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DOES THE DISTANCE TO FORESTS OR BUILDINGS INFLUENCE GREAT KISKADEE (*PITANGUS SULPHURATUS*) NESTING SITE SELECTION?

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Abstract · The expansion of human settlements has produced significant changes in natural ecosystems by fragmenting and reducing their area. Those changes influence the availability of natural and artificial sites used to build nests by birds. Some species nest on perches built by humans, but the characteristics of the perches that are selected are unknown. Our goal was to analyze how characteristics of utility poles and their proximity to human buildings and forest patches influence the presence of Great Kiskadee (*Pitangus sulphuratus*) nests. We counted and described all the poles present along 30 km of gravel and asphalt roads in Rincón de Osa, Costa Rica. We classified each pole according to the number of metal plates, electrical transformers, and lights. We also recorded whether the pole had a Great Kiskadee nest. We measured the distance of each pole with a nest to the nearest human building and forest patch. Nests were more frequent on poles far from forests and near buildings. The characteristics of the poles also influenced the presence of Great Kiskadee nests, possibly due to the lower risk of predation that the structure provides, because there was a greater probability of finding nests on poles with an electric transformer than on poles with wires only. We found that both, perch structure and distance to buildings and forest patches, influence where the Great Kiskadee builds its nests.

Resumen · ¿Influyen la distancia al bosque o la distancia a edificios en la selección del sitio de anidación del bienteveo común (*Pitangus sulphuratus*)?
La expansión de los asentamientos humanos ha producido cambios significativos en los ecosistemas naturales debido a la fragmentación y reducción de sus áreas. Estos cambios influyen en la disponibilidad de sitios naturales y artificiales que las aves utilizan para construir nidos. Algunas especies anidan en perchas construidas por humanos; sin embargo, se desconocen las características de las perchas seleccionadas. Nuestro objetivo fue analizar cómo las características de los postes de electricidad y la proximidad a edificios humanos y parches de bosque influyen en la presencia de nidos del bienteveo común (*Pitangus sulphuratus*). Contamos y describimos todos los postes presentes en 30 km de caminos de grava y asfalto en Rincón de Osa, Costa Rica. Clasificamos cada poste según el número de placas, transformadores eléctricos y luces. También verificamos si cada poste tenía o no un nido del bienteveo común. Medimos la distancia de cada poste con un nido al edificio humano más cercano y a parches de bosque. La presencia de nidos fue más frecuente en postes alejados de bosques y cerca de edificios. Asimismo, las características del poste influyen en la presencia de nidos del bienteveo común, posiblemente por el menor riesgo de depredación que brinda la estructura, pues fue más probable encontrar nidos en postes con transformador eléctrico que postes con solo cables. Descubrimos que tanto la estructura de la percha como la distancia a los edificios y a los parches de bosque influyen en el lugar donde el bienteveo común construye sus nidos.

Key words: Artificial perches · Electrical transformer · Nesting perch innovation · Neotropical bird · Predation · Risk urbanization

INTRODUCTION

Urbanization is a process that modifies natural landscapes (Fisher & Lindenmayer 2007, Murgui & Hedblom 2017), producing a reduction, modification, and fragmentation of natural habitats within or close to cities (McKinney 2006, Wu et al. 2011). In the last decades, urban areas have rapidly increased (Biamonte et al. 2011), causing changes in the behavior, survival, and dispersal of species (Caryl et al. 2016). As a result, some species that survive inside urban areas often modify their behavior to use new resources produced by humans (Mainwaring 2015, Caballero et al. 2016). Meanwhile, other species leave these new ecosystems to inhabit less modified areas (Crooks et al. 2004). Based on their behavior and abundance, species can be classified into three groups: 1) Urban dwellers, species that persist (reproduce and forage) within urban landscapes and whose presence is independent from the original habitat (Lowe et al. 2014); 2) urban users or utilizers, species that occasionally use urban resources like food, but less frequently breed in developed areas (Fischer et al. 2015); and 3) urban avoiders, species that infrequently occur in urban areas, but may persist in natural areas bordered by urbanized landscapes (De Angelo et al. 2011).

In urban landscapes, many dweller and user species exploit new nesting materials (e.g., plastic bags, polyester fibers, or

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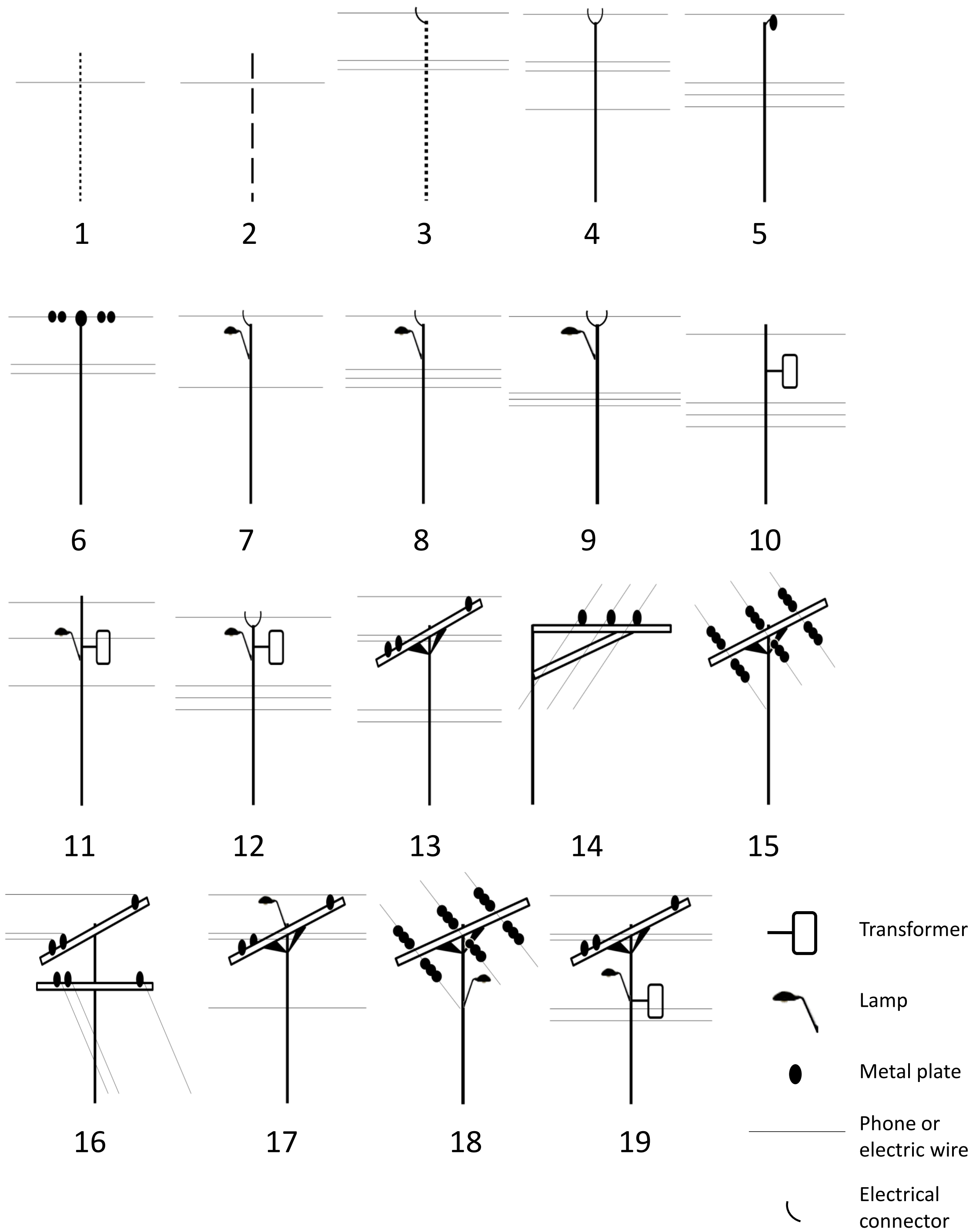

Figure 1. Scheme of electric pole types. Continuous black lines represent poles made of concrete, the dotted line poles made of wood, and the dashed line poles made of metal.

metallic wires) and perches to build nests (e.g., utility poles, roof buildings, or bridge structures; Wang et al. 2015, Protti & Sandoval 2019). This is because natural perches and nesting materials are eliminated or modified, and new perches and substrates are added (Brice et al. 2017). For example, the removal of small ravines, or of mature or dead trees, reduces the occurrence of wood and earth cavity excavators inside urban areas (McKinney 2006, Sandoval et al. unpub. data). However, the addition of new substrates for nesting, such as wooden or concrete poles, and electric or telephone wires, produce or facilitate nest building inside cities (Caballero et al. 2016). Such is the case of the Clay-colored Thrush (*Turdus grayi*), which nests on buildings (Sánchez et al. 2018); the House Wren (*Troglodytes aedon*), which nests in mailboxes (Pierce 1922); woodpeckers (*Melanerpes* sp.), which use utility poles for nest building (Sandoval et al. 2009, Protti & Sandoval 2019); the Azure-crowned Hummingbird (*Saucerottia cyanocephala*), which uses telephone wires to build its nests (Escobar-Ibáñez & MacGregor-Fors 2015); and the Tropical Kingbird (*Tyrannus melancholicus*), which uses poles and related structures (like metal plates) to nest (pers. obs.).

The consequences of the use of artificial perches for nest building are diverse and depend on both the species and the environment. For example, in species that nest near power lines, such as the White Stork (*Ciconia ciconia*), the use of

Table 1. Total distance traveled, pole abundance, and Great Kiskadee nests per disturbance level (1: gravel roads located within 50 m of forests, 2: gravel roads located more than 50 m from forests, 3: asphalt roads located within 50 m of forests, and 4: asphalt roads located more than 50 m from forests).

Disturbance level	Distance (km)	Poles	Nests
1	9.37	156	10
2	9.11	154	9
3	3.54	135	7
4	7.84	180	17

Table 2. Generalized linear models (binomial family) ranked according to the lowest AIC value explaining the presence and absence of Great Kiskadee nests on poles. Bold text indicates the model that best explained the presence or absence of a nest on a pole.

Model	K	AIC	ΔAIC
Forest + building + pole type	**3**	**217.98**	**0**
Building + pole type	2	220.8	2.8
Forest + pole type	2	220.89	2.9
Pole type	1	223.01	5.0
Forest	1	308.92	90.9
Forest + building	2	310	92.0
Null	1	312.7	94.7
Building	1	313.76	95.8

poles as a nesting resource may negatively affect the reproductive success by electrocution of chicks or adults (Kaluga et al. 2011). Furthermore, nests on utility poles could expose the offspring to supraoptimal developmental temperatures by receiving direct solar radiation, or increase the risk of predation because of unusual perch exposure (Deeming & Reynolds 2015). Alternatively, the use of human constructions for nesting could have a positive effect on reproductive success. In regions where the White Stork population density is high, and therefore the availability of natural perches is limited, a preference was found for nesting on power lines because this allowed more individuals to nest (Janiszewski et al. 2015).

Given the positive and negative consequences of nesting in proximity to power lines (Kaluga et al. 2011, Deeming & Reynolds 2015, Janiszewski et al. 2015), it is surprising how few studies have addressed this topic in other species that use this artificial substrate for nesting. Additionally, this substrate occurs within a matrix that varies from natural to urban, allowing us to compare the effect of landscape characteristics on the nesting substrates. Nesting on a pole that supports power lines near human buildings may increase reproductive success because human activities around poles may reduce predation risk by scaring away potential predators (Greeney et al. 2015). Moreover, proximity to a forest border may decrease reproductive success, because at forest borders the abundance and richness of predators are higher compared to sites far from the forest, increasing the probability of predation (Vetter et al. 2013).

Our goal was to analyze how the landscape and pole characteristics influence nest-site selection in a dweller species, the Great Kiskadee (*Pitangus sulphuratus*, Tyrannidae), along an urban gradient in the south Pacific of Costa Rica. If nesting near human structures protects against predators, we expect to find nests more frequently on poles that are closer to human buildings. If the proximity to a forest increases the risk of nest predation, we expect to find nests more frequently on poles that are far from a forest. We used the Great Kiskadee as our model species because it is very common in the study area, has nests that are easily identifiable (they are roofed and bulky, with a lateral entrance, and at least 1.5 times larger than similar nests), and are commonly built on human-made structures, such as poles that support power lines (Stiles & Skutch 1989).

METHODS

We conducted the study from 29 January to 7 February 2017 in Rincón de Osa, Puntarenas province, Costa Rica (8° 41'34.34''N, 83°29'59.74''W, 100 m a.s.l.), during the breeding season of the study species (Stiles & Skutch 1989). We quantified the presence/absence of Great Kiskadee nests on all utility poles (supporting electricity or telephone wires) along a 30 km transect of gravel and asphalt roads. The study area had a gradient of urban development with three areas: urban, rural, and natural. Urban areas were determined where towns occurred with a high density of houses, supermarkets, and other commercial establishments, with roads mainly made of asphalt and a high density of car traffic. In rural areas, housing was less dense, with the majority of houses separated by 10 to 50 m and usually with barns and pastures, and roads were made up of a mix of asphalt or gravel and had less traffic density. In natural areas, houses are separated by at least 1 km, and the main land use were pastures, plantations (e.g., oil palm *Elaeis guineensis* or *E. oleifera*, and teak *Tectona grandis*), and forests, with roads mainly made up of gravel.

We recorded the presence or absence of Great Kiskadee nests on each pole along the 30 km of roads that cross the three areas. We classified each pole according to the type and quantity of structures they support: electrical wires (thick black cables or aluminum cables), telephone wires (slim black cables), electric transformers, artificial light, and metal plates (Figure 1). We used this classification because it takes into account the number of possible structures that a Great Kiskadee can use for nest building. For example, we classified in different categories poles with three cable lines because they have fewer support structures for nest building than poles with three cable lines and a lamp (Figure 1). We also classified in different categories poles with three cable lines without ceramic insulators because they have fewer support structures for nest building than poles with three cable lines and ceramic insulators (Figure 1).

We measured the distance between each pole and the nearest building, and each pole and the closest forest patch, by georeferencing both structures using a Garmin GPSMAP

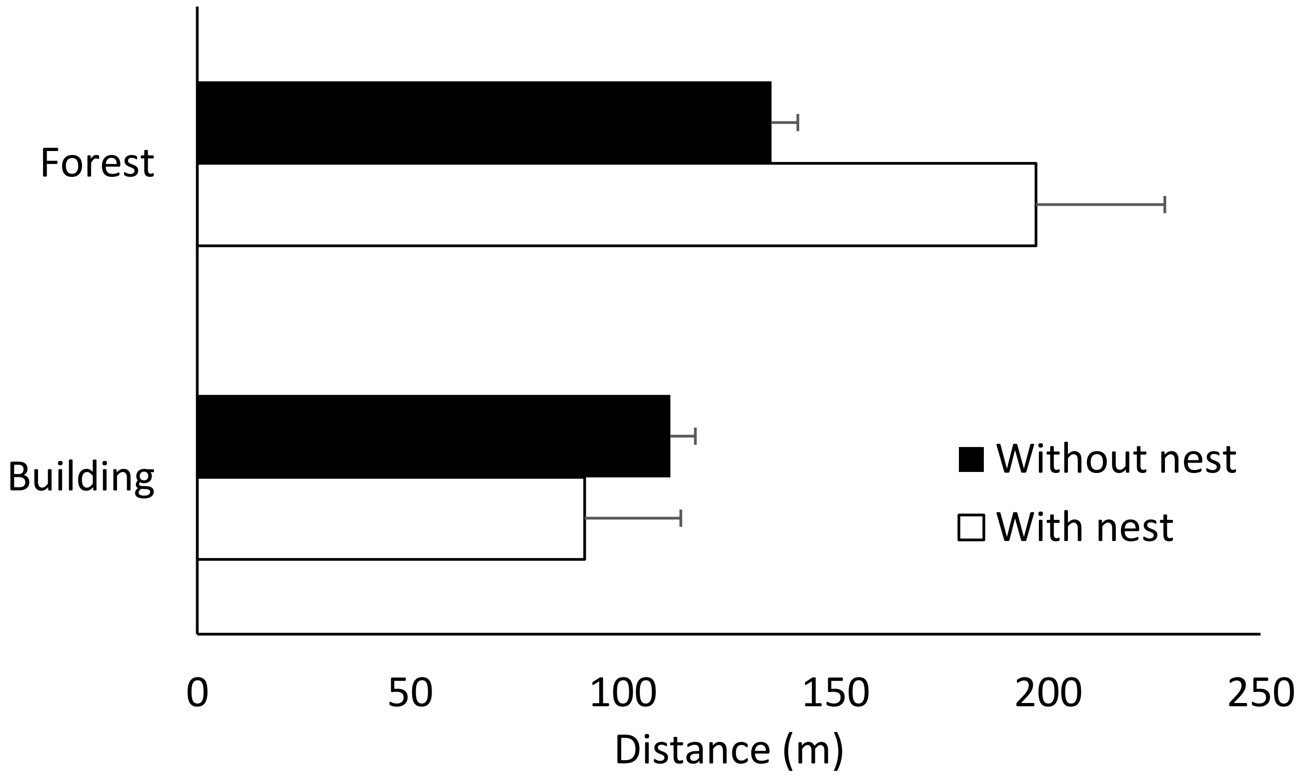

Figure 2. Means and standard error of pole distances to the nearest forest patch (Forest) and human building (Building), with and without nests.

64 S GPS unit (± 3 m precision). We classified as a building each human construction where people work or inhabit (e.g. houses or barns). We also classified between forest patches, all-natural patches (e.g., dense thickets, secondary, or primary forest), or mature plantations of oil palms or timber trees. We defined a mature plantation as one where an understory was found and most trees were more than 5 m in height. We made layers on the map of the study area using Google Earth Pro 7.1.7.2606© to measure the minimum distance between each pole and a wooded patch. To draw the layers, we drew a path that would outline the forest cover around the identified poles using the "route" tool in Google Earth Pro. We used R 3.3.1 and the maptools, spaa, and sp libraries to obtain the distance in meters between each pole and the nearest building.

Pole categories. Wood and metal poles were 6 m tall, and concrete poles 8 m tall. We separated poles according to their main construction material since wood poles are suitable places for cavity nesters and concrete or metal poles are suitable perches for species that build open cup or roofed nests. We separated poles according to the number of metal plates, phone wires, and electrical connectors because a pole with a higher number of plates, cables, or connectors produces more substrates for nesting.

Statistical analysis. To dismiss a pole-density effect according to the level of disturbance of the habitat, we categorized the roads traveled according to the disturbance level of the habitat where each road occurred: category 1 includes gravel roads located less than 50 m from the forest, category 2 includes gravel roads located more than 50 m from the forest, category 3 includes asphalt roads located less than 50 m from the forest, and category 4 includes asphalt roads located more than 50 m from the forest. We counted the number of poles and estimated the density of poles in each disturbance category. All the pole types that we found fewer than five times were included inside a category called "rare".

We conducted a general linear model analysis (GLM) with a binomial error distribution (Hosmer & Lemeshow 2000) to determine which combination of independent variables better explained the presence of a nest on a pole. We used a binomial distribution because our response variable was the presence or absence of nests. We used as predictive variables the minimum distance between the pole and a forest patch (m), the minimum distance between the pole and a building (m), the pole type, and all possible interactions between them. We checked for evenness in the variances and no patterns were found in the distribution of the residuals. Then, we used the Akaike Information Criterion to select the best set of models that explained the presence of a nest on a pole (Burnham & Anderson 2002, Richards 2005). We selected all models that differed by less than two from the first ranked model (Burnham & Anderson 2002, Richards 2005) as the models that better explained the occurrence of a nest on a pole. We used the Hosmer and Lemeshow goodness of fit test to validate the selected models (Hosmer & Lemeshow 2000). We used R statistical software version 3.6.0 (R Core Team 2019) for all statistical analyses.

RESULTS

We found 608 poles of 19 types and 43 Great Kiskadee nests. We never found more than one nest per pole. The highest density of poles occurred in sites with higher disturbance levels, with 38 and 23 poles/km, and both sites with less disturbance had 17 poles/km (Table 1). The best model explaining nest presence, according to the AIC values, was the full model, which included pole type, distance to a building, and forest patch (Table 2). According to this model, the presence of a nest on a pole depended on the pole type, with nests being more frequent on poles with electrical transformers (Figure 1, Table 3). Additionally, there was a greater probability of finding nests on poles far from forests (Z = 2.20, P = 0.03; Figure 2) and near buildings (Z = 2.25, P = 0.02; Figure 2). The Hosmer and Lemeshow goodness of fit test did not exhibit evidence of poor fit ($\chi^2 = 3.87$, df = 8, $P = 0.87$).

DISCUSSION

Bird nest site selection is strongly influenced by the perception of nest predation risk by the parents (Fisher & Wiebe 2006). Therefore, to protect eggs and nestlings, sites with less perceived predation risk will be more selected than sites with a higher perceived predation risk (Eggers et al. 2006). Subsequently, nests on poles near forests can be more accessible to arboreal predators (e.g., monkeys or squirrels) since branches of the surrounding vegetation may facilitate the access to nests, thus reducing nest success. On the other hand, human-modified habitats exhibit lower nest predation than natural ones because human activities deter native predators from approaching nests in urban areas (Béla et al. 2018, Stofberg et al. 2019), as described for the Hooded Vultures (*Necrosyrtes monachus;* Daboné et al. 2019). Thus, the reason Great Kiskadees built nests more frequently on poles away from forests and closer to human buildings could be to reduce nest predation.

Although nesting on exposed perches, such as the poles we observed in the study area, could increase predation risk because they are more conspicuous to visual predators (e.g., birds or lizards), nesting on this type of perch may also offer advantages that improve breeding success. Poles are an elevated structure providing a site with improved predator detection, allowing for early detection of predators and a more active nest defense (Amat & Masero 2004, Van der Vliet et al. 2008). This would benefit Great Kiskadees because they are very aggressive and persistent against predators (Skutch 1976), and early detection may increase the success of nest defense. Another advantage of building nests on a pole that supports power lines is that these lines may cause electrocution to mammals and birds of prey that approach the nest, decreasing potential attacks from these kinds of predators and increasing nest success (Bayle 1999, Janss 2000). In addition, pole height (8 m on average) may limit the access of ground predators (e.g. white-nosed coatis, cats, and rodents) to the nest, also reducing nest predation.

Nests on exposed perches, as observed in the Great Kiskadee, may be affected by higher temperatures because the sun heats the nest directly and for a longer time during the day. This could reduce reproductive success because it increases the temperature beyond optimal for embryo development (Stoleson & Beissinger 1999, Newberry & Swanson 2018). However, the majority of Great Kiskadee nests in our study site built nests on poles with structures that partially blocked solar radiation during the day (i.e., electricity transformers), avoiding direct sun radiation on the nest and thus avoiding excessive temperatures.

In conclusion, we found that the Great Kiskadee nested more frequently on poles far from forests and near buildings, possibly because of the lower risk of predation. In addition, characteristics of the utility pole could be offering advantages that benefit nest success. We suggest that when installing electric lines, bird populations should be considered (i.e. pole designs that favor nesting), especially if the installation of electric lines involves deforestation. For future research, we recommend evaluating bird nest success comparing the thermal characteristics of nests on poles and natural structures. The effect of heat production by an electrical transformer could be altering the development of eggs or chicks, as well as adult incubation behavior; this effect must be analyzed to determine its potential consequences.

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