anthropogenic food sources (Fischer et al., 2012), and increased access to nests by people that manipulate and destroy nests and eggs (López-Flores et al., 2009).

To assess the survivorship of bird nests, we placed artificial bird nests in 5 habitat types with increasing degrees of human disturbance and habitat modification, including 1) a tropical dry forest reserve (TDF hereafter), 2) the Chamela Biological Research Station (CBRS) grounds, embedded in the Chamela-Cuixmala Biosphere Reserve, 3) croplands (CL), 4) Careyes (CAR), a small and heavily built-up town, and 5) Emiliano-Zapata (ZAP), a larger town. While a recent meta-analysis questions the efficacy of artificial nest studies in determining nest survival probabilities in urban areas relative to natural nests

(Vincze et al., 2017), the feasibility of finding sufficient numbers of natural nests in heavily built-up urban areas (i.e., outside of urban parks and green spaces) makes the use of artificial nests necessary. We controlled for important variables that may influence predation rates, such as nest size and height, to focus on habitat-level variations in nest survivorship and the impacts of urban and agricultural areas in the working landscape. Such landscapes are common in the tropical areas of Mexico (Levey et al., 2023), where existing reserves are surrounded by a working landscape with non-native vegetation that contrasts highly with native areas (Levey & MacGregor-Fors, 2021; Levey et al., 2021; MacGregor-Fors & Schondube, 2011; Vázquez-Reyes et al., 2017). Efforts to evaluate the impacts on breeding ecology in these working tropical landscapes are needed to supplement a thin body of work (Estrada et al., 2002; López-Flores et al., 2009; Zuñiga-Palacios et al., 2021) and determine the risks that urban and agricultural areas present for breeding birds. We expected nest survivorship to be lower in CL, CAR, and ZAP relative to the conserved TDF reserve and the CBRS due to higher exposure of nests and greater visibility for predators due to reduced vegetation complexity and density (Estrada et al., 2002; López-Flores et al., 2009; Zuñiga-Palacios et al., 2021).

Materials and methods

We conducted our study in a landscape between the Chamela-Cuixmala Biosphere Reserve (19°29'57.5" N, 105°02'41.6" W) and the town Emiliano Zapata (19°23'16.6" N, 104°57'50.1" W) in the Municipality La Huerta (population: 23,258; INEGI, 2020) on the Pacific coast of Jalisco, Mexico (Fig. 1). Historically, native vegetation cover in the region consisted primarily of tropical dry forest, which consists of deciduous forest with a mean canopy height of 12 m, a dense understory (Rzedowski, 2006), and strong phenological changes due to highly seasonal rainfall in the region (Durán et al., 2002). Other forest types exist in areas with more regular water availability, including semi-deciduous (mean canopy height of 20 m) and mangrove forests (Durán et al., 2002). After a period of increased human occupation and agricultural expansion from 1950-1970, large cover of tropical dry forest and other native forest types in lower elevation zones were converted to small towns and agricultural lands, linked by paved and unpaved roads, creating a landscape mosaic of native and non-native vegetation types (Maass et al., 2005).

In this landscape, we selected 5 habitat types with varying degrees of urban and agricultural disturbance for artificial nest placement: 1) TDF, with closed canopy cover and dense understory, 2) CBRS, which consists

of moderately built-up 1.4 ha area embedded within the Chamela-Cuixmala Biosphere Reserve, 3) CL, consisting of fields of small, herbaceous plants such as maize (*Zea mays*), squash (*Cucurbita* spp.), chili pepper (*Capsicum* spp.), watermelon (*Citrullus lanatus*), and beans (*Phaseolus* spp.) located in the southern edge of the study area (Maass et al., 2005), 4) CAR (19°26'36.15" N, 105°1'49.65" W), a small town with heavy built-up cover, and 5) ZAP, a large town with less built-up cover than CAR (Fig. 1). Both elevations (MSL) of the TDF and CBRS sampling areas were slightly higher than the other habitat types. The TDF and CBRS sampling areas are also in closer proximity to each other than the other sampling locations. We included both habitat categories due to the higher human presence at the Biological Station, the noise generated by people and activities at the station, and a higher density of paved roads that could influence the occupancy of bird and mammals that respond positively to increasing human footprint (Rivera-López & MacGregor-Fors, 2016). Potential bird nest predators in the study region included White-throated Magpie-jays and San Blas jays (*Calocitta formosa* and *Cyanocorax sanblasianus*), Great-tailed grackles (*Quiscalus mexicanus*), mammals (e.g., *Nasua narica*, domestic dogs and cats, rodents, possums, and *Procyon lotor*), and diverse reptiles.

We used a mixture of plant fibers, twigs, and mud from the nest location to create bird nests in the shape of open plant fiber nest cups large enough to hold both the clay and quail eggs. We created open cup nests since many species in the study area construct nests in similar ways (e.g., *Cyanocorax sanblasianus*, *Peucaea ruficauda*, and *Turdus rufopalliat*; Mendoza-Rodríguez et al., 2010) and due to the ease of creating such a nest shape. We placed each nest ~ 2 m above ground to control the tendency of nest height placement to affect predation rates (DeGregorio et al., 2016). We placed 1 Japanese Quail (*Coturnix japonica*) commercial egg and 1 clay egg of similar size for a total of 2 eggs in each nest (Bayne et al., 1997; Estrada et al., 2002). We used clay since it is a malleable material that preserves markings from predation events and has negligible influence on predation rates (Bayne & Hobson, 1999; Bayne et al., 1997). We used commercial quail eggs due to their small size and color speckling that best mimicked natural terrestrial bird eggs relative to domestic chicken eggs and their availability in the study region. We used both a real and clay egg to provide stimulus for a wider range of predators than clay eggs alone and to capture predation event evidence if we could not perceive markings on the quail egg from smaller nest predators (Bayne et al., 1997; Estrada et al., 2002). We used rubber gloves to prevent leaving a human scent when handling nest materials and eggs (Estrada et al., 2002).

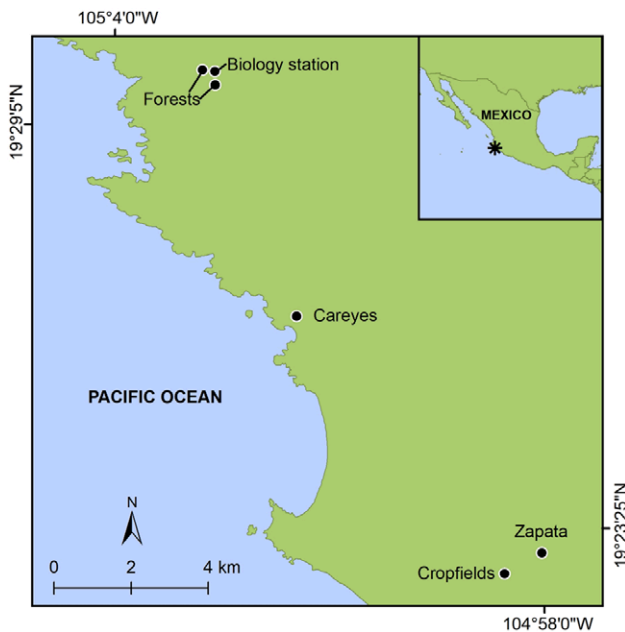


Figure 1. Region of study in the state of Jalisco in western Mexico. We placed artificial bird nests at the localities marked with a black dot and text, including ‘Forests’ (tropical dry forest of the Chamela-Cuixmala Biosphere Reserve), ‘Biology station’ (the Chamela Biological Research Station), ‘Cropfields’ (herbaceous crop plots), ‘Careyes’ (a small, heavily built-up town), and ‘Zapata’ (a large, less built-up town). Nest locations within the marked localities by at least 250 m to increase spatial independence.

We placed 20 artificial nests in each of the 5 habitat types for a total of 100 nests. Nests were exposed for a total of 12 days (April 30 - May 11, 2009), and we checked nests at 3-day intervals for a total of 4 nest visits. We considered nests as failed if the eggs were missing or if there were indications of a predation event on either the clay or quail egg, including scratches, bite marks, or perforations. We removed nests with signs of predation from the sample locations. We considered nests successful if there were no markings on either the clay or quail egg.

We used the program MARK (White & Burnham, 1999) to perform a known fate analysis using our nest check interval to calculate the probability of survivorship of each nest (Dinsmore & Dinsmore, 2007), using the covariables nest height (m), elevation (m asl), habitat type, and time of nest exposure to generate the models. We included the nest height variable in analyses despite controlling the height at 2-m to check for potential interactions with other covariates. We included elevation in our models to account for slight elevation differences between nest site locations and the tendency of lower elevation areas to have higher

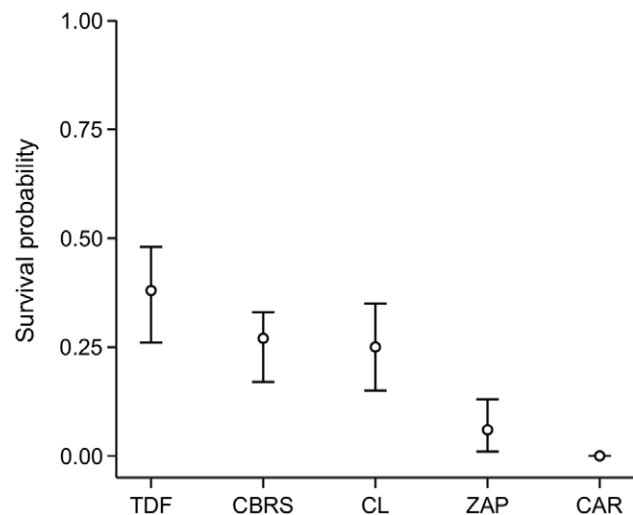


Figure 2. Survival probability with 95% confidence intervals from the Known Fate analysis in MARK of the artificial nests in the conserved tropical dry forest (TDF in the figure), Chamela Biological Research Station (CBRS), cropland (CL), the town of Careyes (CAR), and the town of Zapata (ZAP).

cover of agricultural and urban areas (Maass et al., 2005). We included habitat type to determine the differences between certain habitat types on artificial nest survival. Finally, we included the time of nest exposure since the likelihood of nest survival is tied to the amount of time eggs are exposed to predators (Dinsmore & Dinsmore, 2007). We ranked the models by parsimony using the adjusted Akaike’s Information Criterion for small sample sizes (AICc; Hurvich & Tsai, 1989). We selected the models that best fit our data by calculating the differences in AICc values ($\Delta AICc$) and choosing those with $\Delta AICc$ values less than 2 units from the most parsimonious model (Burnham & Anderson, 2002).

Results

We recorded 82 preyed upon nests of 100 total, including 37 (45.1%) instances of bird predation, 30 (36.6%) instances of unknown predation, 10 (12.2%) instances of egg removal or manipulation by humans, 3 (3.7%) instances of rodent predation, and 2 (2.4%) instances of reptile predation. We recorded 18 nests with no predation signs, with the majority remaining in TDF (44.4%), followed by CBRS (27.8%), CL (22.2%), and ZAP (5.6%). No nests placed in CAR survived the observation period. Nest survival probability was 0.38 (95% CI: 0.26-0.48) in TDF, 0.27 (95% CI: 0.17-0.33) in CBRS, 0.25 (95% CI: 0.15-0.35) in CL, 0.06 (95%

Table 1

Model output from the Known Fate analysis in MARK. Covariates used in the models include habitat, nest height (controlled at 2 m above ground level), elevation, and time of nest exposure.

Model	AICc	ΔAICc	AICc weight	Model likelihood	Parameters	Deviance
Habitat	262.62	0.00	0.44	1.00	5	252.32
Habitat + height	263.96	1.35	0.22	0.51	6	251.55
Habitat + elevation	264.49	1.87	0.17	0.39	6	252.08
Habitat + height + elevation	265.90	3.29	0.09	0.19	7	251.35
Elevation	267.21	4.59	0.04	0.10	5	256.91
Height + elevation	268.74	6.12	0.02	0.05	6	256.32
Time of nest exposure	270.31	7.69	0.01	0.02	4	262.11
Height	272.26	9.64	0	0.01	5	261.96

CI: 0.01-0.13) in ZAP, and 0.0 in CAR (Fig. 2). The most parsimonious model to explain the variation in nest survival probabilities included the lone covariable habitat, followed closely by the combination of habitat and height (Table 1).

Discussion

The impacts of bird nest predation along habitat disturbance gradients vary depending on the severity of habitat modification and the biotic and abiotic conditions of transformed land (Vincze et al., 2017). Novel biotic and abiotic conditions in urban and agricultural settings heavily contrast with native habitat, representing important influences on bird breeding success and, ultimately, biodiversity conservation (DeGregorio et al., 2016). We report a clear decline in the survival probabilities of artificial bird nests throughout a gradient of urban intensity between a conserved tropical dry forest and the largest town.

TDF, the most conserved habitat in the disturbance gradient, had the highest artificial nest survival probability among all studied habitats. This finding is consistent with other artificial nest studies from the tropical Americas that show greater vegetation cover offers increased survival odds by concealing nests more effectively from predators, both within forests with seasonal leaf cover (Vega-Rivera et al., 2009) and relative to more open areas (Estrada et al., 2002; López-Flores et al., 2009). TDF contains a dense understory of vegetation and a closed canopy with darker lighting, which may be a key factor in the detection of nests by predators (Estrada et al., 2002; Vázquez et al., 2021). While some studies have found that conserved areas either have similar or lower nest survival probabilities than in urban settings due to changes in predator abundance

and composition (DeGregorio et al., 2016; Fischer et al., 2012; Zuñiga-Palacios et al., 2021), local factors in this heterogeneous landscape with various habitat types likely favor ample distribution of potential nest predators (e.g., urban birds, domesticated cats, and dogs) in urban areas (Estrada et al., 2002; López-Flores et al., 2009; Rivera-López & MacGregor-Fors, 2016).

Outside of the conserved TDF habitat, CL showed near-equal nest survival probabilities as the CBRS, which were lower than in TDF. Our results indicate that even small (< 2 ha), moderately built-up areas embedded in conserved habitat may increase the likelihood of nest predation to levels found in agricultural land. Synonymous with development is the opening of forest habitat, leading to new abiotic conditions and biotic stimulus that may influence breeding success in birds (Patten & Smith-Patten, 2012; Shochat et al., 2010). In our study area, CBRS has attracted several bird species that are opportunistic omnivores and often associated with open habitats, such as the Great-tailed Grackle (*Quiscalus mexicanus*; MacGregor-Fors et al., 2009). Also attracted to this habitat and CL are potential nest predators such as the White-nosed Coati (*Nasua narica*) and Common Raccoon (*Procyon lotor*), which have been documented to predate bird nests (Estrada et al., 2002; Menezes & Marini, 2017; Robinson et al., 2005). Snakes, which occur at similar compositions inside and outside the reserve, may exhibit increased activity at edge habitats (Chalfoun et al., 2002; Suazo-Ortuño et al., 2008; Vetter et al., 2013). These changes to the nest predator communities in CBRS and CL could have important implications on bird breeding success (DeGregorio et al., 2016), and continued urbanization of these areas may continue to decrease nest survival probabilities to the levels of heavily built-up towns.

The built-up areas along the urbanization gradient in our study had significantly lower nest survival probabilities than the other studied habitats. Urbanization and loss of native vegetation have been shown to negatively influence the survival of bird nests in previous studies (Rivera-López & MacGregor-Fors, 2016; Thorington & Bowman, 2003), and a potential mechanism includes the introduction of novel predation pressures, such as domesticated cats (Patterson et al., 2016), dogs (Zuñiga-Palacios et al., 2021) and humans (López-Flores et al., 2009). While it has been shown that urban areas may increase nest survival and breeding success in birds (Fischer et al., 2012; Kurucz et al., 2021), the urban areas in our study area presented an overwhelming amount of novel predation pressures that are not present in the other studied habitats (Chace & Walsh, 2006; López-Flores et al., 2009), highlighting the importance of evaluating changes in the communities of bird nest predators along habitat disturbance gradients (DeGregorio et al., 2016). Conserving and restoring degraded areas within working landscapes and urban centers through measures such as live fencing, remnant forest preservation, and educational programs on bird breeding ecology may provide vital nesting habitat and increase bird breeding success (Bocz et al., 2017; Zuñiga-Palacios et al., 2021).

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