PERSPECTIVES IN
Biosecurity

VOLUME 3/2018

ISSN 2538-0125

ePress
Unitec Institute of Technology
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PERSPECTIVES IN BIOSECURITY **VOLUME 3/2018**

Contact
epress@unitec.ac.nz

Founded at Unitec Institute of Technology in 2017.

Cover photo: Josie Galbraith.

An ePress publication
epress@unitec.ac.nz
www.unitec.ac.nz/epress/
Unitec Institute of Technology, Private Bag 92025, Victoria Street West, Auckland 1010, Aotearoa New Zealand

ISSN 2538-0125

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This publication may be cited as: Cameron, K.E., Wassenaar, R.J., Panapasa, A., Brown, K.J., Halliday, A.D., Lodge-Osborn, K.R., Robson, E.A., Aley, J.P., Jones, G., Salinsky, J.R., Fraser, D.L., & Adams, N.J. (2018). Measuring the Efficacy of Repellent on House Sparrows (*Passer domesticus*), *Perspectives in Biosecurity, 3*, 5–17.

Contact:
epress@unitec.ac.nz
www.unitec.ac.nz/epress/
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Simple Summary

House sparrows (*Passer domesticus*) are vectors for diseases transmittable to humans and animals, therefore effort is made to deter sparrows from roosting and feeding in urban areas such as cafés and private buildings. In this experiment, four methods of measuring sparrow avoidance of a commercially available avian repellent were trialed in aviaries and in the field. The methods were designed to detect repellency at differing levels of sensitivity. Experiments attempted to measure changes in the use of an aviary in relation to the presence of the repellent and the effect of proximity of the repellent on feeding in both an aviary setting and in the field where alternative food was available. We were consistently unable to detect any repellent effect of this commercially available product, indicating birds were insensitive to any intended aversive properties of its odour or visual appearance. The formulation of effective repellents based on visual and olfactory signals alone is likely to be very challenging.

Abstract

Behavioural analytic techniques were used to assess the efficacy of a repellent to the house sparrow (*Passer domesticus*). The repellent, using a combination of olfactory and visual cues, is aimed at deterring birds from roosting sites where faecal contamination may result in disease transmission to humans and animals, and damage to public and private property. In this experiment, four methods of measuring avoidance by sparrows to a commercially available avian repellent were trialed in aviaries and in the field. In initial experiments, the number of sparrows was recorded in predetermined zones across an aviary, and faecal counts were measured as the position of the repellent varied. In further experiments, food removal was recorded when repellent was placed at varied distances from food sources to test the effect of proximity on sparrow feeding behaviour in the aviaries and in the field. There was no apparent repellent effect of this commercially available product, indicating birds were insensitive to any intended aversive properties of its odour or visual appearance. Therefore, as formulated, the product is unlikely to be of any use in a practical setting. Development of chemical repellents based primarily on olfactory cues might be challenging and require additional aversive stimuli.

Introduction

House sparrows (*Passer domesticus*) are potential vectors for a variety of pathogens (Benskin, Wilson, Jones, & Hartley, 2009) including Campylobacter spp. identified in faecal samples taken from wood, concrete, soil, bark, plastic and grass surfaces (Abdollahpour, Zendehbad, Alipour, & Khayatzadeh, 2014). Increasing the risk of zoonotic disease transfer to humans is the tendency for house sparrows to be closely associated with urban settings, including nesting in the roof cavities of buildings (Shaw, Chamberlain, & Evans, 2008) and feeding on discarded food (Gavett & Wakeley, 1986) available in places such as outdoor café areas. At high concentrations the faeces may also cause damage to property (Whiley, van den Akker, Giglio, & Bentham, 2013). Approaches to deterring wild birds from utilising sites in urban areas for nesting and foraging include the use of physical barriers or exclusion methods such as nets or sharp projections (Alderson & Greene, 1995; Steiger, Fidler, Valcu, & Kemnpenaers, 2008). However, these approaches are not always suitable and can themselves become anchors for sparrow nests (Alderson & Greene, 1995). Another approach is the use of chemical repellents (Alderson & Greene, 1995; Smith, 2014).

Avian chemical repellents have been used and evaluated in situations where the objective is to deter birds from consuming what may be potential food. For example chemical repellents have been used to protect agricultural crops (Avery, 2002; Clapperton, Porter, Day, Waas, & Matthews, 2012) and explored as an approach for deterring birds from consuming baits containing poisons developed for controlling mammal pests (Clapperton et al., 2012; Cowan, Booth, & Crowell, 2015). These approaches involve developing an aversion to the potential food. Primary repellents invoke an immediate aversive response through an unpleasant smell or taste. Secondary repellents invoke a delayed post-ingestion illness or discomfort, resulting in a learned aversion (Avery, 2002). Visual cues, such as colour, for example, blue or green, can enhance avoidance behaviour (Clapperton et al., 2012). Therefore, avian chemical repellents often combine visual and olfactory deterrent mechanisms with secondary repellents, which have delayed physiological effects, to provide effective deterrent (Clapperton et al., 2012).

Numerous chemical compounds have been used within bird repellents as primary and secondary deterrents (Avery, 2002). For example, primary repellents have been used to stop sparrows feeding on food sources by treating the food with tannic acid, which has a bitter taste (Greig-Smith & Rowney, 1987), whereas Optamint® and d-pulegone both use peppermint extracts with associated olfactory and taste cues for repelling birds (Avery, 2002). Secondary repellents include anthraquinone and cinnaminide, which cause discomfort or distress after ingestion (Clapperton et al., 2012; Greig-Smith & Rowney, 1987; Porter, 1995).

There are few studies that isolate bird aversion to odour in repellents other than when combined with a secondary repellent such as anthraquinone. Most birds were thought to rely primarily on visual and auditory inputs to evaluate their surrounding environment, however, there is increasing evidence that olfaction is also an essential sense and this extends beyond its previously recognised importance to groups such as seabirds and other specialist nocturnal bird groups (Steiger et al., 2008). Accordingly, odour-based aversion maybe another option in the design of avian repellents. Stock and Haag-Wackernagel (2013) recorded pigeon behaviour when an 'optically-aversive' and odorous gel was placed in the loft of a church known to house wild pigeons. This repellent thus acts as a primary repellent. Landing and approach behaviour on two shelves with or without contact with the gel decreased over 26 days, but time spent on the shelves with containers of gel increased after four days of exposure, suggesting that the repelling effect on pigeons decreased with time.

The aim of this study was to determine the effectiveness of a commercially available bird repellent presumed to have its effect through its odour and visual characteristics. Initially, tests were conducted, to determine whether placement of repellent at specific locations in the aviary affected the spatial use of the aviary by sparrows, by direct observation of birds and determining the distribution of bird faeces on the floor of the aviary as an indicator of spatial use. The spatial use of the aviary was compared with and without repellent present. It was predicted that birds would avoid areas close to the repellent source. Further experiments tested whether feeding and interaction with food in the aviary were affected by the distance between the repellent and food source. It was predicted that increasingly smaller amounts of food would be removed from food containers as the distance between the repellent and food containers reduced. A final set of experiments tested whether feeding or food interaction by free-living birds in the field would similarly decrease as the distance between the experimentally provided food source and repellent was reduced. These birds would have alternative food sources available in the environment that were outside the range of an odorous repellent. This series of experiments represented a gradient in the ability to detect a possible repellent effect.

Method

Subjects

Wild-caught sparrows served in Experiments 1-5 with six naïve sparrows used in each experiment, and wild sparrows (of unknown number) were exposed to the experimental treatment in Experiments 6-7. Ethical approval for this study (approval notice 001605) was obtained from The University of Auckland Animal Ethics Committee. Consistent with our ethical approval notice, wild sparrows were held captive for a maximum of 26 days. All experiments were conducted in autumn (April-May in New Zealand), Experiments 1-3 in 2015, and Experiments 4-7 in 2016.

Repellent

The gel repellent is commercially available and advertised as a deterrent for pigeons from roosting sites (Bird Free®, ingredients: polysiobutylene 68%, grease 22%, peppermint and cinnamon oils 10%. Jeonjinbio Co. Ltd, Daegu, Korea). It is the colour and consistency of caramel and considered a non-toxic food-grade gel. It is described as providing a visually aversive stimulus detectable within the ultraviolet visual range of birds as flames (Jeonjinbio Co. Ltd, 2017). In addition, the repellent is described as a deterrent based on smell, touch and taste (Jeonjinbio Co. Ltd, 2017). The repellent was presented in small circular trays (5 cm in diameter and 0.5 cm in depth). The manufacturer's instructions suggest the repellent is suitable for preventing birds roosting and utilising possible nesting sites, and multiple trays need to be placed between 15 and 25 cm apart. We utilised single plastic trays of gel and manipulated the distance of the tray from a food source from directly adjacent to the gel (0 cm) to 120 cm, depending on the experiment.

To avoid birds coming into direct contact with the sticky gel and fouling their feathers, a fine plastic mesh was placed over the tray. The mesh did not decrease the repugnance of the gel to the human nose and it is stated by the manufacturer that a single dose of the gel is effective for periods up to four years (BirdFree, 2017); however, we refreshed the gel trays daily to maintain constant volatility of the substance during the experiment.

Aviary Apparatus

Experiments 1-5 were conducted in wooden-framed aviaries 2.4 m deep, 2.4 m wide and 2.4 m high, located at the Unitec campus in Auckland, New Zealand. For Experiments 1-3 the aviaries were placed under an open-walled structure that provided protection from direct rainfall but was otherwise open to the environment. To provide a visual barrier but allow airflow, the aviaries were wrapped in shade cloth on all sides. Due to possible effects of disturbance caused by foot traffic, for Experiments 4 and 5 the aviaries were moved to a concrete pad within a large free-range chicken enclosure to further minimise any external disruption to the animals, including that of the chickens housed in the enclosure, none of which had access to the aviaries.

The aviary contained three perches placed 1.5 m above the floor, running parallel to the entrance. Ledges at the end of the perches allowed for placement of food and the test apparatus (Figure 1). Sparrows were fed a commercially available budgie mix (Animates®). Water was available ad libitum in containers attached to the opposite aviary walls. Cleaning, feeding and observations were completed daily between 12 p.m. and 2.30 p.m.

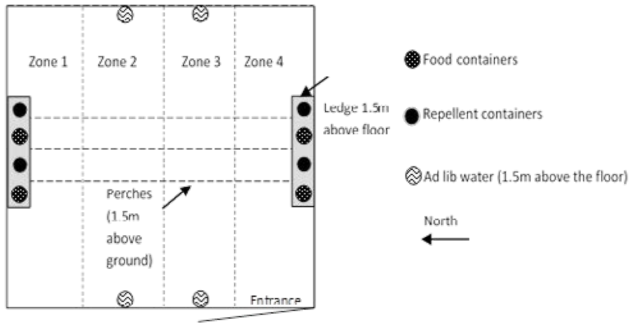

Figure 1. Aviary set up for Experiments 1 and 2 (not to scale). The aviary was delineated into four zones 0.6 m apart. Food was available in Zones 1 and 4 at all times and the presence of repellent containers on shelves was varied with treatment. (Trt 1 = no repellent, Trt 2 = repellent in Zone 1, Trt 3 = repellent in Zone 4; Trt 4 = repellent in Zones 1 and 4).

Experiments 1 and 2: Experiments 1 and 2 were designed to test the effect of the presence or absence of the repellent beside a food source and spatial use of the aviary. The sparrows in the aviary were exposed to four 'treatments' after a week of habituation to the aviary. In Treatment 1 only control containers (empty of repellent) were placed next to the food dishes (Figure 1). In Treatment 2, two controls were replaced by containers of repellent in Zone 1. Treatment 3 was a similar manipulation but containers of repellent were placed in Zone 4. In Treatment 4, the containers of repellent were placed in Zone 1 and in Zone 4. Food was available in Zones 1 and 4 at all times.

Experimental Procedure

Experiment 1, behaviour sampling: A video camera (Panasonic HC-V700 full HD camera on a tripod) was set up to capture bird activity for data analysis. After replenishing the food containers and repellent, and changing the position of the repellent for the next condition, behavioural recordings were conducted between 1.30 and 2.30 p.m., a consistent time slot each day for a total of 16 days. Instantaneous behaviour sampling was undertaken every 30 seconds, recording the position of each bird in the aviary. This provided 120 data points per bird per day.

Experiment 2, faecal deposit: The number of faecal deposits accumulated on the plastic-covered floor of the aviary across a 24-hour period in each of the four zones was recorded. Each day the black plastic was removed and replaced by another sheet marked with Zones 1-4. Data were recorded for a total of 16 days, with four repetitions of each treatment.

Experiments 3-5: Experiments 3-5 were designed to assess whether the distance between the repellent and the food source influenced food removal. Feeding bowls containing bird-seed were placed 30 cm apart at one side of the aviary. Control containers empty of the repellent gel were placed at varying distances from the food containers in two lines, depending on the experiment (Figure 2). Repellent containers were placed inside the control container at the same position in each of the two lines, at a specified distance, each day. Food removal from the food containers over a 24-hour period was determined by weighing the containers between 12 p.m. and 2 p.m. Thereafter the seed in the containers was replenished and re-weighed. The location of the paired repellent containers was set for the next day, following a randomised schedule.

Experiment 3: The control containers were secured to the plastic-covered floor at 30 cm, 60 cm, 90 cm and 120 cm in two rows centred between and extending from three food containers (Figure 3). Food containers were not provided on shelves as in Experiments 1 and 2. Repellent was located at each distance for two days (one day in each direction). Preliminary analysis indicated food removal did not vary with the position of the repellent container. Accordingly, additional trials in which repellent was placed immediately adjacent to the food source at 0 cm and 15 cm were conducted at one end of the aviary for two further experimental sessions (two days) each as post hoc additions. Data were recorded for 12 days.

Experiment 4: The control containers were secured at 0 cm, 15 cm, 30 cm and 45 cm in two rows extending from two food containers. A tray was placed underneath the food containers to catch food 'spillage' (mass of food in container – mass of food spilled = mass of food removed). After two days of habituation the position of the repellent was randomised at each distance for five days each, in addition to five days where no repellent was present. Data were recorded over a 25-day period.

Experiment 5: Repellent was located in one row at each distance each day to measure the effect of the controls on food removal and food spillage. The repellent was located at each distance for five days each, randomised over a 24-day period after two days of habituation. The repellent was located in Line A only for the first 12 days and in Line B for the second 12 days. There were no post-habituation-period days where the aviary was free of repellent, due to the 26-day limit on sparrow captivity.

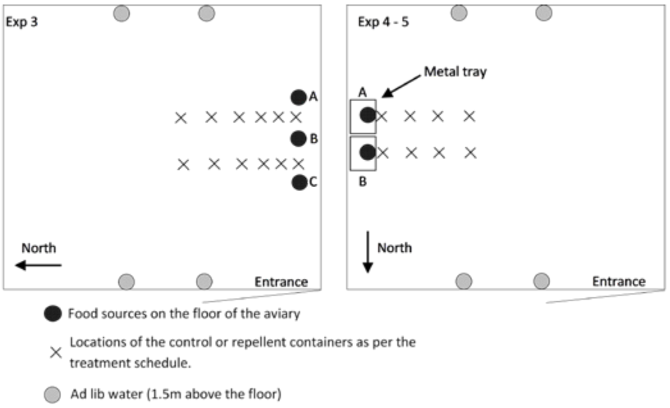

Figure 2. Aviary set up for Experiments 3 and 4-5 (not to scale), showing the locations of the repellent and control containers, and the food. In Experiment 3, the control containers were placed at 0 cm, 15 cm, 30 cm, 60 cm, 90 cm and 120 cm with the food containers on the right side of the aviary and control containers extended to the centre of the aviary. The set up was then repeated from the opposite side for all but 0 cm and 15 cm distances as these were added post hoc. In Experiments 4-5, two rows of control containers extended from two food containers from the left side of the aviary only at 0 cm, 15 cm, 30 cm and 45 cm.

Field Study Apparatus

Experiments 6 and 7: The field study was conducted using a similar methodology to Experiments 4 and 5 to measure the effect of the repellent on wild sparrows that had alternative food sources. The experiment was conducted in the cordoned-off northeast section of a 14.7 m x 18 m free-range hen enclosure where sparrows were known to forage for surplus chicken food. The experiment could not be accessed by the domestic hens (*Gallus gallus domesticus*) and spotted doves (*Streptopelia chinensis*). The experimental food was potentially accessed by green finches (*Carduelis chloris*) and goldfinches (*Carduelis carduelis*), however, the populations of these birds were small compared to sparrows. Black plastic sheeting (2 m long x 1.5 m wide) was placed over an area of grass. Hanging bird-seed feeders were suspended over the centre of the black plastic 50 cm apart and 50 cm from the ground, and were filled with budgie seed. Metal trays (25 cm x 30 cm) were placed underneath the feeders. Control containers were glued in two lines (A and B) starting from directly under the hanging feeders and at distances of 15 cm, 30 cm and 45 cm from the feeders. In Experiment 6, repellent was located in both lines at a particular distance each day, and in Experiment 7 repellent was located in one line. The position of the repellent-containing tray was determined on a randomised schedule whereby the same distance was not repeated on successive days.

Experimental Procedure

The amount of food spillage and the amount removed from feeders were determined as described for Experiments 4 and 5. It was necessary to correct seed weights, due to exposure to rain in the field setting, by correcting the measurement of wet seed to dry matter. The correction factor of 0.5 was determined by the drying of wet seed over 48 hours and determining the fractional mass gain.

Statistical Analyses

The data for Experiments 1 and 2 was aggregated across treatment and zone. Repeated measures ANOVAs were used to compare the effect of the repellent in each treatment with the number of sparrows (Experiment 1) and faecal count (Experiment 2) recorded within each zone. The data for Experiments 3-5 were aggregated for each distance, and food removal and spillage was standardised for graphing due to the escape of individual sparrows during the experiment. For Experiments 6 and 7 total removal and spillage amount was used because the number of wild sparrows in the area was unknown. Repeated measures ANOVAs were used to compare the effect of distance between the food and repellent on food removal and spillage.

Results

The gel maintained its strong odour throughout the course of the experiments with no apparent change in appearance.

Experiment 1: Behavioural sampling

The frequency at which sparrows were recorded averaged over all days of the experiment was highest in Zone 1 across all treatments, irrespective of the placement of the repellent (Figure 3a). A repeated measures ANOVA revealed a significant main effect of zone on the number of sparrows observed in each zone [F (3, 9) = 1014.63, p <.001, η_p^2 = 1.0]. Pairwise comparisons, with significance levels adjusted using the Bonferroni correction, showed the number of sparrows was highest in Zone 1 compared to the other zones (all *ps* <.001) and higher in Zone 2 compared to Zone 3 (p =.036). In contrast, there was no significant effect of treatment on the number of sparrows observed in each zone [F (3, 9) = 1.02, p = .427, η_p^2 = 0.25] or the interaction between zone and treatment type [F (9, 27) = 1.42, p = .229, η_p^2 = 0.32].

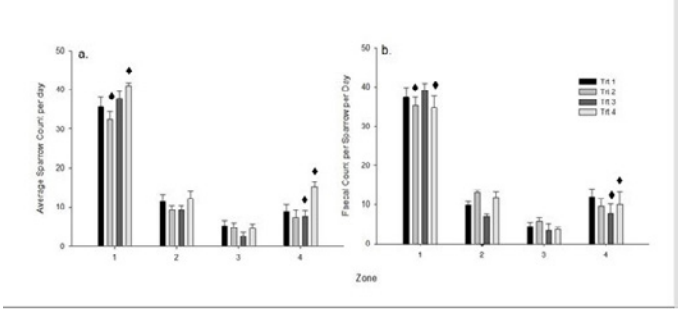

Figure 3. Average counts of sparrows (a, Exp 1) and faecal deposit (b, Exp 2) counts were recorded in each observational period in each zone across Treatments 1-4 and across all experimental days. Standard error bars are shown. The diamond symbol signifies the location of the repellent during each treatment. Trt 1 = no repellent, Trt 2 = repellent in Zone 1, Trt 3 = repellent in Zone 4; Trt 4 = repellent in Zones 1 and 4.

Experiment 2: Faecal deposit count

The number of faecal deposits was highest in Zone 1 irrespective of treatment (Figure 3b). A repeated measures ANOVA revealed a significant main effect of zone on the number of faecal deposits [F (3, 9) = 216.00, p <.001, η_p^2 = 0.99]. Pairwise comparisons, with significance levels adjusted using the Bonferroni correction, showed the number of faecal deposits was highest in Zone 1 compared to the other zones (all *ps* < .007) and higher in Zone 4 compared to Zone 3 (p = .037). There was a small but significant effect of treatment on the number of faecal deposits found in each zone [F (3, 9) = 7.11, p = .009, η_p^2 = 0.70]; and an interaction effect trending towards being significant between zone and treatment type [F (9, 27) = 2.14, p = .062, η_p^2 = 0.42].

The strongly favored use of Zone 1 by sparrows across all treatments in Experiments 1 and 2 suggests there were factors affecting the behavior of the sparrows that potentially obscured any repellent effects. Surrounding activities included a nearby building renovation closest to Zone 4 and the frequent use of the area surrounding the aviaries by students of the institute.

Experiment 3: Proximity effects

Food removal was expressed as per sparrow per day because during the experiment one sparrow escaped, requiring standardisation of the food removal measure. Food removal decreased as the distance between the food source and repellent increased (Figure 4). A repeated measures ANOVA revealed a significant difference in food removal when the distance between the food and repellent was varied [*F* (5, 25) = 8.62, $p < .001$, $\eta_p^2 = 0.66$]. Pairwise comparisons, with significance levels adjusted using the Bonferroni correction, showed that significantly more food was removed when the repellent was immediately adjacent to food (0 cm) compared to when the repellent was placed 30 cm away ($p = .004$) and significantly more food was removed at 15 cm compared to 30 cm ($p = .026$). There was, however, more variability, measured using the standard error of the mean, in food removal when the repellent was located at distances further from the repellent. Variability in food removal was greater when food was more distant from the repellent [60 cm (*SE* = 1.10 g) and 120 cm (*SE* = 1.29g)] than when in close proximity [0 cm (*SE* = 0.62g) and 15 cm (*SE* = 0.59g)]. This increased variability in food removal and increased spillage when food was in containers more distant from the repellent may reflect a difference in actual feeding behavior associated with proximity to the repellent.

Paired t-tests revealed a significant difference in food removal between food (containers) A (*M* = 3.5g, *SE* = 0.16g) and B [*M* = 3.2g, *SE* = 0.12g; t (11) = 3.03, $p = .012$, $d = 0.69$]; and between food sources B (*M* = 3.2g, *SE* = 0.12g) and C [*M* = 3.5g, *SE* = 0.13g; *t* (11) = 3.57, $p = .004$, $d = 0.63$]. There was no difference in food removal between food sources A (*M* = 3.5g, *SE* = 0.16g) and C (*M* = 3.5g, *SE* = 0.13g), [*t* (11) = 0.62, $p = .546$, $d = 0.10$], but removal was low at B compared with A and C. This suggests that the direction of the experimental set-up (closest to a building renovation or the entrance to the aviary) did not cause differential food removal from the food containers based on location.

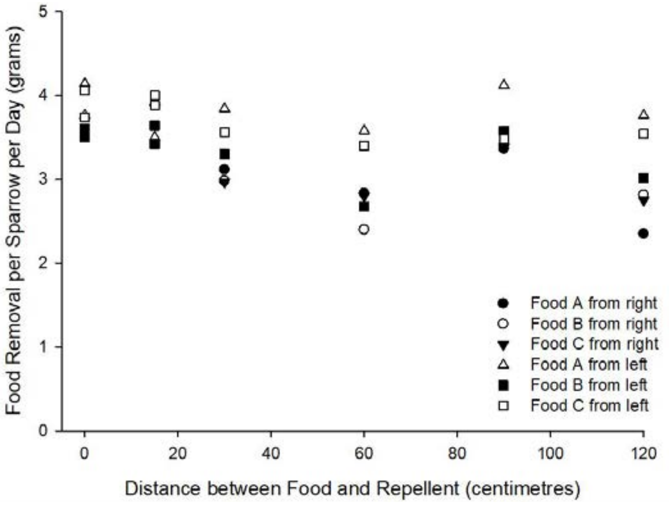

Figure 4. Food removal per sparrow per day (grams) as distance (cm) between repellent and food containers A, B and C was varied (Exp 3). Food removal in both the initial (from right) and reverse (from left) directions are shown.

Experiment 4: Proximity effects

Food removal was expressed as removal per bird per day, as during the experiment one sparrow escaped. Food removal within a particular line was similar, irrespective of the distance between the food container and the repellent [*F* (4, 16) = 2.17, $p = .120$, $\eta_p^2 = 0.35$] but differed between the two lines of repellent [*F* (1, 4) = 185.48, $p < .001$, $\eta_p^2 = 0.98$] (Figure 5a). Food removal was significantly higher in Line A compared to Line B across, irrespective of the position of the repellent. There was no interaction effect between line or distance on food removal [*F* (4, 16) = 0.57, $p = .688$, $\eta_p^2 = 0.13$].

There was significantly greater food spillage in Line B compared to Line A across distances [*F* (1, 4) = 21.63, $p = .010$, $\eta_p^2 = 0.84$; Figure 5b]. There was no significant effect of distance on food spillage [*F* (4, 16) = 1.56, $p = .232$, $\eta_p^2 = 0.28$] or interaction between line and distance on food removal [*F* (4, 16) = 0.50, $p = .734$, $\eta_p^2 = 0.11$].

Experiment 5: Proximity effects (single repellent line)

In Experiment 5, the repellent was present in either Line A or Line B only each day (Figure 6a). There were no significant differences in food removal between Lines A and B across distances [*F* (1, 2) = 0.14, $p = .744$, $\eta_p^2 = 0.07$], or in repellent versus non-repellent lines [*F* (1, 2) = 1.46, $p = .346$, $\eta_p^2 = 0.42$] or across distances [*F* (3, 6) = 0.88, $p = .502$, $\eta_p^2 = 0.31$]. Similarly, there were no interaction effects between each of the variables: Lines A and B, presence of the repellent and the distances between food and the repellent (all *p*s > .05).

There were no significant differences in food spillage (Figure 6b) between Lines A and B [*F* (1, 2) = 5.87, $p = .136$, $\eta_p^2 = 0.75$], or when repellent was

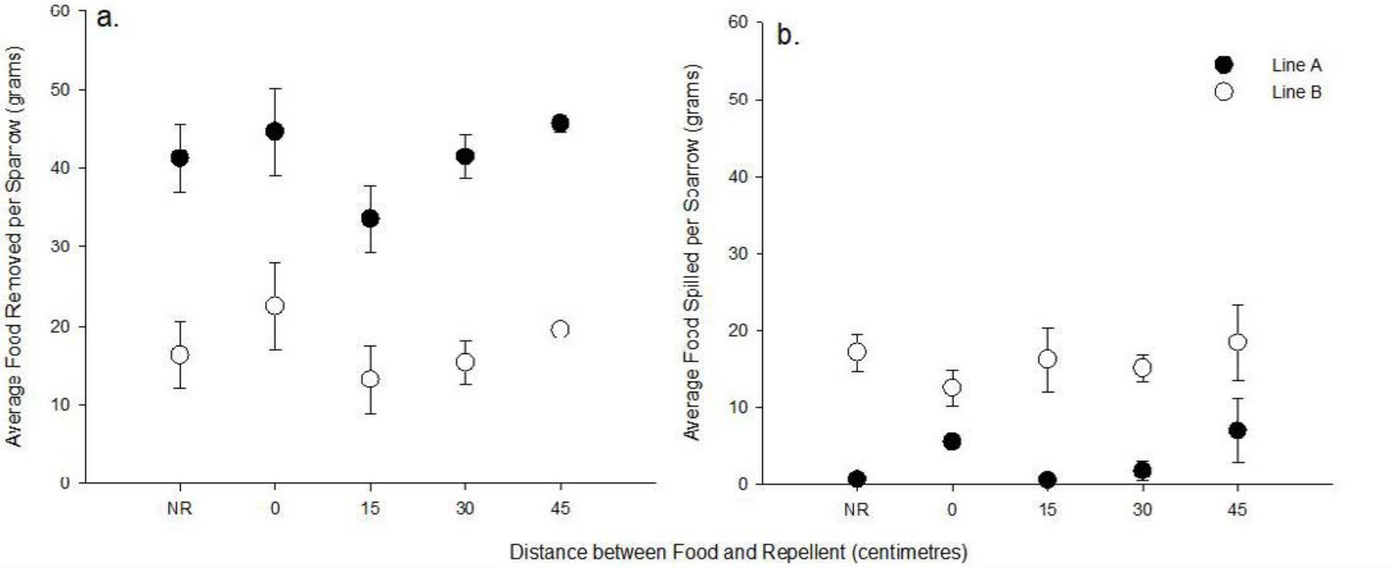

Figure 5. Average food removed (a) and spilled (b) per sparrow (grams) as the distances (cm) between the food and the repellent were varied in Lines A (solid circles) & B (open circles). Standard error bars are shown. (NR = no repellent).

present or not [*F* (1, 2) = 0.89, *p* = .794, η_p^2 = 0.42], or across distances [*F* (3, 6) = 0.56, *p* = .660, η_p^2 = 0.22]. Similarly, there were no interaction effects between each of the variables Lines A and B, presence of the repellent and the distances between food and the repellent (all *p*s > .05). An interaction between the line, presence of repellent and distance that approached significance (*p* = .060), reflected a generally higher food spillage per sparrow in repellent Line A compared to non-repellent Line B across distances and a generally higher food spillage in non-repellent Line A compared to repellent Line B across distances.

Experiment 6: Field study

In Experiment 6, repellent was placed in both Lines A and B simultaneously at each distance (Figure 7a). There was a significant difference in food removal between Line A and Line B [*F* (1, 4) = 9.98, *p* = .034, η_p^2 = 0.71]; however, there was no significant main effect of distance on food removal [*F* (4, 16) = 0.23, *p* = .919, η_p^2 = 0.05] or significant interaction between line and distance on food removal [*F* (4, 16) = 0.45, *p* = .768, η_p^2 = 0.10].

There was no main effect of line on food spillage, [*F* (1, 4) = 0.14, *p* = .911, η_p^2 = 0.004] or distance on food spillage [*F* (4, 16) = 0.97, *p* = .450, η_p^2 = 0.20] and no interaction between line and distance on food spillage [*F* (4, 16) = 1.37, *p* = .288, η_p^2 = 0.26 (Figure 7b)].

Experiment 7: Proximity effects (single repellent line) field study

There were no significant differences in food removal between Lines A and B [*F* (1, 2) = 5.80, *p* = .138, η_p^2 = 0.74], between repellent and non-repellent lines [*F* (1, 2) = 0.90, *p* = .444, η_p^2 = 0.31] or across distances [*F* (3, 6) = 1.47, *p* = .313, η_p^2 = 0.42; Figure 8a]. An interaction effect between line and the presence of repellent was trending towards significance [*F* (1, 2) = 17.32, *p* = .053, η_p^2 = 0.90].

There were no significant differences in food spillage between Lines A and B [*F* (1, 2) = 6.98, *p* = .118, η_p^2 = 0.78, or in repellent and non-repellent lines [*F* (1, 2) = 1.30, *p* = .373, η_p^2 = 0.39] or across distances [*F* (3, 6) = 1.08, *p* = .426, η_p^2 = 0.35; Figure 8b]. There were no interaction effects between each of the variables in spillage across Lines A and B, presence of the repellent and the distances between food and the repellent (all *p*s > .05).

General Discussion

This series of experiments aimed to measure the efficacy of a commercially available repellent for deterring sparrows. These progressed through experiments that tested whether the presence of repellent altered the spatial use of an aviary through to more sensitive indicators of repellency based on levels of food removal

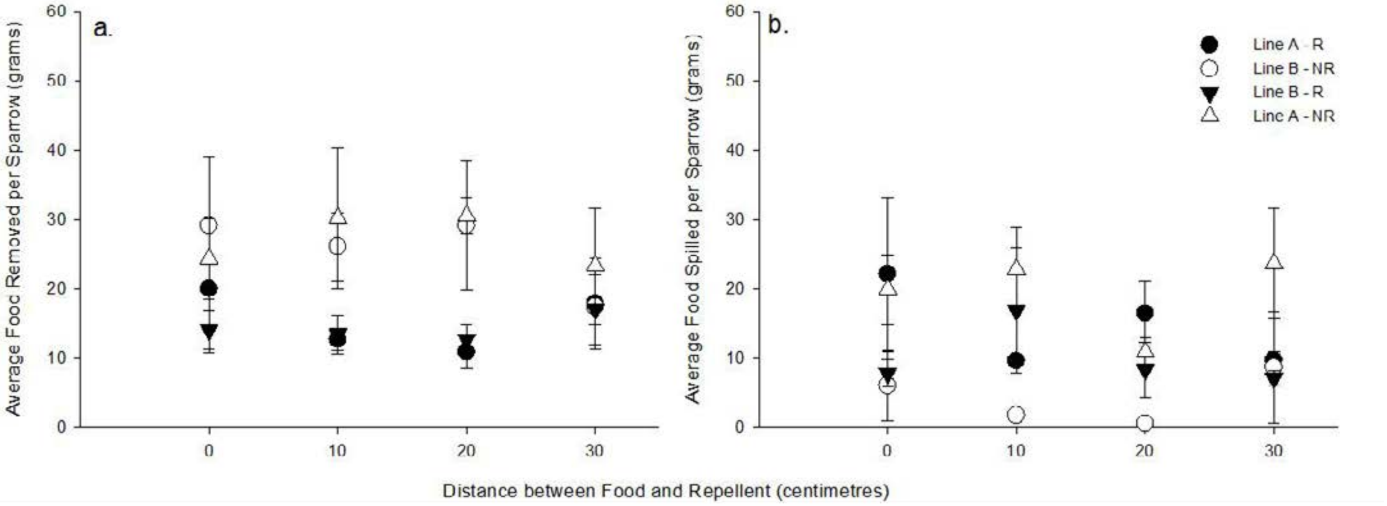

Figure 6. Average food removed (a) and spilled (b) per day (grams) as distances (cm) between food and repellent were varied in Lines A & B. Line A (repellent R: solid circles; no repellent NR: solid triangles) or Line B (repellent R: open triangle; no repellent NR: open circles). Standard error bars are shown.

and spillage from containers at varying distances from the repellent. In addition, in the field experiments, birds could make a choice of where to feed; whether at the feeders closer to or further from repellent or at alternate food sources. None of these experiments provided evidence of a repellent effect of the gel on sparrows.

Based on the position of captive sparrows (Experiment 1) and locations of faecal accumulation (Experiment 2) in the aviary, the birds preferred a particular area within the enclosure. However, this preference was independent of the location of the repellent and suggests that an environmental factor, such as an area more disrupted by foot traffic closest to Zone 4, was causing birds to focus their activity in Zone 1 of the aviary. In addition, there was the possibility that the aviary door and repeated human entry affected feeding behaviour; however, there was no difference in food removal in Experiment 3 when the set up was reversed (Figure 4) and experimenters entered the aviary once per day for a short period to replenish food, thus it was concluded that there was minimal disruption. The results of the latter experiments support the conclusion of lack of effect of the aviary door; in Experiment 4 more food was removed from the container furthest from the door, and in Experiment 5 more food was removed from the container closest to the door.

We did demonstrate some significant differences in food removal rates in relation to distance from the gel. However, contrary to expectations, food removal increased when the repellent was close to the food (Experiment 3). In other experiments, we demonstrated some significant differences in food removal and spillage between food sources but that did not differ between distances from the gel (Experiments 4 and 6). As with the earlier experiments, the differences in feeding between the food sources suggest some spatial bias in the feeding which appears unrelated to the presence of the repellent. We did note differences in the variability of the amount of food removal related to distance of the food bowl from the repellent, which may suggest some differences in the way birds interact with the food in relation to proximity to the repellent.

The properties of the gel used in the current series of experiments were based on it having aversive smell, optical or visual properties acting as a primary repellent. Olfactory repellents are assumed to target aspects of the animals' chemosensory systems, eliciting irritation as a defense mechanism (Stevens & Clark, 1988). For example, airborne delivery of methyl anthranilate (MA) may act as potent avian irritant stimulating the nociceptive system associated with the mucosa of the noses and eyes, and by being detected orally (Stevens & Clark, 1988). Our results suggest that the volatile substances within the tested gel had no such effects. The visual, apparently aversive, signal from the repellent is described by the manufacturer to be detectable within the ultraviolet visual range of birds as flames (Jeonjinbio Co. Ltd, 2017). While birds can detect ultraviolet light, a study on pigeons found no evidence of a visual repelling effect (Day et al., 2003).

Consistent with its likely use in field settings, one of the major bases of the design of the current

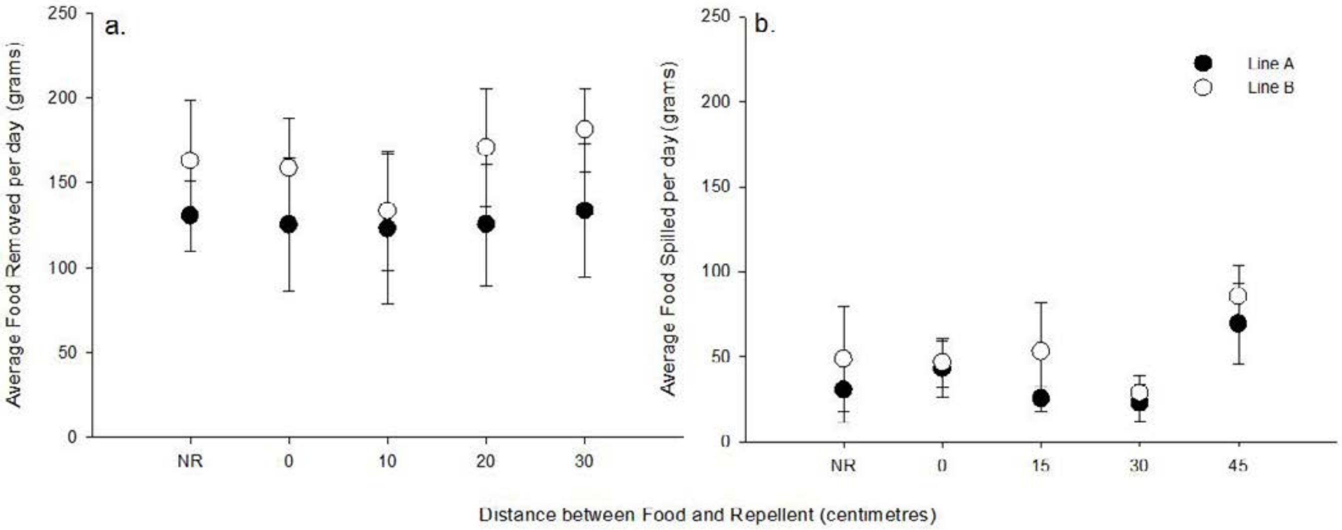

Figure 7. Average food removed (a) and spilled (b) per day (grams) as distances (cm) between food and repellent was varied for Line A (solid circles) and Line B (open circles). Standard error bars are shown. (NR = no repellent).

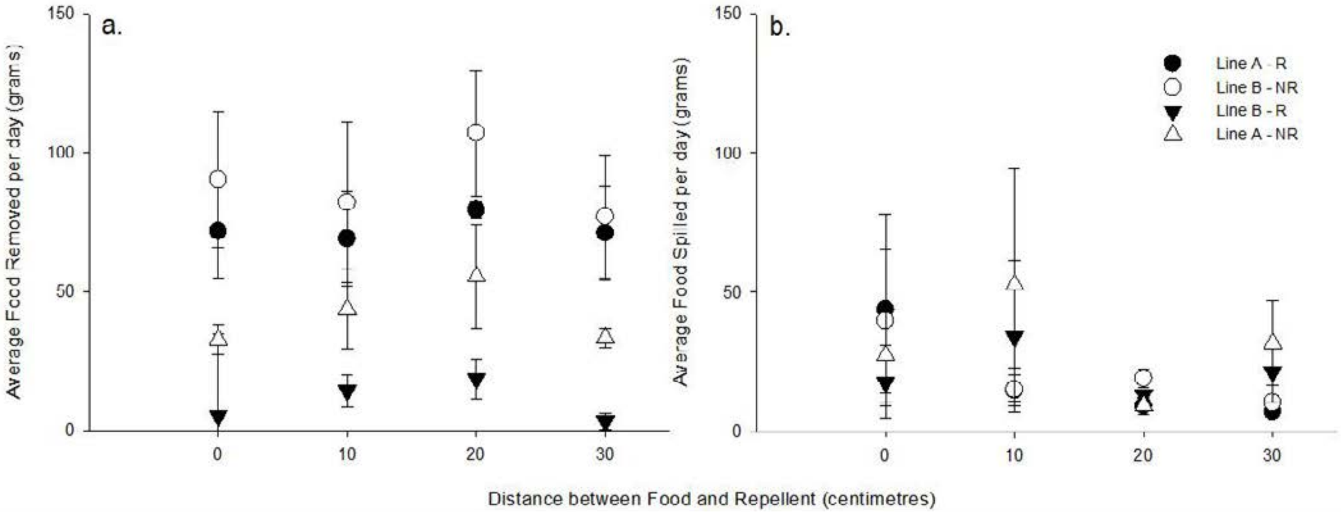

Figure 8. Average food removed (a) and spilled (b) per day (grams) as distances (cm) between food and repellent were varied in Lines A or B. Line A (repellent R: solid circles; no repellent NR: solid triangles) or Line B (repellent R: open triangle; no repellent NR: open circles). Standard error bars are shown.

experiment was to test the effects of the repellent over an extended period of up to 26 days. It is possible that such a design may have hidden an early repellent effect that was lost because birds habituated to the smell that was acting as a primary repellent with no physiological effects or consequences. Post hoc analyses, however, comparing the initial and final series of replications within each experiment showed no habituation in the form of increased food removal in each experiment. Many repellents are intended to have an effect beyond their immediate location, known as common hazing (Cook, Rushton, Allan, & Baxter, 2008). These include scarecrows, model predators and bird distress calls. There is a reduced effectiveness of such repellents, particularly if presented continually or on a predictable schedule (Cook et al., 2008). Primary repellents used over more extended periods are frequently ineffective, as an early learned avoidance of a mildly unpleasant sensation decays rapidly (Day et al., 2003), especially where the outcome is access to a valued resource such as food.

It is possible that we may not have been able to detect a very mild repellent effect using the approaches described because provision of a high-value resource such as food masked any repelling effect. Such low repellence may only be detected when tested in situations where birds need to make a choice between utilising a low-value superabundant resource associated with a repellent, and another without. However, such a low repellent effect is unlikely to be of any use in a practical setting.

Approaches to increase the efficacy of a non-ingestive repellent and possibly decrease habituation include the addition and combining of other stimulus dimensions such as a different olfactory signal (Clapperton et al., 2012), altering the location of the repellent more frequently and randomly, and providing a consequence of an aversive event rather than simply 'simulating risk' (Bishop, McKay, Parrott, & Allan, 2003; Gill et al., 1998), as with scarecrows. The formulation of effective repellents based on visual and olfactory signals alone is likely to be very challenging, therefore future measurement of these types of repellent might be effective with additional aversive stimuli.

Acknowledgments

We would like to acknowledge the help of Peter Visser, of Key Industries, in giving Unitec students the opportunity to participate in applied research, and Unitec Research and Enterprise office Tuapapa Rangahau for assisting with funding this project through the Research Voucher Scheme. We would also like to thank Felicity Bowden and Unitec students using the Unitec Small Animal Unit for putting up with large aviaries in their learning spaces.

References

Abdollahpour, N., Zendehbad, B., Alipour, A., & Khayatzadeh, J. (2014). Wild-bird feces as a source of *Campylobacter jejuni* infection in children's playgrounds in Iran. *Food Control*, *50*, 378-381. http://doi.org/10.1016/j.foodcont.2014.09.007

Alderson, C., & Greene, A. (1995). Bird-deterrence technology for historic buildings. *APT Bulletin*, *26*(2-3), 18-30.

Avery, M. L. (2002). Avian repellents. *USDA National Wildlife Research Center – Staff Publications*, *462*, 1-8.

Benskin, C. M. H., Wilson, K., Jones, K., & Hartley, I. R. (2009). Bacterial pathogens in wild birds: A review of the frequency and effects of infection. *Biological Reviews*, *84*(3), 349-373. http://doi.org/10.1111/j.1469-185X.2008.00076.x

Bird Free. (2017). Retrieved from https://www.bird-free.com/

Bishop, J. D., McKay, H. V., Parrott, D., & Allan, J. (2003). Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives. *Food and Rural Affairs*, (December), 1-52.

Clapperton, B. K., Porter, R. E. R., Day, T. D., Waas, J. R., & Matthews, L. R. (2012). Designer repellents: Combining olfactory, visual or taste cues with a secondary repellent to deter free-ranging house sparrows from feeding. *Pest Management Science*, *68*(6), 870-877. http://doi.org/10.1002/ps.3244

Cook, A., Rushton, S., Allan, J., & Baxter, A. (2008). An evaluation of techniques to control problem bird species on landfill sites. *Environmental Management*, *41*, 834-843.

Cowan, P., Booth, L., & Crowell, M. (2015). Repellents with potential to protect kea and other native birds from aerial poisoning for possum and rat control. *New Zealand Journal of Ecology*, *40*(1), 29-41.

Gavett, A. P., & Wakeley, J. S. (1986). Diets of house sparrows in urban and rural habitats. *The Wilson Bulletin*, *98*(1), 137-144.

Gill, E. L., Feare, C. J., Cowan, D. P., Fox, S. M., Bishop, J. D., Langton, S. D., … Gurney, J. E. (1998). Cinnamamide modifies foraging behaviors of free-living birds. *The Journal of Wildlife Management*, *62*(3), 872-884.

Greig-Smith, P. W., & Rowney, C. M. (1987). Effects of colour on the aversions of starlings and house sparrows to five chemical repellents. *Crop Protection*, *6*, 402-409.

Jeonjinbio Co. Ltd. (2017). BirdFree factsheet. Retrieved from http://www.jjbio.co.kr

Porter, R. E. R. (1995). A preliminary evaluation of three food flavoring compounds as bird repellents. In R. J. Mason (Ed.). *Repellents in Wildlife Management: Proceedings of a Symposium*. (pp. 393-399). Denver, CO: National Wildlife Research Center.

Shaw, L. M., Chamberlain, D., & Evans, M. (2008). The house sparrow *Passer domesticus* in urban areas: Reviewing a possible link between post-decline distribution and human socio-economic status. *Journal of Ornithology*, *149*(293), 293-299. http://doi.org/10.1007/s10336-008-0285-y

Smith, I. (2014). Bird free: The long-lasting deterrent. *International Pest Control*, *56*(3), 150-151.

Steiger, S. S., Fidler, A. E., Valcu, M., & Kempenaers, B. (2008). Avian olfactory receptor gene repertoires: Evidence for a well-developed sense of smell in birds? *Proceedings of the Royal Society B: Biological Sciences*, *275*, 2309-2317. London, UK: The Royal Society Publishing.

Stevens, G. R., & Clark, L. W. R. (1988). The use of aerosol repellents as an avian deterrent strategy. In R. O. Baler & A. Crabb (Eds.). *Proceedings of the 18th Vertebrate Pest Conference*. Davis, CA: University of California, Davis.

Stock, B., & Haag-Wackernagel, D. (2013). Effectiveness of gel repellents on feral pigeons. *Animals*, *4*(1), 1-15. http://doi.org/10.3390/ani4010001

Whiley, H., van den Akker, B., Giglio, S., & Bentham, R. (2013). The role of environmental reservoirs in human campylobacteriosis. *International Journal of Environmental Research and Public Health*, *10*(11), 5886-5907. http://doi.org/10.3390/ijerph10115886

Authors

Kristie E. Cameron, Graham Jones, Diane L. Fraser and Nigel J. Adams are Lecturers in Environmental and Animal Sciences at Unitec Institute of Technology, Auckland, New Zealand. Jodi R. Salinsky was a Lecturer at Unitec at the time of the study, but now works for the University of Auckland. Roxanne J. Wassenaar, Ayellet Panapasa, Kelsey J. Brown, Angela D. Halliday, Kaitlyn R. Lodge-Osborn, Emily A. Robson, and Joanne P. Aley are all former students in this department.

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