**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).

A Nikon D5300 camera with a 70-300mm Nikkor lens was set up on a tripod to record the trials a minimum 15m away. One observer then walked toward the crows, visibly dropped food, and then returned to the camera. To accurately classify foraging behaviors, the camera was pointed and zoomed on the bait location and/or the foraging crows. Whenever sentinels were spotted or heard, their presence was announced verbally on the video. We recorded up to 20 minutes of foraging for each trial. Trials ended if the crows flew away and vacated the area for more than 5 minutes. The observer(s) would then remain on-site for at least 10 minutes after the crows’ departure in case the crows returned to the area.

For recurrent sampling, a crow-caller was used for 20 minutes upon leaving bait if no crows were present, whereas no crow-caller was needed during opportunistic sampling since the crows were already present.

In addition to the foraging event, the group size and frequency of disturbances 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”.

**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 1). 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. For video analyses, we used the Behavioral Observation Research Interactive Software (BORIS v.8.9.4) [4].

**Table 1:**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. |  |

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**Statistical Analysis**

All statistical analysis was performed in the R environment (v.4.2.2; R Core Team 2022) [5].

We calculated the proportion of total recorded time spent performing each behavior for every individual when in the presence and absence of a sentinel. Individuals that were not alert or did not forage were omitted from analysis. The proportion of time spent moving was omitted from this analysis as not all bouts of movement were recorded in their entirety.

To determine the effects of generalized environment and sentinel presence on foragers’ allocation of time 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].

We recorded the duration of bouts of each behavior for every individual in BORIS. Bouts of less than 0.01s. were removed and bouts of movement were omitted from analysis.

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, and disturbance frequency as fixed effects and the individual ID as a random effect. The function “rlmer()” from the “robustlmm” package was used for this analysis [7].

A post hoc pairwise t-test was performed on significant factors identified by the model to identify significant differences in the duration of bouts of all behaviors using the “emmeans” function from the “emmeans” package [8].

We subsequently fit robust linear mixed models on each behavior separately using a similar formula as described above but without the behavior type as a fixed effect. This was performed to disentangle the effects of behavior and analyze the effects of sentinel presence and generalized environment on each behavior separately. Pairwise t-tests were performed as appropriate using the “emmeans” function from the “emmeans” package [8].

The peck rate was calculated for every individual by dividing the total number of pecks at food performed by the total duration of foraging (or 'Head Down') behavior. Individuals that did not forage were excluded.

To determine the effects of sentinel presence and generalized environment on the peck rate of foragers, we fitted a robust linear model using the presence of a sentinel, generalized environment, group size, bait presence and the disturbance frequency 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 ran a chi-squared test to determine if the generalized environment or other environment and social factors affected the likelihood of a sentinel being present in our videos.

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 fit a generalized linear mixed model using a Poisson distribution. Sentinel presence, generalized environment, disturbance frequency and bait presence were used as fixed effects, 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]. Pairwise t-tests were performed as appropriate using the “emmeans” function from the “emmeans” package [8].

**RESULTS**

We made 64 observations across 25 videos. 81 observations were made for the proportion data. 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.

Crows allocated similar proportions of time to foraging and vigilance (Estimate = 0.0263, SE = 0.0236, t-stat = 1.16, p = 0.248), and neither the presence of a sentinel (Estimate = -0.0335, SE = 0.0234, t-stat = -1.4314, p = 0.154) or the generalized environment (Estimate = 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.

5091 bouts were recorded, of which 1173 bouts of movement and 21 observations of duration less than 0.01s were removed. Bouts of alertness and foraging were significantly different (Estimate = -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 (Estimate = 0.1974, SE = 0.0720, t-stat = 2.7406, p = 0.006). All bouts in green areas were significantly longer than those in commercial areas (Estimate = 0.3534, SE = 0.0873, t-stat = 4.0482, p = <0.001). The interaction between generalized environment and sentinel presence had a significant effect (Estimate = -0.2524, SE = 0.0882, t-stat = -2.8630, p = 0.004). The interaction between behavior type and generalized environment was also significant (Estimate = -0.2023, SE = 0.0537, t-stat = -3.7690, p = <0.001). Lastly, disturbance frequency had a significant effect on the duration of all bouts (Estimate = -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 all bouts. The following results are averaged over the three behaviors, group size and bait presence, and the p-values are adjusted using the 'FDR' method for 6 tests. In commercial areas, the presence of a sentinel increased the duration of foraging bouts (Estimate = -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 of all behaviors (Estimate = -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 (Estimate = -0.157, SE = 0.0720, z-ratio = -2.117, p = 0.0589). All other comparisons were not significant (p < 0.3430)

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

Post hoc pairwise t-tests revealed significant differences in the duration of bouts of foraging behavior. The following results are averaged over the levels of group size and bait presence and the p-values are corrected using the "fdr" method for 6 tests. In the absence of a sentinel, foragers in green areas had significantly longer bouts of foraging behavior than in commercial areas (Estimate = -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 (Estimate = -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 (Estimate = -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 (Estimate = -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 (Estimate = -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 (Estimate = 0.1352, SE = 0.0684, z-ratio = 1.977, p = 0.0577).

In contrast to foraging 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). Sentinel behavior did not have a significant effect on the duration of alert behavior. However, the interaction between sentinel behavior and generalized environment was significant (Estimate = -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.

We calculated the peck rate of 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 (Estimate = 5.29, t-stat = 2.312, p = 0.021). The interaction between generalized environment and disturbance frequency also significantly affected peck rate (Estimate = 16.15, t-stat = 3.046, p = 0.002). Lastly, the presence of bait significantly increased the peck rate of foragers (Estimate = 13.99, t-stat = 2.231, p = 0.020).

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.

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. 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).

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. The following results are averaged over the levels of bait presence and the p-values were corrected for 6 tests using the “fdr” method. In the absence of a sentinel, individuals exhibited marginally more transitions from foraging to alert behavior in commercial areas (Estimate = 0.864, SE = 0.372, z-ratio = 2.321, p = 0.0608). However, in the presence of a sentinel, individuals exhibited marginally more of the same transitions in green areas (Estimate = -0.749, SE = 0.363, z-ratio = -2.062, p = 0.0785). In green areas, individuals performed more transitions from foraging to alert behavior when in the presence of a sentinel (Estimate = -1.124, SE = 0.346, z-ratio = -3.250, p = 0.0069).

**FIGURES:**