FACTORS AFFECTING NEST SITE SELECTION AND DAILY NEST SURVIVAL OF KILLDEER (CHARADRIUS VOCIFERUS) IN A HIGHLY URBANIZED ENVIRONMENT.

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ABSTRACT

Killdeer (*Charadrius vociferus)* are a commonly found ground nesting shorebird within urbanized environments in North America. Killdeer population numbers have been decreasing and this study aimed to investigate their nest site selection preferences and Daily Survival Rate (DSR) in Downsview Park, located in Toronto, Ontario, Canada. Nest survival checks were performed on Killdeer nests during the nesting period in 2023 and 2024. I also performed habitat analyses and placed motion-triggered cameras around the park to measure predator and anthropogenic disturbance rates. I found no significant difference in habitat between real nest sites and randomly selected sites, indicating no strong nest site selection preferences. DSR for nests was within range at 0.949 (27% nest success) and decreased as *Canine* activity rates increased. Human activity rates had no effect on DSR. There was no evidence of an ecological trap.

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INTRODUCTION

Habitat selection is a fundamental component of ecology and evolution (Matthiopoulos et al., 2015; Northrup et al., 2022). High-quality habitat generally provides better food resources, increased protection from predators or other environmental factors and more breeding opportunities (Pulliam, 1988) often resulting in a direct positive effect on an individual's fitness and a net positive effect at the population level (Battin, 2004). Poor-quality habitat can have the opposite effect, providing inadequate food resources, fewer breeding opportunities and/or increased mortality with negative effects on fitness (Battin, 2004). As such, the population level effects of variation in habitat quality result in evolutionary pressure on all organisms to evolve mechanisms for adaptive habitat selection (Schlaepfer et al., 2002). For example, Peppermint Shrimp (*Lysmata pederseni*) have been found to use specialized chemical senses to find high quality sponge habitat in expansive coral reefs (Ashur & Dixson, 2019). On a larger scale, numerous species of birds and mammals have evolved long-distance migration in search of high-quality habitats in response to seasonal environments (Alerstam 2003, Acevedo et al. 2022). However, as novel anthropogenic environments arise, these specialized mechanisms may fail and organisms may be forced into poor-quality habitat (Zuñiga-Palacios et al., 2021). When habitat selection mechanisms fail species can fall into an ecological trap (Battin, 2004). The term ecological trap, originally coined by Dwernychuk and Boag in 1972, describes the phenomenon by which organisms preferentially select poor-quality habitats, resulting in variety of negative effects at the population level.

Ecological traps can have devastating effects on all taxa especially in the context of human modified environments (Zuñiga-Palacios et al., 2021). Mayflies (*Ephemera danica*) have been observed to mistake asphalt roads for highly polarized water and lay their eggs on the road where they inevitably failed to hatch (Egri et al., 2017). Glass bottles may be appealing as a sheltered habitat for insects and small vertebrates, however, once they enter the bottles, they may become physically trapped and drown when it rains or be cooked in the sun (Kolenda et al., 2022). Hundreds of dead insects and small mammals can be found inside discarded glass bottles in this manner (Kolenda et al., 2022). One of the first demonstrations of an ecological trap examined the nesting association between Lesser Scaup (*Aythya affinis*) and Ring-Billed Gulls (*Larus delawarensis*) whereby the Lesser Scaup could benefit from the collective predator mobbing behaviours of the gulls during nesting but after hatch, departing ducklings risked predation by the very gulls that provided them with protection during nesting (Dwernychuk & Boag, 1972). More recently, anthropogenic elements have become a dominant source of ecological traps. Anthropogenic architecture, such as migratory fish ladders that were engineered specifically to help fish, may become ecological traps if not implemented correctly, (Pelicice & Agostinho, 2008). Migratory fish ladders have been installed throughout Brazilian river impoundments to help facilitate the passage of migratory fishes through electrical power stations. Migratory fish that would normally spawn in small streams further downriver are encouraged to migrate through these ladders into upstream hydroelectric lakes, forcing them to spawn in poor-quality deep limnetic habitat. These migratory fish are unable to move freely and return after crossing the ladder resulting in a negative effect on populations (Pelicice & Agostinho, 2008). Ecological traps may affect animals of all sizes. Brown bears (*Ursus arctos*) are well known to frequent landfills and human settlements for easily available food sources (Penteriani et al., 2018). This behaviour becomes a trap because the food found at these sites is of low quality for the bears and may have adverse health effects (Penteriani et al., 2018). There are also the lethal dangers that anthropogenic elements such as vehicles, hunters and animal control pose to brown bears (Penteriani et al., 2018). Traps can range from lethal, as seen in the mayfly example, to subtle, as seen in the adverse effects on the health of brown bears. The population effects of ecological traps vary with species life history. Species with rapid reproductive cycles and large numbers of offspring are more resistant to the population decreases that can be caused by traps, whereas populations of long-lived animals with few offspring can be devastated by the effects of an ecological trap, resulting in population collapses (Zuñiga-Palacios et al., 2021).

The United Nations predicts 68% of the world's population will be living in urban centers by the year 2050 (United Nations, 2019). This rapid increase in urbanization will create Urban Ecological Novelties (UENs) that come in the forms of new food sources, urban architecture and novel anthropological habitat analogs (e.g. man-made lakes, parking lots, urban parks, etc. (Zuñiga-Palacios et al., 2021). It is largely unknown how species will utilize these UENs, and itis important to take a preventative approach to identify when UENs become traps (Lowry et al., 2013). Urban habitat generally has higher heterogeneity compared to non-urban habitat and urban bird populations can have increased phenological variation and show more plastic responses to accommodate this type of habitat (Capilla-Lasheras et al., 2022). Urban bird populations nest earlier, have smaller clutch sizes and exhibit lower nestling survival than their non-urban conspecifics as a result (Capilla-Lasheras et al., 2022). Despite the drawbacks of urban habitats, there are several synanthropic species that utilize UENs and have largely overcome the heterogeneity of urban habitat. Barn swallows (*Hirundo rustica*), are one such species that has adapted to nesting in urban structures and in close proximity to human activity (Wang & Hung, 2019). American robins (*Turdus migratorius*), one of the most abundant thrush species in North America, also nest in close proximity to humans, nesting in urban parks and even residential buildings (Malpass et al., 2017).

Killdeers (*Charadrius vociferus*) are a species of ground nesting shorebird that are abundant throughout North America and make a yearly migration from as far as South America to Canada for breeding (Figure 1). Killdeer are an ideal study species to investigate the presence of ecological traps in urban environments because they are ubiquitous in urban green spaces. Historically, Killdeer, like many shorebirds, nest near bodies of water, open grasslands, rocky outcrops and sandy terrain; ideal areas for feeding on invertebrates. Killdeer nests are often found in urban green spaces and parking lots which are UENs that are analogous to the habitats they prefer (Zuñiga-Palacios et al., 2021). Like many other ground nesting shorebirds, Killdeer show a variety of anti-predator behaviours and nest defences techniques. They use broken wing displays in which they fain an injury and draw predators away from the nest site (Humphreys & Ruxton, 2020). They also employ egg nest camouflage through spotted and irregular patterns on their eggshells that mimic the habitats they use for nesting (Kostoglou et al., 2021; Skrade & Dinsmore, 2013).

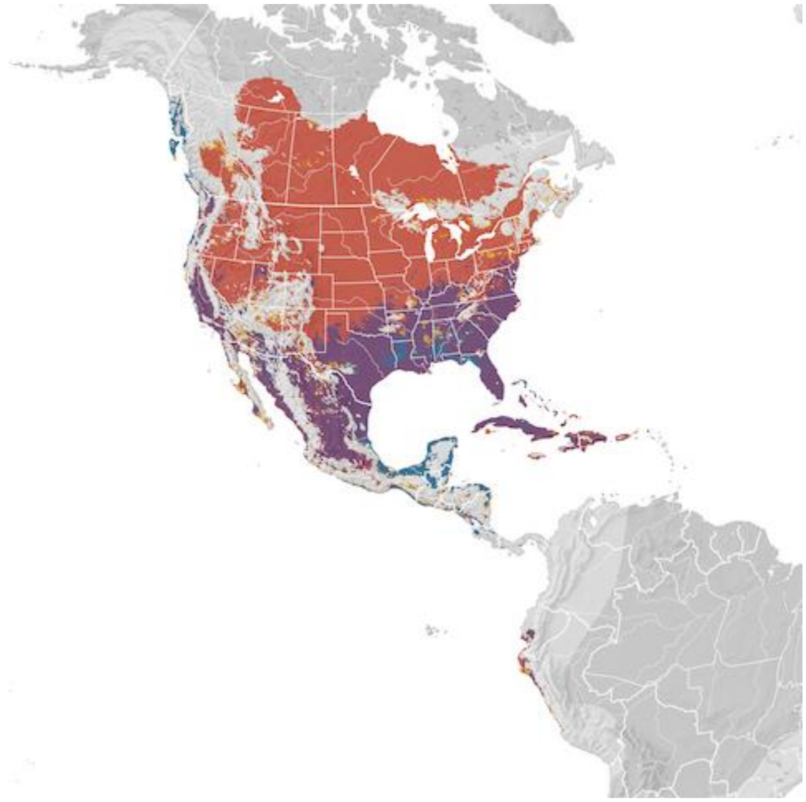

Figure 1 - Killdeer Range Map eBird data from 2008-2022. Purple indicates locations where the Killdeer are present year-round, red indicates the breeding season, blue indicates the non-breeding season, and yellow indicates locations where the species is present during the pre-breeding and post-breeding seasons. Areas of light gray indicate species absence (or very rare occurrence). Areas of darker gray indicate areas in which predictions could not be made due to a lack of data. Estimated for 2022. Fink, D., T. Auer, A. Johnston, M. Strimas-Mackey, S. Ligocki, O. Robinson, W. Hochachka, L. Jaromczyk, C. Crowley, K. Dunham, A. Stillman, I. Davies, A. Rodewald, V. Ruiz-Gutierrez, C. Wood. 2023. eBird Status and Trends, Data Version: 2022; Released: 2023. Cornell Lab of Ornithology, Ithaca, New York. https://doi.org/10.2173/ebirdst.2022

The objectives of this study were to (1) evaluate nest site selection of Killdeer, (2) estimate daily nest survival rates of Killdeer and (3) investigate the factors affecting Killdeer nest survival in a highly urbanized environment. I hypothesized that Killdeer would preferentially select nesting habitat that avoids human disturbance by nesting further from roads and trails and in sites that have lower predation risk with lower vegetation density and further from sight blocking terrain (SBT). I also hypothesized that daily nest survival of Killdeer would decrease with high anthropogenic disturbance and that anthropogenic disturbance such as humans, vehicles and dogs would be the most important factor affecting daily nest survival in Killdeer.

METHODS

Study Site

The study was conducted in Downsview Park, located at 70 Canuck Avenue, North York, Toronto, Ontario, Canada (43.7440° N, 79.4841° W) from April 1st to August 10th, in 2023 and 2024. Downsview Park is an urban green space that was created in 1995 when the former Downsview Canadian Armed Forces base was decommissioned and converted into an urban park that is owned and operated by Canada Land Company (https://downsviewpark.ca/our-story). Downsview Park occupies 118-hectares (281 acres) of green space just North of the Toronto downtown core and is one of the busiest parks in Toronto with almost 200,000 visitors a year (https://downsviewpark.ca/our-story). Downsview Park is a highly maintained park that contains several man-made and maintained ecosystems. The park consists of a variety of ecosystems ranging from highly disturbed event spaces that host annual festivals to small bodies of water, grasslands, hillocks, fields, forests, agricultural lands, and even an off-leash dog park. This varied landscape provides habitat for many species of mammals and birds, including larger mammalian predators like Racoons (*Procyon lotor) and* Coyotes (*Canis latrans*), and raptors such as Osprey (*Pandion haliaetus*) and Red-tailed Hawks (*Buteo jamaicensis*). Shorebirds such as Killdeer (*Charadrius vociferus)* frequently nest in open fields, plowed fields and event spaces where water sources for feeding are available in the park.

Study Species

Killdeer are a species of ground nesting shorebird that are abundant throughout North America and migrate annually to as far as the Canadian subarctic for breeding (Figure 1) (Jackson & Jackson, 2020; Birdlife). Killdeer, like many shorebirds, nest near bodies of water but prefer open grasslands, rocky outcrops, and sandy terrain - ideal areas for feeding on invertebrates which make up most of their diet. Unlike many shorebirds Killdeer have a remarkable tolerance for human disturbance and frequently nest in close proximity to human activities (Jackson & Jackson, 2020).

Killdeer perform yearly migrations ranging from as far south as Ecuador and Panama to the North American Subarctic (Figure 1; Jackson & Jackson, 2020). They perform a medium-distance partial migration traveling during the day and night in flocks of 6 to 30 individuals (Jackson & Jackson, 2020). Breeding starts at 1 year of age for both sexes. After arriving at the breeding grounds the formation of breeding pairs can begin as early as February and March (Jackson & Jackson, 2020). Killdeer breeding begins with pair formation after arriving at the breeding grounds after migration. Nest sites are chosen ≥6 days before the egg laying period and males initiate the creation of a nest scrape (Jackson & Jackson, 2020). Nests found in Downsview Park were constructed using a variety of materials including gravel, small rocks, mulch chips, small sticks, bits of plastic and discarded cigarette filters (Figure 2). Eggs are laid 1 egg per day in clutches of 3 to 4 and on rare occasions greater than 4. Eggs are generally tan or cream coloured with irregular darker-brown blotches and have a radially symmetrical teardrop shape. Clutches of 3 to 4 eggs are often arranged in the nest with their narrow ends pointing inward resembling a clover leaf (genus *Trifolium*). Eggs are incubated biparentally for 22-28 days after which the precocial and nidifugous chicks are guarded by the parents until they are able to fly at 20 to 31 days after hatching (Jackson & Jackson, 2020; Lensington, 1980). Pairs have multiple clutches per year and can have up to 3 per season and 2 successful clutches per pair is common (Jackson & Jackson, 2020).The main ground predators for Killdeer and other *Charadriidae* shorebirds are *Procyonids*, *Canidae* and *Mustelid* families (Dorsey et al., 2025; Isaksson et al., 2007; Jackson & Jackson, 2020; Johnson & Oring, 2002; Nol & Brooks, 1982). Avian predators include, Gulls (*Larus* spp.), American Crow (*Corvus brachyrhynchos*), Common Raven (*Corvus corax*) and some raptors (*Accipitridae* spp) (Jackson & Jackson, 2020; Nol & Brooks, 1982).

Figure 2– Killdeer nest with 2 eggs and 1 newly hatched chick.

Nest Searching and Monitoring

Nesting areas were searched daily during the laying and incubation period each year. Nest searching and subsequent checks were performed between the hours of 07:00 and 20:00 EST. When adult Killdeer were located, they were observed for potential nesting behaviours such as broken wing displays or alarm calls. If a nest was suspected, the observer backed away from the bird and observed the bird with 8x40 binoculars until it returned to the nest. When necessary, the observers hid underneath a camouflage blanket until the Killdeer returned to the nest. If the exact location of the nest could not be determined from a distance, the general nesting area was systematically searched by walking transects in the suspected nest area until the nests were located.

Once nests were found, latitude and longitude were recorded with a Garmin® GPSMAP® 64st Series GPS and the sites were marked with a natural marker (stone or feather) placed at 3m and 5m from the nest in order to facilitate subsequent nest visits. If the nest was found during incubation (4 eggs), 2 eggs were floated in a clear cup of lukewarm water to estimate incubation stage using the floatation method (Liebezeit et al., 2007). Nests were visited every 5 days during incubation, then daily for 2 days prior to the estimated hatch date to confirm hatch of at least 1 chick. Nests were not visited on days with heavy rain in order to reduce stress on the incubating Killdeer and avoid causing temperature changes on the eggs when the adults performed distraction displays. Nests with at least 1 egg surviving to hatch were considered to be successful (Mayfield, 1975). Chick survival was not monitored beyond hatching.

Motion triggered cameras (Moultrie® A-Series Digital Game Cameras, Model "MCG-13202") were also set up near nests, when possible, to capture footage of predators and to verify nest fate. Cameras were placed between 0.3 meters and 0.6 meters from the ground on a tree, fence or pole within 5 meters of the nest, directly facing the nest. All efforts were made to hide the cameras to avoid detection by predators (McKinnon & Bêty, 2009) and theft by humans. Low brush and plants within the camera's field of view were cleared (when possible) to reduce false triggers. Nighttime photos used an invisible infrared LED flash to illuminate the target. Cameras were set to take three pictures in rapid succession with a one-minute delay when triggered by movement. Pictures were taken at the high-resolution setting and checked every four days for SD card storage space and battery level. Cameras in areas with high human traffic were hidden behind vegetation or placed on secure objects with cables, when possible, to avoid theft. Cameras were not placed on nests that were in very public areas to avoid additional stress on the nesting birds created by curious park visitors. Cameras were collected upon hatch or nest failure. Camera footage of failed nests was searched for signs of predation. Predators seen near a nest preceding a predation event were assumed to be the predator when no direct evidence of the predation event was captured. Partial identifications of predators were checked by a second researcher and when predator identification was unclear, the predators were classified as large mammalian, small mammalian or avian predators.

Covariates

Predator and Human Activity Rates

Mammalian and avian predator activity rates were estimated using motion-triggered cameras (Moultrie® A-Series Digital Game Cameras, Model "MCG-13202") set in 6 stratified locations to cover a variety of different habitat types (Figure 3). Site 1 was located near an educational centre where tour groups are frequently guided through the park. Site 1 habitat was moderately wooded with several clearings and an intermediate level of landscaping by the park staff. Site 2 was located near a large field/event space that had park maintenance vehicles regularly travelling through it. The habitat included a large, frequently mowed lawn with large patches of gravel and very few trees. Site 3 was located near a pond which had lower levels of landscaping. The habitat consisted of bullrushes (*Typhaceae*) interspaced with dogwoods (*Cornaceae*) and surrounded by low growing thistle plants (*Cirsium*). Site 4 was located within an orchard near the periphery of the park. This site was heavily landscaped by park staff and was bordered by a busy street. The habitat consisted of dwarf fruit trees and decorative shrubs planted in rows of mulch. Between the rows were mowed lawns. There was also a concrete building containing a public washroom situated in the middle of these highly tended gardens. Site 5 was located within the community/commercially run farm. The farming plots mainly contained rows of planted crops with several greenhouses throughout the area. Vehicles and machinery were seen in the area infrequently and most of the plots were tilled by hand. The entire area was surrounded by chest high fences with large gates that were almost continuously open to the public. Site 6 was located within the most densely wooded area of the park. The habitat consisted of large trees, some of which were >0.33 meters in diameter. The forest was dissected with many dirt paths which were often bordered by wooden railings to deter pedestrians from leaving the trails.

In 2023, 6 cameras were deployed for 2 sessions between the dates of June 19th to 22nd and July 10th to 14th continuously. In 2024, 6 cameras were deployed for 2 sessions between the dates of June 5th to 19th and July 17th to 31st continuously. Cameras were placed between 0.3 meters and 0.6 meters from the ground on a tree, fence or pole. Nighttime photos used an invisible infrared LED flash to illuminate the target. Cameras were set to take three pictures in rapid succession (approximately 0.7 seconds between photos) with a one-minute delay when triggered by movement. Field of view was 60 m from the camera location. Low brush and plants within the camera's field of view were cleared (when possible) to reduce false triggers. Pictures were taken at the high-resolution setting and checked every four days for SD card storage space and battery level. Camera positions were relocated between sessions to avoid systematic predator false negatives. Camera positions were repositioned no more than 100 m from each other between sessions. A 5-minute time to independence interval was applied to all photos.

Figure 3 – Satellite photo of Downsview Park using Google Earth showing the study area and labels 1-6 indicating the activity monitoring sites.

Predators captured on the motion-triggered cameras within 60m of the camera were counted and identified to class and species when possible. When blurry and incomplete images of predators were captured, the shape and posture of the animal was compared to that of animals that are known to frequent Downsview Park. Each individual of a species captured on the camera was counted as 1 event. Individuals of the same species that were captured in the same five-minute period were counted only once (5-minute time to independence filter).

Each human that was captured on camera was counted as 1 event. Individual people were counted as a separate event for every complete 5 minutes they were captured on the cameras. Individuals that left the field of view and then returned were not counted again as a new event until 5 minutes from the initial capture (5-minute time to independence filter). Babies in strollers were counted as individual people. People walking with a domestic dog (*Canis lupus familiaris)* were counted as both a human and domestic dog event. Sightings of lone domestic dogs and human-accompanied domestic dogs where not counted as separate categories because the lone domestic dogs were assumed to have a nearby attendant that was out of the camera's view. There were no observations of feral or stray domestic dogs during the study period. Vehicles were defined as any motorized device that was self-propelling and operated by a person. Remote control drones were not recorded. People that were within vehicles, even if visible (i.e. on a motorcycle), were not counted towards human activity. All images of humans were deleted after analysis was completed. The number of events captured per camera were divided by the total number of camera hours to estimate an activity rate per species, per hour. Predator and human activity rates for each Killdeer nest were based on data from the camera station that was located the closest to the nest.

Habitat

Vegetation Density

Vegetation density was estimated within 20 X 20-meter quadrats centred on each nest (or the nearest GPS coordinate when the nest cup was no longer present). Both trees and shrubs were considered and were defined as follows. Trees were defined as any plant with a central wooded stock that was > 15cm in diameter at breast height. Shrubs were defined as any multibranched and wooded plant like dogwoods plants in the family *Cornaceae* with a height of at least 50 cm. Sumac plants (*Rhus coriaria*), which are found in great abundance at the study site, were considered to be shrubs and were counted by how many complete $30cm^2$ blocks were present. Each $30cm^2$ block was counted as a single shrub. When the edge of the quadrat cut through the diameter of large trees or shrubs, they were only included if the center point of the tree/shrub was on the inside of the quadrat. Vegetation density was calculated as number of trees and shrubs per meter squared.

Sight Blocking Terrain

The nearest sight blocking terrain (SBT) was recorded as an index of the ability to detect a potential predator approaching the nest. Sight blocking terrain was defined as any man-made structure or woody plant within 50m of the nests that exceeded 50cm in height and obstructs a portion of the field of view of an incubating Killdeer. Terrain that is closer to the nest will naturally block a larger proportion of the field of view, much like moving a large box closer to an observer. This would therefore lower the distance and potentially reduce predator detection range. Measurements were taken from the center of the nest cup to the SBT using a 50m tape measure that was held parallel to the ground between two researchers.

Indirect Human Disturbance

Indirect human disturbance was estimated by measuring the distance of the nest to the nearest road and the nearest trail. Distance measurements were taken after the nest fates had been determined. The distance from the center of the nest cup to the edge of the nearest road or path was measured using a 50m tape measure held parallel to the ground between two researchers. Distances that exceeded 50m were determined using Google Earth Pro's line measuring tool. Roads were defined as any paved or gravel thoroughfare which was used by vehicles such as cars or park staff utility vehicles. Paths were defined as any paved or gravel thoroughfare which were used primarily by pedestrians and were not commonly driven on by vehicles.

Random sites

The above covariates were all collected at 15 random sites each year in August. Random sites were selected by generating evenly distributed random real numbers using Microsoft Excel (2016) and the built-in "RAN" function (Mersenne Twister algorithm (MT19937)) and creating random GPS coordinates within the area of the park. When points fell on private land that was not accessible to the research team, the point was removed, and the site randomization process was repeated. The random points were found within the study site using a handheld GPS (Garmin® GPSMAP® 64st Series GPS) and once the researcher was within 1 m of the site a flag was placed in the ground, and all measurements were made from that point. When the random points were located in water, the points were moved to the nearest accessible point and measurements were made from the new point.

Statistical Analysis

All variables were tested for pairwise correlations using a Spearman's rank correlation in program R as the data were not normally distributed. Covariates with pairwise correlations>±0.60 were not used in the same models to reduce multicollinearity (Figure 4). Human activity rates (r=0.69) and coyote activity rates (r=0.85) were found to be highly positively correlated with year (Figure 4). Coyotes were also found to be highly positively correlated with total predator activity (r=0.90) and large predator activity (r=0.97; Figure 4). Human activity rates were positively correlated with vehicle activity rates (r=0.89), dog activity rates (0.61) and coyote activity rates (r=0.77; Figure 4). Large vegetation density and distance to SBT showed a weak negative correlation (r= -0.55; Figure 4).

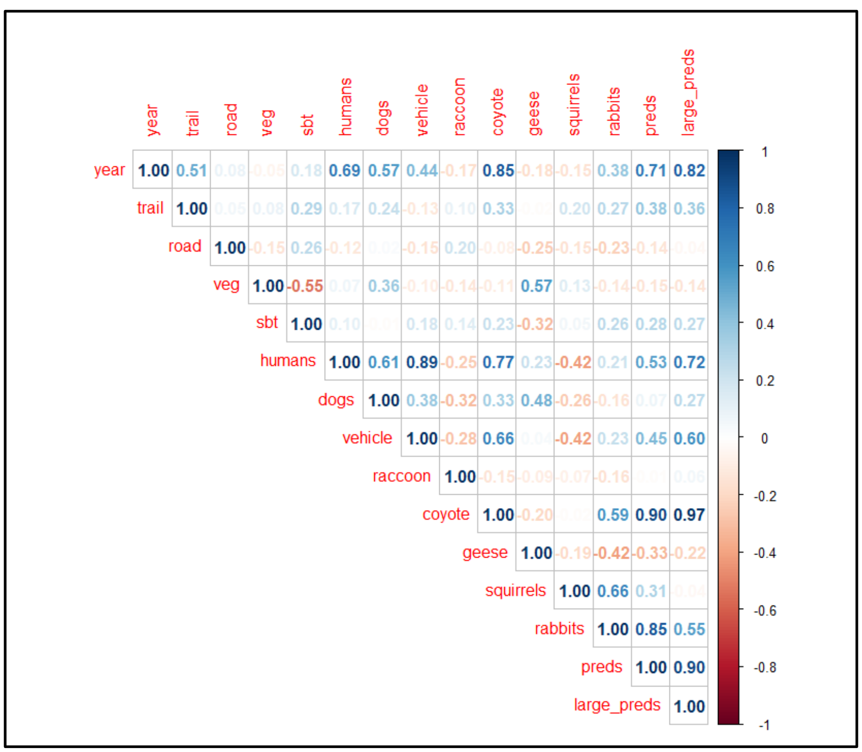

Figure 4 - Heat map showing the covariance of all nest variables using the spearman method.

Habitat Selection

To assess habitat selection of nest sites, a non-parametric Mann-Whitney U test was performed to test if there was a significant difference in habitat measures between Killdeer nest sites and random sites located throughout the park. The test was performed using the program R (R Core Team, 2024). Additionally, a Bonferroni correction was applied to the 4 habitat variables resulting in a corrected p-value of 0.05/4 = 0.0125.

Describing Variation in Daily Nest Survival

Variation in daily nest survival was assessed by generating 16 a-priori models (Table 1) using Program RMark (Laake, 2013). Models were compared using Akaike information criterion corrected (AICc) and the top model was identified as the model with the lowest AICc (Burnham & Anderson, 2004). Models within <2.0 ΔAICc of the top model were considered competitive.

Nest success was estimated using the following formula:
Nest success = $DSR^{\text{(average incubation time)}}$
(Mayfield, 1975).

For where average incubation time for Killdeer was:
(22 + 28) / 2 =25
(Jackson & Jackson, 2020).

All means are presented ± SD unless otherwise stated.

Table 1: Model List for RMark daily survival rate analysis

	Hypotheses	Candidate Models
1	Null	Intercept
2	Year	Intercept + Year
3	Timing of Breeding	Intercept + Estimated Hatch Date
4	Predator Activity Rates	Intercept + Total Predators
5	Direct Human Disturbance	Intercept + Human
6	Vegetation Density	Intercept + Veg
7	Predator Detection	Intercept + SBT
8	Vehicle Disturbance	Intercept + Vehicle
9	Domestic Dogs	Intercept + Dogs
10	Confirmed Predators	Intercept + Coyotes
11	Non-predator interactions	Intercept + Canada Goose
12	Indirect Human Disturbance	Intercept + Distance to Trail + Distance to Road
13	Habitat	Intercept + SBT + Veg
14	Canines	Intercept + Dogs + Coyotes
15	Disturbance	Intercept + Humans + Distance to Trail + Distance to Road + Dogs + Geese
16	Full Model	Intercept + All Variables (minus correlated)

RESULTS

A total of 16 nests were monitored in 2023, and 14 in 2024. The average lay date in 2023 was May 15 ± 20.5 and the average lay date in 2024 was May 9 ± 26.8. The proportion of monitored nests that successfully hatched at least one chick was 75.0% in 2023 and 28.6% in 2024. One of the monitored nests in 2024 was found to have 7 eggs and is one of few documented occurrences of nests containing more than 4 eggs. Of the 4 nests monitored with cameras (2 each year), predation events were only recorded at 2 nests, with coyotes as the confirmed predator (Figure 5). Unexpectedly, park management placed 2 exclosures on Killdeer nests (1 each year) to protect nests from human trampling. The first exclosures consisted of a wooden cube frame of approximately 1 meter surrounded on 4 sides and no roof, with thin, orange plastic mesh fencing enclosing it. There were 4 entrances cut out of the snow fence at ground level (20cm high) for the birds to enter and exit. The second exclosure was constructed of 2 flagpole stands that were strapped together resembling an L shape that was enclosed with thin, orange plastic mesh fencing that covered half of the nest. These 2 exclosure protected nest were included in the analysis because the evidence of the affect of exclosures is unclear for Killdeer (Johnson & Oring, 2002; Nol & Brooks, 1982).

In 2023, nests were located in areas of relatively low average vegetation density of 0.01 ± $0.03m^2$, at an average distance of 7.00 ± 6.67 m from walking trails and 25.72 ± 16.78 m from roads (Table 2). The average distance of nests to sight blocking terrain was 10.56 ± 7.05 m in 2023. In 2024, nests were located in areas of relatively low vegetation density of 0.01 ± $0.01/m^2$, at an average distance of 18.20 ± 12.71 m from walking trails and 29.99 ± 17.83 m from roads (Table 2). The average distance of nests to sight blocking terrain was 16.68 ± 14.09 m in 2024.

Table 2: Descriptive statistics of nest habitat variables between the years of 2023 and 2024 in Downsview Park Toronto, ON, Canada

Year	2023 (n=16 nests)			2024 (n=14 nests)			
	Mean ± SD	Min	Max	n	Mean ± SD	Min	Max
Distance to Trail	7.00 ± 6.67	0.05	22.50	14	18.20 ± 12.71	2.30	48.60
Distance to Road	25.72 ± 16.78	2.90	57.00	14	29.99 ± 17.83	14.60	75.00
Vegetation Density	0.01 ± 0.03	0.00	0.0875	14	0.01 ± 0.01	0.00	0.04
Sight Blocking Terrain (SBT)	10.56 ± 7.05	0.15	24.00	14	16.68 ± 14.09	0.05	46.05

Camera traps were deployed at 6 sites and had an average number of trapping days of 7.1± 4.7 (Table 3). A total of 24 camera trapping sessions were initiated and 3 sessions were lost due to equipment damage and theft (Table 3). The average activity rate of coyotes per hour in both years was very low at 0.00 ± 0.00 coyotes/hr in 2023 (only 2 total coyote events) and 0.02 ± 0.01 in 2024 (5 total coyote events; Table 4). Average human activity rates showed high variability with an average activity rate of 0.87 ± 0.91 in 2023 and 4.76 ± 3.01 in 2024 (Table 4). Dogs were recorded at an average rate of 0.02 ± 0.02 in 2023 and 0.07 ± 0.11 in 2024. Vehicles were recorded at an average rate of 0.07 ± 0.07 in 2023 and 0.18 ± 0.11 in 2024. Animal activity rates were generally low with raccoons and squirrels having the lowest rate of approximately 0.00 for both years during the collection period. Geese were recorded at an average rate of 0.44 ± 0.78 in 2023 and 0.13 ± 0.32 in 2024. Rabbits were recorded at an average rate of 0.02 ± 0.04 in 2023 and 0.03 ± 0.02 in 2024.

Table 3: Camera trap efforts presented by site

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Average Camera Trapping Days	7.5±5.4	10.0±6.1	4.3±2.6	6.5±5.0	6.3±5.4	8.4±6.6
Total # Photos	30511	7425	6746	16675	15028	2742
Successful Cameras	4	2	3	4	4	4
Cameras Broken/Stolen	0	2	1	0	0	0

Coyote Predation Events

The coyote predation event in 2023 took place on June 23rd at 3:20 am at a nest located in a gradient that was made of heavy gravel and decorative grasses in the South parking lot of Downsview Park. The predation event was approximately 4 minutes in length. The incubating adult Killdeer was flushed from the nest and then, less than a minute later, a four-legged animal resembling a coyote lowered its mouth to the nest. The coyote then left the site and 3 minutes later the adult Killdeer returned to the nest, inspected the nest and then left, not to be seen again. On the subsequent nest visit, no adult or eggs were found at or around the nest site.

The predation event in 2024 took place on May 9th, at 09:20pm at a nest located in a garden row, that was within the orchard section of the park. The predation event was approximately 3 minutes in length. The incubating adult Killdeer flushed from the nest and less than a minute later a coyote approached the nest. It sniffed near the nest for a moment and then tipped its snout towards the nest, presumably to eat the eggs (Figure 5). It then looked up turning towards the camera, then left. The adult Killdeer returned to the nest 3 minutes later, inspected the nest and then left, not to be seen again. On the subsequent nest visit, no adult or eggs were found at or around the nest site.

Figure 5 - Coyote predating a Killdeer nest captured using motion-triggered camera

Table 4: Descriptive statistics of activity rates between the years of 2023 and 2024 in Downsview Park Toronto, ON, Canada

Year	2023			2024			
	Mean ± SD	Min	Max	n	Mean ± SD	Min	Max
Human Activity Rate	0.87 ± 0.91	0.26	2.39	14	4.76 ± 3.01	1.14	7.26
Dog Activity Rate	0.02 ± 0.02	0.01	0.06	14	0.07 ± 0.11	0.02	0.32
Vehicles Activity Rate	0.07 ± 0.07	0.00	0.19	14	0.18 ± 0.11	0.03	0.27
Raccoon Activity Rate	0.00 ± 0.00	0.00	0.01	14	0.00 ± 0.00	0.00	0.00
Coyote Activity Rate	0.00 ± 0.00	0.00	0.00	14	0.02 ± 0.01	0.00	0.03
Geese Activity Rate	0.44 ± 0.78	0.00	1.75	14	0.13 ± 0.32	0.00	0.89
Squirrels Activity Rate	0.00 ± 0.00	0.00	0.01	14	0.00 ± 0.00	0.00	0.01
Rabbits Activity Rate	0.02 ± 0.04	0.00	0.10	14	0.03 ± 0.02	0.00	0.04
Predator Activity Rate	0.00 ± 0.00	0.00	0.01	14	0.02 ± 0.01	0.00	0.03
Large Predator Activity Rate	0.00 ± 0.00	0.00	0.01	14	0.02 ± 0.01	0.00	0.03

Habitat Selection

Across both years, Killdeer nest habitat did not significantly differ from habitat at randomly selected sites (Table 5). Though not significant, there was a trend for Killdeer nests to be located closer to trails and in areas of lower vegetation density when compared to random sites (Table 5; Figure 6).

Table 5: Habitat Variables for real nests versus random sites in Downsview Park, Toronto, ON.

	Distance to Trail (m)		Distance to Road (m)		Vegetation Density		SBT (m)	
	Random	Real	Random	Real	Random	Real	Random	Real
Mean	22.21	12.20	31.87	27.78	17.30	4.21	14.19	13.43
SD	23.537	11.611	28.336	17.714	26.349	9.0364	15.943	11.534
n	30	28	30	28	30	28	30	28
W	297.5		416.5		300		455	
P-Value	0.05763		0.9628		0.03948		0.5914	

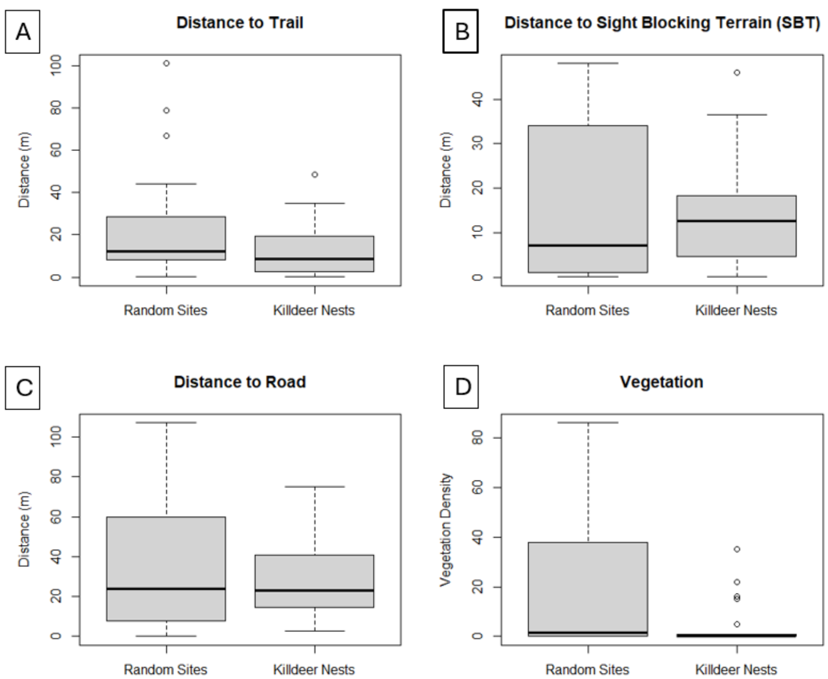

Figure 6 - Killdeer nest site habitat selections compared to randomly selected sites within Downsview Park, Toronto, Ontario. A) Distance to nearest trail that was not paved and was not used by vehicles. B) Distance to the nearest piece of sight blocking terrain. C) Distance to nearest road that was used by vehicles. D) Density of large vegetation (trees and shrubs) that was within a 20m x 20m quadrat around the site.

Daily Survival Rate

Across both years, the constant daily survival rate (DSR) was relatively low at 0.949, meaning that on average across the incubation period of 25 days, likelihood of a nest producing at least one chick (nest success) was 27.0%. Variation in daily nest survival was best described by a model including activity rates of dogs alone (Table 6). This top model indicated a negative effect of dog activity on daily nest survival (Table 7). A second model fell within 1.39 AICc of the top model and included both activity rates of dogs and coyotes (Table 6). This model indicated a negative effect of dogs and a negative effect of coyotes (Table 8).

Table 6: List of model selection results describing variation in DSR.

Model Name	Model	npar	AICc	ΔAICc	Weight	Deviance
Domestic Dogs	S(~dogs)	2	44.9298	0	0.61620	40.8776
Canines	S(~dogs + coyote)	3	46.3241	1.39439	0.30685	40.2193
Disturbance	S(~humans + trail + road + dogs + geese)	6	49.2396	4.30982	0.07143	36.8679
Non-predator interactions	S(~geese)	2	58.0841	13.1543	0.00086	54.0319
Year	S(~year)	2	63.8236	18.8938	4.86E-05	59.7714
Indirect Human Disturbance	S(~trail + road)	3	64.4843	19.5545	3.50E-05	58.3795
Null	S(~1)	1	64.6903	19.7606	3.15E-05	62.6730
Vegetation Density	S(~veg)	2	65.2066	20.2769	2.44E-05	61.1544
Predator Detection	S(~sbt)	2	66.1646	21.2348	1.51E-05	62.1124
Breeding Timing	S(~hatchdate)	2	66.4945	21.5647	1.28E-05	62.4423
Vehicle Disturbance	S(~vehicle)	2	66.5944	21.6646	1.22E-05	62.5422
Predator activity rates	S(~preds)	2	66.65274	21.72299	1.18E-05	62.60056
Direct Human Disturbance	S(~humans)	2	66.72121	21.79146	1.14E-05	62.66903
Confirmed Predators	S(~coyote)	2	66.72512	21.79537	1.14E-05	62.67294
Habitat	S(~sbt + veg)	3	67.10763	22.17789	9.42E-06	61.00283

Table 7: Parameters of the top ranked model explaining variation in DSR.

Variable	estimate	se	lcl	ucl
S:(Intercept)	4.664847	0.6232127	3.443351	5.886344
S:dogs	-66.855601	17.8756180	-101.891810	-31.819390

Table 8: Parameters of the second ranked model explaining variation in DSR

Variable	estimate	se	lcl	ucl
S:(Intercept)	5.139739	0.9372245	3.302779	6.976699
S:dogs	-73.232540	20.7279350	-113.859290	-32.605786
S:coyote	-25.976614	32.6975460	-90.063806	38.110578

DISCUSSION

I hypothesized that Killdeer would select nesting habitat that reduced direct or indirect anthropogenic disturbance. Contrary to my predictions, I found no evidence of anthropogenic avoidance during nest site selection as there was no statistically significant difference in distance to trails or roads between randomly selected sites and the observed Killdeer nesting sites. There was a trend towards the selection of nests in areas of lower vegetation density, but the results were not significant after applying the Bonferroni correction. I also hypothesized that daily nest survival of Killdeer would decrease as anthropogenic disturbance increased and that anthropogenic disturbance would be the most important factor explaining daily nest survival in Killdeer. My data only partially supported this hypothesis as variation in daily nest survival was best described by activity rates of domestic dogs, which is linked to human activity. All other direct and indirect effects of human disturbance were not present in any of the top models. Daily nest survival decreased as dog activity rates increased and is likely due to increased stress on nesting adults caused by more frequent and longer lasting nest flushes. A further competitive model including the additive effect of activity rates of dogs and coyotes also indicated negative effects of both on daily nest survival. Overall, DSR across both years was 0.949 (27.0% estimated nest success rate) which is relatively high but aligns with previously reported estimates for Killdeer in rural and urban environments (Atuo et al., 2018; Johnson & Oring, 2002; Mabee & Estelle, 2000; Nol & Brooks, 1982).

Habitat Selection

Killdeer and other ground nesting plovers employ several strategies for nest defence which includes habitat selection (Conway et al., 2005; Dorsey et al., 2025). I predicted that Killdeer would select habitat with lower vegetation density and larger distance from sight blocking terrain both of which can bestow advantages in detecting and deterring ground predators. My data did not reveal any significant difference in vegetation density between Killdeer nest sites and random sites. Similarly, in California, USA, Johnson & Oring (2002) also found no difference in the distance of shrubs from the nest between Killdeer nest sites and random sites. In Texas, USA, Killdeer preferred nesting on dry ground, with low vegetation and no woody vegetation compared to mudflats and no vegetation (Conway et al., 2005). In a congener, the Piping Plover (*Charadrius melodus*), nests were located further from vegetation and in areas with low density or sparsely clumped vegetation (Espie et al., 1996; Gaines & Ryan, 1988). In combination with these studies, my results indicate that there may be a preference for nesting in low density vegetation in Killdeer and other plovers, but detecting this preference by using comparisons with random sites has not been successful.

There has been little standardization in how shorebird habitat is quantified and as a result comparison between studies becomes challenging. As a result of this inconsistency a new way of evaluating the habitat of shorebirds known as viewshed was recently developed. Viewshed combines several elements of habitat and the visual range of prospective nest predators (Dorsey et al., 2025). Predators are categorized based on their height and visual range. For example, a coyote, standing at 0.5m, has a greater visual range than a racoon, standing at 0.25m. GIS is then used to determine the topology of the terrain around the nesting site and which classes of predators are able to detect the nest from a set distance (Dorsey et al., 2025). The approach takes into consideration the types of predators, the topology, the vegetation and the sight blocking terrain elements which gives a holistic representation of the pertinent habitat element for shorebird survival (Dorsey et al., 2025). In this study, SBT was as an index of predator visibility from the perspective of the incubating adult, but there appeared to be no effect on habitat selection. Viewshed is a promising alternative to traditional habitat analysis that should be employed for any further research conducted on Killdeer habitat selection.

Humans are a common source of disturbance for Killdeer in urban environments and can cause nest flushes which deplete the resources of nesting adults and possibly reduce nest survival (Lord et al., 2001). I predicted that Killdeer would show anthropogenic avoidance when selecting habitat by nesting further from roads and trails that are frequented by humans and vehicles. My results indicated that Killdeer in Downsview Park did not appear to select sites to reduce direct or indirect human disturbance. In an industrial oil patch in Oklahoma, USA, Atuo et al. (2018) found that Killdeer showed high affinity for nesting in gravel driveways versus nearby areas of low grass cover. Though the lack of human avoidance during nest site selection was a surprising result in my study, the results of Atuo et al. (2018) indicate that it is not uncommon, even in areas of much higher anthropogenic disturbance and vehicle risk.

Nest Survival

Killdeer daily survival rates for the years of 2023 and 2024 was estimated at 0.949 with an estimated nest success rate of 27.0%. Despite the highly urbanized nature of Downsview Park, nest success estimates for Killdeer was slightly higher than most previous studies conducted in relatively undisturbed rural areas. A study performed in the Nevada, USA evaluated the nest survival of Killdeer in a protected wetland and found that unprotected nests had a nest success rate of 12.4% and exclosure protected nest had a nest success rate of 46.7% (Johnson & Oring, 2002). Johnson & Oring (2002) conducted their study in a conservation area which can be considered a rural population that is largely undisturbed by humans. In another rural area, Long Point, Ontario, Canada, Nol and Brook (1982) studied the effectiveness of exclosures on Killdeer nest survival. They found a nest success rate of 25.9% for protected nests on the Long Point peninsula and 64.0% for unprotected nests on the mainland (Nol & Brooks, 1982). The habitat on the peninsula consisted of wide sandy beaches and pebbled islands and is relatively undisturbed (Nol & Brooks, 1982). Another exclosure study in Colorado, USA found that unprotected Killdeer nests had a nest success rate of 28.5% and an exclosure protected nest success rate of 14% (Mabee & Estelle, 2000). In the highly industrialized oil patch frequented by heavy machinery mentioned above, Atuo et al. (2018) estimated nest success of Killdeer at 1.98%. In the less disturbed peripheries of the industrial zone, nest success increased to 11.88% (Atuo et al., 2018). These low estimates of nest success in Atuo et al. (2018) may be explained by the ineffectiveness of Killdeer nest defence strategies on industrial vehicles compared to urban and rural threats such as pedestrians and predators (De Framond et al., 2022; Jackson & Jackson, 2020). Though the 27% nest success rate at Downsview Park was initially interpreted as low and potentially indicative of an ecological trap, the fact that it was higher than most previous estimates (with the exception of Nol and Brooks 1982) may indicate that the Downsview Park population is doing relatively well.

The findings of this study are unique due to Downsview Park's highly urbanized environment and high level of anthropogenic disturbance. The study by Nol & Brook (1982), took place near a public beach, and was not situated in the center of a major metropolitan area surrounded by residential and commercial land. The DSR of Downsview Killdeer population was similar to that of the findings of the populations found in the natural and largely undisturbed habitats of Grand Basin, Colorado, USA (Johnson & Oring, 2002; Mabee & Estelle, 2000). The Downsview Park population also showed a greater nest success rate than the Long Point population in Nol & Brooks (1982). However, these results are not directly comparable because the Long Point nests were protected by exclosures which may have affected the results. Interestingly the population at Long Point that was not protected with exclosures and was connected to the mainland had a much higher nest success rate than that of Downsview. The nest success of the Downsview population was also very high compared to highly disturbed industrial habitat of Atuo et al. (2018) when compared to nests that were situated on the peripheries of the oil pads. The findings of this study would suggest that the Killdeer of Downsview Park have a nest survival rate that falls within the range of existing literature and does not support the existence of an ecological trap in urban green spaces with high levels of anthropogenic disturbance.

Interestingly, coyotes were the only confirmed predators captured on cameras during the study even though other potential predators such as raccoons and dogs were present. In Nol & Brooks (1982), Killdeer nesting on the mainland site in proximity to residential areas were depredated by domestic dogs, whereas nests on the more secluded peninsula of Long Point were mainly depredated by smaller mammals like raccoons and avian predators. In California, USA, Johnson & Oring (2002) reported almost entirely avian predators except for two nests which were depredated by mammals. One was depredated by a North American Badger (*Taxidea taxus*) and the other depredated was by a Long-tailed Weasel (*Mustela frenata)* that depredated the adults as well as the eggs (Johnson & Oring, 2002). Mabee & Estelle (2000) reported a variety of nest destruction primarily caused by small predators like snakes, skinks, and rodents. Trampling and crushes by humans, vehicles and cattle were also a common cause of nest destructions (Atuo et al., 2018; Mabee & Estelle, 2000). That only coyotes were detected in our study may be due to the low number of predation events captured on camera. Coyotes are a common urban species and are residents of many cities in North America. These meso-predators have undergone a 40% range increase over the past 120 years to inhabit almost all of Eastern North America (Hody & Kays, 2018; Jensen et al., 2022). Due to the lack of higher-level predators in cities, coyotes act as an apex predator in urban spaces (Jensen et al., 2022; Peterson et al., 2021). Although there is some evidence of opportunistic bird and egg predation, until now, there was little evidence that coyotes were a direct predator for Killdeer and their nests (Jensen et al., 2022; Peterson et al., 2021). Coyotes show higher diet plasticity in urban environments, and this may lead to a higher prevalence of shorebird depredations in urban spaces. Killdeer nest defence techniques are tailored towards defending against ground threats such as red foxes (*Vulpes vulpes*) which are a common predator of midsized birds (Peterson et al., 2021). Nest defence strategies include broken wing displays, ungulate displays, false brooding and nest crypsis, all of which distract ground predators and deter nest destruction (De Framond et al., 2022; Deane, 1944; Jackson & Jackson, 2020).

Domestic dogs were recorded at a much higher rate than coyotes in Downsview Park and although they were not recorded as direct predators, domestic dog activity rates best explained variation in DSR. Given the lack of direct evidence of predation by domestic dogs and their close association with humans, the deleterious effect of domestic dog activity can likely be attributed to nest disturbance. Non-predators, like humans or domestic dogs, force shorebirds, like Killdeer, off the nest which slows incubation and needlessly depletes energy reserves (Brunton, 1988). Domestic dogs have a high likelihood of causing a nest flush and subsequent nest defence response even if they are accompanied by a human (Lord et al., 2001). The presence of a human also decreases the likelihood that a domestic dog will depredate a nest (Lord et al., 2001). Nearly all captured events involved visitors accompanied by domestic dogs with the dogs on a leash and closely monitored by the visitor. Domestic dogs are one of the most prevalent and ecologically significant predators in the world (Gómez-Serrano, 2021; Lord et al., 2001; Silva-Rodríguez & Sieving, 2012). Dog walkers are common in urban parks and have a notable impact on shorebird survival throughout North America (Lord et al., 2001). Nest flushing is a metric frequently used to determine disturbance for nesting shorebirds (Gómez-Serrano, 2021; Lord et al., 2001). Gómez-Serrano (2021) found that although humans and domestic dogs were both treated as predators by beach nesting plovers, lone pedestrians caused nest flushes in

47.6% of nests, and pedestrians with a domestic dog caused flushes in 93.8% of nests. They also found that the most disruptive group were lone dogs which caused a flush in 100% of nests. These findings are concurrent with other studies on the impacts of domestic dogs and the survival rates of beach dwelling plover species like New Zealand Dotterels (*Charadrius obscurus*). Lord et al.'s (2001) findings showed that New Zealand Dotterels that were more frequently disturbed by humans habituated to their presence and would spent less time off of their nests after a flushing event. They also found that when shorebirds were flushed from the nest by a person accompanied by a domestic dog, the shorebirds spent longer periods of time off the nest before returning. This extended time off of the nest exposes the eggs to potential predators and temperature stress which can impact the survival of the eggs (Lord et al., 2001). Lord et al. (2001) concluded that shorebirds perceive domestic dogs as a larger threat than humans alone and my data provides support for this conclusion. In addition to the habituation of human activity, humans without domestic dogs can create a shielding effect where predators are less common. Prey species may become less sensitive to human disturbances and be less likely to deploy anti-predator strategies (Geffroy et al., 2015). Domestic dogs were present in both top models and were the most highly weighted of the variables. This leads to the conclusion that the disturbances caused by domestic dogs have a substantial negative impact on Killdeer nest survival. This negative effect may be even larger when considered at a population level. An estimated nest survival rate of 27.0% would only yield an average of one chick per nest and that does not account for predation during the fledging period. These findings could contribute to the 50% decline in overall Killdeer population seen since the 1980s (Smith et al., 2023).

Human activity rates did not have a direct effect on Killdeer nest survival. Shorebirds do not appear to consider humans as major threats and show less assertive nest defence and habituation to human activity under prolonged exposure (Comber & Dayer, 2022). Defence attempts that are made against non-predatory human disturbances can be energy sinks that deplete resources that are required for true predator interactions (Comber & Dayer, 2022). Despite no effect of humans on DSR, there is a connection between domestic dogs and humans. There was only a moderate statistical correlation between domestic dogs and humans, however every dog had a human closely associated with them. In an increasingly urbanized environment, one can expect the number of dog walkers to increase proportionally with new housing developments. Downsview Park is a highly urbanized recreational park that is surrounded by residential housing and businesses, and intensification of housing and condo developments is ongoing. There are few spaces in Canada that are more highly disturbed with recreational human activities such as community events, recreation sports and music concerts that can draw thousands of visitors to the park. Human activity in the park was very high with an overall average of 0.91 human interactions per hour in 2023 and approximately triple that rate in 2024 at 3.01 human interactions per hour. The highest recorded rate was 7.26 human interactions per hour. Despite this high level of direct and indirect human disturbance in the park there was no significant effect of human interactions on nest survival. The yearly discrepancy could be explained by the poor air quality seen in Toronto in 2023 as a result of wildfires in the province of Quebec. There was no evidence of human activity rates or vehicle activity rates influencing Killdeer DSR. A likely mechanism to explain these findings is shorebirds' ability to habituate to human disturbances (Baudains & Lloyd, 2007). Shorebirds that nest on busy beaches have been found to return to nest more quickly when frequently disturbed by pedestrians (Baudains & Lloyd, 2007; Lord et al., 2001). The New Zealand Dotterel, a shorebird that frequently nests on recreational beaches, was found to habituate to human activity and spend less time off the nest when nesting on highly disturbed beaches (Lord et al., 2001). Furthermore, Lord et al. (2001) found the intensity of the distraction displays performed by the nesting adults did not change based on the type of approach the humans made. The presence of an accompanied domestic dog was the only factor that affected the intensity of duration of distraction displays (Lord et al., 2001). New Zealand dotterels that nested on busier beaches spent less time off the nest when flushed and as a result spent less energy and time away from incubating their eggs (Lord et al., 2001). Both Baudains & Lloyd (2007) and Lord et al. (2001) present mechanisms that could explain the findings of my research which reported DSR is within range of other populations in similar habitats. There was no significant effect of human disturbance on nest survival. However, this may be misleading due to the close association between domestic dogs which were found to be the chief factor affecting DSR.

Camera trapping in a highly urbanized environment proved to be logistically challenging and forced adaptations to camera trapping protocols. Camera damage and theft resulted in some data loss that could have reduced the accuracy of activity rate collection. Furthermore, the application of a 5-minute time to independence filter could have created a bias in sampling and resulted in unnecessary data loss (Cite. Peral et al., 2022). Although, Peral et al. (2022) suggested that time to independence filters lead to incorrect inferences on animal activity rates, this study had no instances of predator data being discarded due to this protocol. Time to independence intervals were almost exclusively used when evaluating human activity rates which was not addressed in Peral et al. (2022). The 5-minute time to independence filter was used here to avoid over representation of individual people standing or performing activities (such as picnics) within the trigger range of the camera traps. Additionally, humans are easily identified on an individual basis, which allowed for more accurate evaluation of large groups of people and not erroneously over-representing individuals. Further research will be required to determine the effects that the use of time to independence intervals has on the accuracy of human activity rates.

CONCLUSION

Shorebirds have seen a marked decline in populations throughout North America and Killdeer are no exception (Smith et al. 2023). Since the 1980s there has been an approximately 50% decrease in North American Killdeer population sizes at nearly 5% reduction per year (Smith et al. 2023). This alarming rate of population loss manifested itself in 2024 when the International Union for the Conservation of Nature (IUCN) updated Killdeer's red list status to near threatened (BirdLife International, 2023). In the context of increasing urbanization, it is more important than ever to understand factors affecting Killdeer nest survival in urban environments. The results of this study indicate that Killdeer nesting in Downsview Park do not appear to be caught in an urban ecological trap. Killdeer in the park are not preferentially selecting poor quality habitat, and nest survival rates fell within range of other Killdeer populations in the literature. Direct human activity did not affect daily nest survival, but domestic dog activity did have a substantial negative impact on Killdeer nest survival. Though nest survival rates were similar to other urban and rural populations (Johnson & Oring, 2002; Mabee & Estelle, 2000; Nol & Brooks, 1982), these studies indicate relatively low nest survival rates that, together with our study, provide valuable insight into the 50% decline in overall Killdeer populations since the 1980s (Smith et al. 2023).

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