**Site Selection**

We launched a community science initiative in the greater St. Catharines and Niagara region called Crowkemon Go ([www.crowkemon.weebly.com](http://www.crowkemon.weebly.com)). Community members were invited to report the location of spotted crows during the spring months to locate areas where the likelihood of finding crows was high. In total, the community recorded 247 crow sightings using Crowkemon Go. In April-May 2022, we visited potential sites and baited with whole peanuts to attract crows and reinforce the association of these locations with food. In case the presence of nestlings affected adult vigilance (see [1]), we limited data collection to the summer months (June-September 2022) . One site was selected for recurrent sampling (Fairview Park, 43°10'57.4"N 79°14'44.9"W). We also visited areas with many crow sightings for opportunistic sampling, as the presence of crows was not guaranteed at other potential recurrent sampling locations.

**Field observation**

Data collection was performed during the 2-3 hours following sunrise (approx. 6-9AM). No sampling was performed when it was raining or during adverse weather (e.g. thunderstorm, heatwave).

Upon arriving at the recurrent sampling location, a Nikon D5300 camera with a 70-300mm Nikkor lens was set up on a tripod a minimum 15m away from a concrete pad (predetermined bait location), zoomed in on it. If crows were already foraging in the area, we would begin recording immediately and not bait the site. If not, an observer approached and visibly dropped 30g of Cheez-Its, then returned to the camera. If crows were on-site, recording would start immediately, whereas if the crows were absent, a crow-caller would be used for 20 minutes (1 call per min, 5mins on, 5 mins off) to attract them. We would then begin recording upon the arrival of the crows and recorded a maximum of 20 minutes. The recording was stopped if the crows vacated the area for longer than 5 minutes and we remained in the area for 10 minutes post-departure in case the crows returned. If the crows returned, we would continue the trial.

For opportunistic sampling, we would look for crows using Crowkemon Go. If we found crows that were already foraging, we would set up in the same manner as for recurrent sampling and did not bait the site. Conversely, if the crows were not already foraging, we would bait the site as we did for recurrent sampling.

The presence of a sentinel, whether heard or seen, was announced verbally during the recording. Additionally, the group size and frequency of disturbances (per min) were also recorded. For each location, we classified the type of environment using St. Catharine municipal zoning maps. The ‘generalized environment’, a factor used for all subsequent analyses, was categorized by labeling all types of green spaces as “green”, and all types of commercial area as “commercial” (Table 1).

**Table 1:**Explanation of generalized environment

|  |  |
| --- | --- |
| Generalized Environment | Zones included |
| Commercial Area | Arterial Commercial, Business Commercial Employment, Community Commercial, Major Commercial |
| Green Area | Major Green Space, Minor Green Space |

**Video Analysis**

We classified behaviors as either “foraging”, “moving” or “alert”, with “alert” being the behavior of most vigilance, and “foraging” the behavior of least vigilance due to inability of an individual to effectively scan their surroundings while pecking at or looking for food on the ground. The behaviors were defined by the position of the focal individual’s head and body posture (Table 2). For video analyses, we used the Behavioral Observation Research Interactive Software (BORIS v.8.9.4) [4]. We recorded the duration of bouts of each behavior for every individual and bouts of less than 0.01s. were removed and bouts of movement were omitted from analysis. Since not all bouts of movement were recorded in their entirety, “moving” behavior was excluded from analyses. We also calculated the proportion of time spent performing each behavior. Individuals that did not perform “alert” or “foraging” behavior were omitted from the analysis of the proportion of time allocated to each behavior. The same individual may have two observations if it foraged in both the presence and absence of a sentinel. Four observations were removed since the individuals did not perform alert and/or foraging behavior.

In addition to these behaviors, we also recorded the number of pecks (handling food with their beaks for the purpose of eating it) to quantify foraging effort. The peck rate (per min) was calculated for every individual by dividing the total number of pecks at food performed by the total duration of “foraging” behavior. Individuals that did not forage were excluded.

**Table 2:**Ethogram of behaviors analyzed during foraging events.

|  |  |  |  |
| --- | --- | --- | --- |
| Behavior | Code | Definition | Illustration |
| Foraging | Head Down | Focal individual is stationary and has its head downwards or in a non-upright position, either pecking or handling food, looking for food, or engaging in other behaviors that make vigilance ineffective (e.g. preening). |  |
| Moving | Moving | Focal individual is moving, either by flying, hopping (leaping), or walking. |  |
| Alert | Head Up | The focal individual is stationary and has its head and body in an upright position. Individuals can have a mobile (scanning) or immobile head but must not be looking downwards. Individuals can be handling food. |  |

*All illustrations are under creative commons license (copyright-free)*

**Statistical Analysis**

All statistical analysis was performed in the R environment (v.4.2.2; R Core Team 2022) [5]. We first ran a chi-squared test to determine if the generalized environment, the group size, or the disturbance frequency affected the likelihood of a sentinel being present in our videos.

To determine the effects of generalized environment and sentinel presence on the proportion of time foragers allocated to each behavior, we fitted a linear model using behavior type, sentinel presence and generalized environment as fixed effects. We performed this analysis using the “lm” function in the R Stats package (v.3.6.2, R Core Team 2022) [6].

To determine the effects of generalized environment and the presence of a sentinel on the duration of bouts of all behaviors, a robust linear mixed model on the log-transformed duration of bouts was fitted using behavior type, presence of a sentinel, generalized environment, group size, bait presence as fixed factors, the disturbance frequency (per min) as fixed effects and the individual ID as a random effect. The function “rlmer” from the “robustlmm” package was used for this analysis [7].We subsequently fit robust linear mixed models on each behavior to determine the effects of sentinel presence and generalized environment on each behavior

To determine the effects of sentinel presence and generalized environment on foraging efficiency, we fitted a robust linear model on the peck rates using the presence of a sentinel, generalized environment, group size, and the presence of bait presence as fixed factors, the disturbance frequency as a fixed effect, and the individual ID as a random effect.

Finally, we counted the number of transitions from each behavior to determine the effects of sentinel presence and generalized environment on the frequency of each transition type. We fitted a generalized linear mixed model using a Poisson distribution on the number of occurrences of each transition. Sentinel presence, generalized environment, and bait presence were used as fixed factors, the disturbance frequency (per min) was used as a fixed effect, and the total number of transitions was used as a random effect in the model. The function “glmer()” from the “lme4” package was used for this analysis [9].

Post hoc estimated marginal means tests were performed as appropriate using the “emmeans” function from the “emmeans” package [8]. P-values were corrected using the “fdr” method, and the results were averaged over the unused categorical factors.

**RESULTS**

**Sentinel presence**

Neither the generalized environment (χ2 = 0.1221515, df = 1, p = 0.727), group size (χ2 = 0.2481203, df = 1, p = 0.618), or the disturbance frequency (χ2 = 2.032678, df = 2, p = 0.362) significantly affected the likelihood of a sentinel being present.

**Allocation of time to each behavior**

We made 64 observations across 25 videos. 81 observations were made for the proportion data. Crows allocated similar proportions of time to foraging and vigilance ( = 0.0263, SE = 0.0236, t-stat = 1.16, p = 0.248), and neither the presence of a sentinel ( = -0.0335, SE = 0.0234, t-stat = -1.4314, p = 0.154) or the generalized environment ( = 0.0336, SE = 0.0230, t-stat = 1.4625, p = 0.146) had an effect on the proportion of time allocated to either alert or foraging behavior.

**Duration of bouts of all behaviors**

In total, 5091 bouts were recorded, of which 2110 bouts were of alert behavior, and 1787 bouts were of “foraging” behavior. 1173 bouts of movement and 21 observations of duration less than 0.01s were removed. Bouts of alertness and foraging were significantly different ( = -0.2557, SE = 0.0511, t-stat = -5.002, p = <0.001), with bouts of alertness being significantly shorter than bouts of vigilance. Sentinel presence increased the duration of all bouts significantly ( = 0.1974, SE = 0.0720, t-stat = 2.7406, p = 0.006). Bouts of all behaviors in green areas were significantly longer than those in commercial areas ( = 0.3534, SE = 0.0873, t-stat = 4.0482, p = <0.001). The interaction between generalized environment and sentinel presence had a significant effect ( = -0.2524, SE = 0.0882, t-stat = -2.8630, p = 0.004). The interaction between behavior type and generalized environment was also significant ( = -0.2023, SE = 0.0537, t-stat = -3.7690, p = <0.001). Lastly, the disturbance frequency had a significant effect on the duration of all bouts ( = -0.0878, SE = 0.0295, t-stat = -2.9748, p = 0.003), with bout duration decreasing as disturbance frequency increased.

Post-hoc pairwise testing revealed significant differences in the duration of bouts of all behaviors. In commercial areas, the presence of a sentinel increased the duration of bouts ( = -0.157, SE = 0.0653, z-ratio = -2.402, p = 0.0489). In the absence of a sentinel, foragers in green areas had longer bouts ( = -0.252, SE = 0.0821, z-ratio = -3.074, p = 0.0127). Foragers in commercial areas and in the absence of a sentinel had marginally shorter bouts than in green areas and in the presence of a sentinel ( = -0.157, SE = 0.0720, z-ratio = -2.117, p = 0.0589). All other comparisons were not significant (p < 0.3430)

**Duration of bouts of “foraging” behavior**

Generalized environment had a significant effect on the duration of bouts of foraging behavior, with bouts being longer in green areas ( = 0.3826, SE = 0.0778, t-stat = 4.9194, p = <0.001). Sentinel presence had no significant effect on the duration of bouts of foraging ( = 0.0919, SE = 0.0718, t-stat = 1.2799, p = 0.201). The interaction between generalized environment and sentinel presence was also significant ( = -0.2272, SE = 0.0914, t-stat = -2.4849, p = 0.013). Larger groups had significantly longer bouts of foraging behavior ( = -0.1519, SE = 0.0684, t-stat = -2.2205, p = 0.026). The presence of bait decreased the duration of foraging bouts ( = -0.1385, SE = 0.0697, t-stat = -1.9885, p = 0.047). Increasing disturbance frequency significantly decreased the duration of foraging bouts ( = -0.1075, SE = 0.0301, t-stat = -3.5664, p = <0.001).

Post hoc tests revealed significant differences in the duration of bouts of foraging behavior. In the absence of a sentinel, foragers in green areas had significantly longer bouts of foraging behavior than in commercial areas ( = -0.3826, SE = 0.0778, z-ratio = -4.919, p < 0.0001). In the presence of a sentinel, foragers in green areas also had significantly longer bouts of foraging behavior than in commercial areas ( = -0.1555, SE = 0.0665, z-ratio = -2.337, p = 0.0291). The presence of a sentinel had no significant effect on the duration of bouts of foraging behavior when in commercial areas ( = -0.0919, SE = 0.0718, z-ratio = -1.280, p = 0.2006). In the presence of a sentinel and in green areas, foragers had a significantly longer bouts of foraging behavior than in the absence of a sentinel and in commercial areas ( = -0.2474, SE = 0.0662, z-ratio = -3.738, p = 0.0006). When in the absence of a sentinel and in green areas, foragers also had significantly longer bouts of foraging behavior than in the presence of a sentinel and in commercial areas ( = -0.2907, SE = 0.0870, z-ratio = -3.340, p = 0.0017). In green areas, foragers in the presence of a sentinel had marginally shorter bouts of foraging behavior than in the absence of a sentinel ( = 0.1352, SE = 0.0684, z-ratio = 1.977, p = 0.0577).

**Duration of bouts of “alert” behavior**

In contrast to foraging behavior, sentinel behavior, generalized environment, group size, bait presence and disturbance frequency had no significant effect on the duration of bouts of alert behavior (p < 0.141). However, the interaction between sentinel behavior and generalized environment was significant ( = -0.2736, SE = 0.1352, t-stat = -2.0243, p = 0.043). Post hoc pairwise t-tests revealed no significant differences in the duration of bouts of alert behavior.

**Foraging efficiency**

We calculated the peck rate (per min) for 81 observations. Two observations were removed as the individual did not perform any foraging behavior. Neither the presence of a sentinel nor the generalized environment alone had a significant effect on the peck rate of foragers (p > 0.702). Peck rate increased significantly with disturbance frequency ( = 5.29, t-stat = 2.312, p = 0.021). The interaction between generalized environment and disturbance frequency also significantly affected peck rate ( = 16.15, t-stat = 3.046, p = 0.002). Lastly, the presence of bait significantly increased the peck rate of foragers ( = 13.99, t-stat = 2.231, p = 0.020).

**Pathway analysis**

Transitions from head down to pecking were significantly affected by the presence of bait, with more transitions occurring in the presence of bait (IRR = 1.7096, SE = 0.3842, z-stat = 2.3858, p = 0.017). All other factors did not affect this transition (p-value > 0.385). Transitions from pecking to alert behavior were similarly affected by the presence of bait, significantly increasing when bait was present (IRR = 2.2037, SE = 0.5378, z-stat = 3.2378, p = 0.001). All other factors did not affect this transition (p-value > 0.313). Transitions from alert to foraging behavior were not significantly affected by any factors, however, bait presence had a marginally significant effect (IRR = 1.5134, SE = 0.3506, z-stat - 1.7888, p = 0.074), increasing the number of transitions from head up to head down. Transitions from foraging to alert behavior were significantly affected by generalized environment (IRR = 0.4213, SE = 0.1569, z-stat = -2.3214, p = 0.020), disturbance frequency (IRR = 0.7281, SE = 0.1085, z-stat = -2.1301, p = 0.033), and the interaction between generalized environment and sentinel presence (IRR = 5.0.212, SE = 2.4571, z-stat = 3.2977, p = 0.001).

Post hoc testing on the number of transitions from foraging to alert behavior revealed significant differences. in the presence of a sentinel, individuals exhibited marginally more of the same transitions in green areas ( = -0.749, SE = 0.363, z-ratio = -2.062, p = 0.0785). However, in the absence of a sentinel, individuals exhibited marginally more transitions from foraging to alert behavior in commercial areas ( = 0.864, SE = 0.372, z-ratio = 2.321, p = 0.0608). In green areas, individuals performed more transitions from foraging to alert behavior when in the presence of a sentinel ( = -1.124, SE = 0.346, z-ratio = -3.250, p = 0.0069).

**FIGURES:**