CPS 2014 RFP
FINAL PROJECT REPORT

Project Title
Evaluation of falconry as an economically viable co-management strategy to deter nuisance birds in leafy green fields

Project Period
January 1, 2015 – December 31, 2015

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Objectives
Objective 1: *To characterize key bird behavior and attractants in the leafy greens farmscape with a known history of bird intrusions and human pathogen-driven crop losses. A detailed questionnaire will be used to record landscape features, management practices, and animal damage costs that may be associated with bird intrusions. In collaboration with growers in the central California coast, the fields with a highest risk for significant nuisance bird intrusions will be selected and enrolled confidentially in the falconry pilot study (Objective 2).*

Objective 2: *To build data-driven support capacity for implementation of commercial falconry to reduce the risk of microbial contamination of leafy greens. Commercial falconry will be evaluated as a non-lethal, effective, affordable, and sustainable approach to reduce the risk of microbial contamination of leafy greens due to bird intrusions. We will enroll test fields where falcons will be strategically deployed at different points during production and measure their effect on bird flocking and foraging behavior, and crop damage (fecal deposits, feeding) compared with nearby control fields. We will use data on application costs, effectiveness, value of the crop, and impact of the deterrent to estimate cost effectiveness of commercial falconry relative to potential reduced intrusion events and crop destruction.*

Funding for this project provided by the Center for Produce Safety through:
CPS Campaign for Research

FINAL REPORT

Abstract

To test the efficacy of falconry to deter pest birds in leafy greens fields, several trials were performed in spring and fall 2015 in Monterey County, California. The goal was to evaluate nuisance bird attractants, and whether the number of birds decreased in leafy greens blocks during bird abatement treatment using falconry, and whether reductions persisted after falconry. Ranches suitable for falconry were enrolled confidentially and were divided into treatment and control blocks. Bird counts were conducted by a trained field crew in defined time intervals around each block. Furthermore, we aimed to evaluate whether fecal contamination of leafy greens was related to the number of birds, and whether it was reduced by the use of falconry. For these purposes, transects were designed in the blocks to count birds and number of plants visibly contaminated with bird feces. Overall, we found a high variability in the presence, abundance, and diversity of birds in both in the treatment and control blocks, as well as the frequency of bird intrusions and foraging on the ground in the fields. The presence of birds was particularly low in the spring, however, we observed a higher number of transects with less birds during and after the falconry treatment blocks compared with the control blocks. Bird populations were much higher in the fall, but the first trial in September was confounded by interference with a falconer working at an adjacent vineyard. In October and November, we were able to document more definitively the efficacy of falconry in reducing bird numbers over 5 days of treatment and for 3 days post-treatment. Likewise, the percentage of plants visibly contaminated with bird feces was low (range from 0 to 1.9%) overall, but we detected a correlation between reduction of birds in treatment blocks and reduced bird feces in these blocks compared with controls. We also found that the number of birds seen on the ground (foraging) was a better indicator of fecal contamination than the number of birds seen in total (fly overs plus ground foraging). In summary, findings from this proof-of-concept study suggest that falconry is a viable approach to reduce bird intrusions and fecal contamination in leafy green fields when large numbers of nuisance birds are present. Season plays an important role in bird abundance, with fall being the most effective time to use falconry for bird control (abatement) in produce fields in the central California coast. Additional studies with more farms are needed to determine the effect of using falconry in combination with other non-lethal bird abatement approaches (e.g., audio-visual deterrents) to maximize the cost-effectiveness of this approach.

Background

Wild birds are common in agricultural areas, and represent a potential source of zoonotic enteric pathogen contamination (e.g., *Campylobacter*, *Salmonella*, Shiga toxin–producing *E. coli*) of leafy greens and other fresh produce. Birds aggregating in large numbers may cause heavy fecal contamination of the production environment, especially under roosting areas (e.g., trees, powerlines). Foodborne pathogen strains associated with fresh produce–related outbreaks have been found in environmental samples, including fecal material from local wild or feral animal populations collected during root cause investigations (Jay et al., 2007; Gardner et al., 2011; Laidler et al., 2013). A wild animal shedding a zoonotic foodborne pathogen could contaminate plants directly through fecal deposition or indirectly via fecal contamination of agriculture water or soil in contact with the plants. Our research group and others have documented foodborne pathogen prevalence in some of the more common wild bird species in the central California coast near leafy green produce fields. For example, *E. coli* O157 was detected in two wild bird species (American crow, brown-headed cowbird) sampled on a feedlot in a leafy green production region (Jay et al., 2010). In a CPS-funded survey in the same region, one dark-eyed junco was found positive for *E. coli* O157:H7 among over 800 small bird samples (some recaptures), while 2.7% of birds were positive for *Salmonella* (https://cps.ucdavis.edu/amass/documents/researchproject/260/113011FINAL%20GORDUS%20CPS%20Wildlife%20survey%20for%20E.%20coli.pdf). Results from these prevalence surveys indicate a risk of foodborne pathogen contamination of leafy greens from wild bird intrusions, but ultimately that level of risk will be dependent on multiple factors, including bird population density, behavior (flocking, foraging), and vulnerability of the crop (Jay-Russell, 2013).

Avian foraging causes damage to virtually every food crop, including almond (Hasey & Salmon, 1993), sunflower (Avery & DeHaven, 1982), corn (De Grazio, 1978), rice (de Mey et al., 2012), and arable crops (Coleman & Spurr, 2001), and is likely to cost billions of dollars in lost production annually (Bomford & Sinclair, 2002). Leafy green growers report that controlling nuisance birds (e.g., crows, blackbirds, starlings, geese), particularly social species that aggregate in large numbers and may cause focal or widespread fecal contamination in agriculture fields, remains the most challenging area of co-management in fresh produce production. There is an urgent need to better understand bird attractants in leafy green production fields, and mitigate these risks through cost-effective, environmentally friendly deterrent approaches.

Methods to prevent birds from entering or damaging a crop fall into five categories: 1) exclusion; 2) lethal; 3) chemical; 4) visual; and 5) auditory. The success of each type of deterrent is determined by application cost, product efficacy, value of the crop, and any impact the deterrent has on the final product delivered to consumers. All methods seek to either eliminate birds, or to create conditions in which birds are scared or uncomfortable. In this way, most systems seek to recreate conditions that are similar to risk of predation, with most attempting to mimic predators or to mimic intraspecific alarm calls. While most of these methods are efficient at deterring birds when they are first initiated, birds quickly habituate to almost all methods if they are not reinforced by actual predators (Bomford & Sinclair, 2002).

Despite the multitude of examples of bird damage and the wide array of methods used to attempt to deter birds, very few commercially available methods have been tested scientifically. Furthermore, many of these methods are not currently practical or desirable for leafy green produce production. For example, exclusion netting is the most effective method for preventing bird damage but is costly to purchase and install, and is not efficient unless installation is consistent. Lethal methods including shooting, poisoning, and trapping birds, are only effective if a large enough number of the pest birds can be killed, and even large-scale attempts at removing millions of birds can have negligible economic benefit for growers (Blackwell et al., 2003). Similarly, lethal methods are tightly controlled since they are not always species-specific (especially in the case of poison), and can kill protected or even endangered species. Chemical deterrents are currently being developed, but in fresh market crops the ability to use these products may be limited by the effect of the chemical deterrent on products for consumers and delays in approval for registration with regulatory agencies.

Visual and auditory deterrent methods are probably the most common bird control approaches used by leafy green growers. For example, reflective tape, mirrors, kites, and balloons rely on triggering a fear response in birds by creating novel movement, color and light sources, or by mimicking predators. Auditory methods, such as the use of gas-cannons, loud vehicles, distress calls, and horns, have been shown to have limited efficacy depending on the crop type and pest species (Bishop et al., 2003). Both auditory and visual methods are the most commonly used but are rarely effective over an entire growing season due to habituation, and they may be annoying to surrounding landowners. The efficacy of visual and auditory deterrents have been shown to vary significantly between almost complete removal of birds, to virtually no effect (Bishop et al., 2003). A study comparing a commercially-available reflecting device with more common and less costly eye-spot balloons found that the eye-spot balloons were more effective (Fukuda et al., 2008). In the United States, reflective tape was found to be effective in reducing damage from red-winged blackbirds (*Agelaius phoenice*us) and house sparrows (*Passer domesticus*) but not effective in reducing damage from mourning doves (*Zenaida macroura*) and American goldfinches (*Carduelis tristis*) in arable crops (Dolbeer et al., 1986). Furthermore, both visual and acoustic methods have been shown to have little ongoing effect on avian foraging, because birds quickly habituate to them. Starlings (*Sturnus vulgaris*) habituate to distress calls in 7–13 days (Summers, 1985). Up to 100% of crows can be removed from a roost site using lasers but they return within one day without ongoing treatment (Gorenzel et al., 2002). Similarly, the use of pyrotechnics can be highly effective over short periods of time, but birds quickly habituate to them (Bishop et al., 2003). There is even some indication that scaring methods increase damage by causing birds to expend more energy and therefore consume more fruit (Bomford & Sinclair, 2002). Acoustic or visual methods alone are likely to cause habituation quickly, but combinations of methods may increase the time to habituation. Broadcasting alarm and distress calls in conjunction with other conventional methods (including the use of gas cannons) reduced damage to Pinot Noir crops in California (Berge et al., 2007).

Additionally, most conventional deterrents are not discriminatory and can affect non-pest species, including threatened endemic birds, thereby running counter to co-management goals. For example, growers may supplement visual/audio deterrent approaches with removal of bird shelter/habitat near leafy green fields, resulting in a homogenous agricultural landscape with few shrubs and trees, which has negative implications for native biodiversity (Tscharntke et al., 2005). Some desirable avian species provide agricultural environments with natural pest control services, and current bird deterrent methods therefore have the potential to reduce these ecosystem services (Sekercioglu et al., 2004).

Trained raptors have been used for biological control of nuisance birds at airports, stadiums, agricultural fields, and garbage dumps (Baxter & Allan, 2006). Commercial falconers offer their services throughout the U.S. to protect valuable crops from pest birds, but their efficacy at controlling detrimental birds has heretofore not been scientifically evaluated. In a preliminary study of the use of falcons to reduce damage to strawberries, an intensive release program minimized fruit damage further away from immediate shelter but not in beds adjacent to natural shelter. Researchers concluded that falconry for bird control in that setting was site-specific, and depended on proximity of safe shelter, bird species, and availability of other food sources.

Falconry may be an ideal method for preventing contamination of fresh market leafy greens because of the short time frame before and during harvest in which crop contamination from bird intrusions has the potential to be dangerous to humans. Specifically, leafy greens may be an ideal study system for assessing the value of falconry for reducing the abundance of pest birds for these reasons: 1) fields nearing harvest maturity are relatively small despite being in a much larger area seeded on different dates, and typically have little cover so can be patrolled by a single falconer; 2) the crop itself is not a major food source for the pest birds so they may be deterred more easily; 3) repeated harvests over the course of a year allow for more variables to be tested; 4) the short timeframe prior to harvest in which leafy greens are especially susceptible to contamination by bird feces may make a potentially highly effective method, such as falconry, an economically viable method for pest control; and 5) falconry supports co-management by being both environmentally friendly (target specific and does not require poisons, chemicals, or habitat removal) and neighbor friendly (does not require loud noises or unattractive visual scare devices).

Research Methods and Results

Methods

General methods

Commercial ranches growing leafy greens in Monterey County were enrolled confidentially in the study and divided into two to four (20- to 40-acre) treatment and control blocks based on similar production practices and farm landscape. Requirements for safe falconry included distance from major roads/highways, buildings, and other raptors. UC Davis field crews conducted bird counts by walking 100-m transects set up on the roads around the blocks. Bird counts were started at sunrise by walking each transect at 10-minute intervals over 3 hours. Observers also recorded the date and location, crop, weather parameters (wind, temperature), irrigation and presence of workers and equipment in the study block. Species and number of birds flying over transects, or on the ground, plants, or sprinkler heads in the field were recorded using standardized U.S. Geological Survey (USGS) 4-digit alpha coding for bird species. The observers also recorded if the birds were seen in flocks or individually.

Commercial falconers from Tactical Avian Predators were hired for bird abatement (http://www.tacticalavianpredators.com/index.html). The research protocol (#18660) was approved by the UC Davis Institutional Animal Care and Use Committee (IACUC). Figure 1 shows a falconer deploying raptors for nuisance bird abatement at vegetable fields.

Specific methods

Spring trials

Two trials were performed in spring 2015 (May and June) using blocks from Ranch A (560 acres) and Ranch B (350 acres) as treatment and control fields, respectively. In May, we conducted a 1-day pilot trial of falconry to refine methodology. Bird abundance and diversity were monitored pre- and post-treatment for two consecutive days. In June, we performed a three-day trial, and expanded the pre- and post-monitoring to 4 days based on findings from the pilot trial. At the time of the spring trials, the blocks were fallow, recently seeded, or had lettuce or broccoli in the emerging stage.

Fall trials

Three trials were performed in fall 2015: #1 (September), #2 (October), and #3 (October–November). The first fall trial took place from Sept 19–28 (10 days), and comprised 2 days of surveys pre-treatment, 5 days of falconry treatment, and 3 days of surveys post-treatment at Ranch A. In the treatment field, two blocks with four transects each were selected (one with mustard and one with lettuce). Six transects were established at the Ranch B (control) including two fallow blocks and four blocks with mustard. The blocks and transects chosen were located in surroundings similar to the treatment field (cactus, vineyard, rangeland, etc.).

The second fall trial took place from October 8–20 (12 days), and comprised 4 days of surveys pre-treatment, 5 days of falconry treatment, and 3 days of surveys post-treatment. Ranch B was taken out of production in October, and we had to identify new control blocks. Because of the size of Ranch A, control blocks were found far enough from our treatment site to expect no interference with the effect of falconry (1.54 km).

The third fall trial was marked by the presence of rain and the end of the leafy green season, and lasted from October 26 to November 4 (9 days). We performed 1 day of surveys pre-treatment (additional pre-treatment days were not possible due to wet roads), 5 days of treatment, and 3 days of surveys post-treatment (extended by one day because of the rain).

Only two blocks at Ranch A still had leafy greens (lettuce), which were used as treatment and control blocks, respectively. The second day of survey post-treatment coincided with the start of harvest in both blocks and the end of the 2015 leafy green growing season at Ranch A.

Surveys of fecal contamination in leafy greens

Randomly selected rows were walked at a pace of 100 m/10 min to assess visible fecal contamination on the plants. We recorded the number of feces observed, their size (large when the diameter of the urea portion was more than 1 cm), and the presence of clusters (a cluster was defined as multiple feces found in and around adjacent plants). To estimate the percentage of fecal contamination, we counted the number of plants (lettuce heads and mustard) transversally in a row (6 and 10, respectively) and the approximate diameter (30 and 20 cm, respectively). With the use of Google Maps we measured the length of each row. With these data, we were able to estimate how many mustard plants or lettuce heads were planted in a certain row, and then divide the total number of feces seen by the number of plants estimated. We further analyzed whether the estimated percentage of plants with visible fecal contamination was different between blocks, and whether differences were related to the number of birds seen—in total and on the ground—during the trial in that specific transect.

Results

Bird attractants (Objective 1)

Bird abundance was lower in the spring compared with the fall months (Table 1). In the spring, 11 species were seen during 9 days at both ranches, with American crows, blackbirds, and barn swallows being the dominant species. Bird population dynamics changed dramatically in the fall, with 24 different species observed. Large flocks of European starlings, red-winged and Brewer's blackbirds (large flocks of up to 500 birds) were the dominant species in treatment and control fields. For the first time, horned larks were observed in the fields and gathered in groups of up to 37 individuals. Killdeer were also observed at the treatment lettuce field, mainly using a water drainage pond and the reservoir (maximum flock size 12). Crows were less abundant in fall compared with the spring, and common ravens made their first appearance in the fields in fall. Waterfowl were not common at these ranches probably because the location was inland from the coast. Seagulls were seen in the fall coming to and from a landfill but were outside the perimeter of the transects and did not land in the vegetable fields (not included in the counts). Interestingly, a number of raptors were observed flying over the blocks: American kestrel and red-tailed hawk. Additionally, we saw golden eagle, sharp-shinned hawk, Northern harrier, merlin, and prairie falcon nearby but outside the transects.

We identified key factors acting as attractants for nuisance birds in our fields. Specifically, the vineyards adjacent to both the control and treatment fields acted as an attractant for red-winged blackbird, Brewer's blackbird, and European starling, among others (Table 1). Adjacent cactus fields also served as attractants for nuisance birds that were likely seeking food and shelter, especially American crows. In contrast, in blocks that were closest to rangeland, the predominant species were Western meadow larks and horned larks (seen throughout the study). Birds also used adjacent broccoli fields as shelter, with groups of up to two dozen observed on the ground, sprinkler risers, and broccoli plants. In almost all cases, when birds were observed in lettuce or other leafy green fields, a combination of attractant factors were occurring at the same time: border with a food or shelter source (e.g., broccoli, cactus, vineyard, water drainage, reservoir) or availability of a perching spot, such as power lines, to rest. Other hotspots for bird abundance at both Ranch A and Ranch B included irrigation storage reservoirs. However, birds were observed mainly flying over the leafy green fields without landing/foraging while traveling between the vineyards with their preferred food (grapes), shelter (cactus, broccoli), and water (irrigation reservoirs). The majority of bird intrusions into leafy green fields involved blackbirds and starlings and occurred during the fall months after the grapes were harvested.

Falconry trials (Objective 2)
As noted above, bird abundance was low at the ranches during the spring trials, so we used this period to optimize the survey protocol. A slight reduction in nuisance bird numbers following the 3-day trial was documented mostly related to blackbird fly-overs (data not shown).

Bird counts increased during the first fall trial in September compared with counts in the spring; however, we did not find a significant difference in total numbers for the treatment and control fields (Figure 1), or foraging on the ground (Figure 2). Of note, the September trial was complicated by the presence of another falconer conducting bird abatement at the vineyard adjacent to Ranch A. Both falconers had to agree on when each of them would fly their falcons, as two birds flying in the same range can be problematic. We may have predicted an additive effect with use of two falconers, but our observations instead suggested that the other falconer may have driven birds into our treatment fields. These data were not used in our final analysis of treatment and control fields but do highlight the challenges of research on commercial properties where adjacent land use cannot necessarily be predicted or controlled.

The most definitive data supporting the effectiveness of falconry in leafy green fields was obtained during the trials in October and November. Figure 4 shows an immediate reduction in total birds when the falcon is introduced on day 4; the numbers continued to drop toward zero and the reductions persisted for 3 days after falconry (days 9–11) during fall trial #2. Reductions in the treatment blocks were less dramatic during fall trial #3, but total counts (Figure 5) and birds on the ground (Figure 6) were lower in treatment compared with control blocks. This trial ran for only 9 days due to rain and harvest.

Fecal contamination in leafy greens
A total of 24 transects were monitored for fecal contamination during fall trials #2 and #3. The percentage of plants contaminated in a given row ranged from 0 to 1.9%. Interestingly, Figure 7 shows how the highest percentage of contamination was found in the lettuce control field. This is notable because the number of birds seen in the control block during the fall trials was not consistently high. The lettuce treatment block had lower levels of fecal contamination, which suggests that falconry treatment was effective in deterring the birds from foraging in the lettuce field. Figures 8 and 9 show how the total number of birds seen during the trial and the number of birds on the ground, respectively, are related to the percentage of fecal contamination events. Total number of birds (fly-overs and foragers) did not predict fecal contamination; the number of birds foraging on the ground was the best indicator for fecal contamination, with >150 birds as most likely to cause a higher risk scenario that may require mitigation such as removal of crop.

Outcomes and Accomplishments

This project was conducted as a proof-of-concept study for the Center for Produce Safety to systematically gather science-based data useful for designing future, more comprehensive bird control research projects (for example, the effectiveness of combinations of non-lethal bird control such as falconry and audio/visual deterrents). The project successfully applied food safety and conservation approaches in a co-management context to address animal intrusion risks from birds in leafy greens production. The funds also supported, in part, the research and training of a postdoctoral scholar who won First Place Poster in her session at the UC Davis 1st Annual Postdoctoral Research Symposium presenting this study.

The complexity of leafy green production and unpredictability of bird population dynamics made this a challenging study to conduct with controls. The study was further complicated by the presence of a commercial falconer in September at a neighboring vineyard adjacent to the treatment field. Likewise, the presence of wild raptors may also have influenced bird presence and abundance while we were performing the surveys. Other challenges included unpredictable weather conditions and planting/harvest schedules that introduced undesirable variability in the number and location of treatment and control blocks as well as the total days per trial. We also proposed originally to measure the effect of falconry during harvest but were unable to time the falconry with unpredictable harvest days. Lastly, because only one producer enrolled in the study, we were not able to conduct an economic analysis of costs associated with bird damage compared with falconry and other bird control costs, and potential benefits.

Summary of Findings and Recommendations

- Surrounding crops, adjacent land use and season had a major influence on bird activity in and around leafy green fields enrolled in this study in Monterey County during the 2015 growing season. Important attractants included landscape features that provided food, shelter, and perching spots for nuisance birds. The predominant species observed in large flocks were Brewer's blackbirds, red-winged blackbirds and European starlings.
- Falconry was effective in reducing bird counts at leafy green fields during and after treatment, but the results were dependent on inter-related factors including season and bird abundance. In the central coast, falconry would likely be most cost-effective during the fall when large numbers of nuisance birds are known historically to enter the fields.
- Falconry may also directly reduce bird intrusions and fecal contamination in leafy green fields, especially when >150 birds are present and seen foraging on the ground.
- Several limitations inherent in the pilot study must be taken into consideration. For example, the lack of blocks with high and constant bird activity, the natural variability of bird presence and abundance between days, as well as production and environmental conditions, which made it difficult to draw robust conclusions.
- Additional studies with more farms are needed to determine the effect of using falconry in combination with other non-lethal bird abatement approaches (e.g., audio-visual deterrents) to maximize the cost-effectiveness of this approach. We also recommend evaluation of using the falcons for longer treatment periods (>5 days) and follow-up post-treatment for more than 3 days to determine the length of the effect.
- Ultimately, management of pest birds requires an integrated approach based on the unique situation of each ranch and each problem. The findings of this proof-of-concept study emphasize the continued importance of considering adjacent land use during environmental assessments before planting and harvest. Recommendations for growers include taking into account the management of pest birds performed by neighboring ranches and considering the use of falconry to decrease bird intrusions into fields when flocking birds are most abundant.

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Publications and Presentations

Jay-Russell, MT (2015) Evaluation of falconry as an economically viable co-management strategy to deter nuisance birds in leafy green fields. Lightening Round Session, Center for Produce Safety Research Symposium, Atlanta, GA.

Navarro-Gonzalez N, Kross S, Suslow T, Jay-Russell MT (2015) Falconry in fresh produce fields as a potential deterrent of nuisance birds to avoid fecal contamination. First Annual UC Davis Postdoctoral Research Symposium, Davis (CA). Best Poster award.

Navarro-Gonzalez N, Jay-Russell MT (2016) Use of falconry as deterrent of nuisance birds in leafy greens fields in Northern California. 27th Vertebrate Pest Conference, Newport Beach, CA (abstract accepted for oral presentation).

Budget Summary

Budget Appropriations		**Expenses to Date**		**Liens**		**Balance**	
Salary	19,847	Salary	18,600	Salary	0	Salary	1,247
Leave	0	Leave	-23	Leave	0	Leave	23
Supplies	19,334	Supplies	17,424	Supplies	0	Supplies	1,910
Travel	3,320	Travel	6,691	Travel	0	Travel	(3,371)
Benefits	6,835	Benefits	4,525	Benefits	0	Benefits	2,310
Total Direct:	49,336	**Total Direct:**	47,217		0		2,119
Indirect	0	Indirect	0		0		-
Total:	**49,336**	**Total:**	**47,217**	**Total:**	**0**	**Total:**	**2,119**

Balance: $2,119 will be used for registration and travel expenses for the PI (Jay-Russell) and postdoctoral scholar (Navarro-Gonzalez) to attend the 2016 CPS Research Symposium.

APPENDICES

Table and Figures

Table 1. Diversity of bird species identified during spring and fall trials in treatment (falconry) and control fields, Monterey County, 2015.

Species	**Spring (9 days)**	**Fall #1 (10 days)**	**Fall #2 (12 days)**	**Fall #3 (9 days)**	**TOTAL**
American crow	202	45	148	55	450
American kestrel	0	1	0	1	2
American robin	2	0	27	0	29
Barn swallow	86	25	0	0	111
Blackbird, Brewer's	429	1956	5047	2484	9916
Blackbird, red-winged	134	257	101	0	492
Blackbird, unspecified	350	677	452	178	1657
Black phoebe	0	7	6	2	15
Brown-headed cowbird	0	5	0	0	5
California towhee	0	2	0	0	2
Common raven	0	1	0	21	22
European starling	14	552	2562	3815	6943
Horned lark	0	181	8	0	189
House finch	15	8	5	3	31
House sparrow	0	72	0	0	72
Killdeer	0	82	8	1	91
Mallard	6	0	0	0	6
Mourning dove	32	29	4	0	65
Northern flicker	0	0	1	0	1
Northern mockingbird	4	10	0	0	14
Other: mixed blackbirds and starlings	0	1101	657	283	2041
Red-tailed hawk	1	0	2	0	3
Say's phoebe	0	11	26	13	50
Sparrow, unidentified	0	37	288	172	497
Turkey vulture	16	5	0	2	23
Western meadowlark	3	23	126	436	588
White-crowned sparrow	0	1	8	3	12
Yellow-rump warbler	0	0	5	0	5
TOTAL	1294	5088	9481	7469	23332

Figure 1. Professional falconer conducting nuisance bird abatement ("Treatment") at a produce farm in Monterey County.

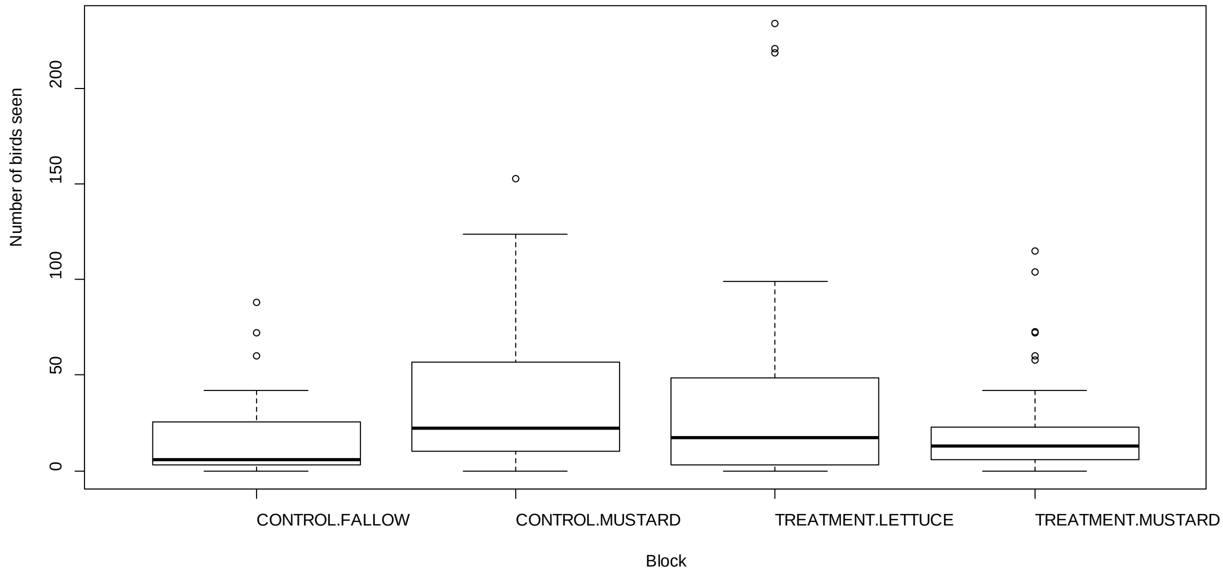

Figure 2. Boxplot showing the number of birds seen during surveys in each of the study blocks (fall trial #1). The horizontal line shows the median, the bottom and top of the box show the first and third quartiles. The vertical dashed lines show the maximum and minimum values.

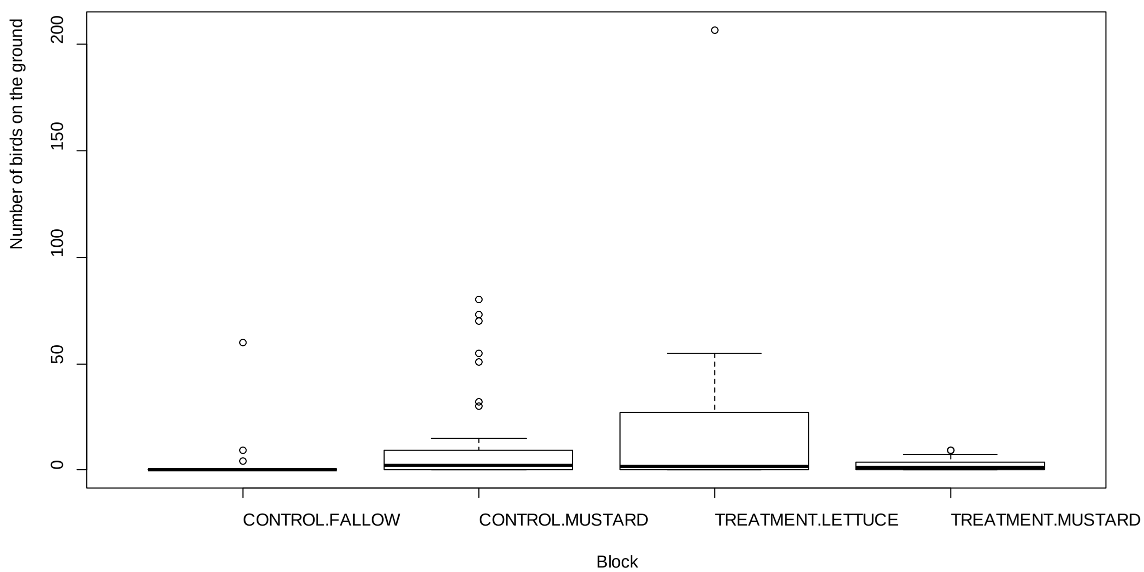

Figure 3. Boxplot showing the number of birds seen on the ground during surveys in each of the study blocks (Fall trial #1).

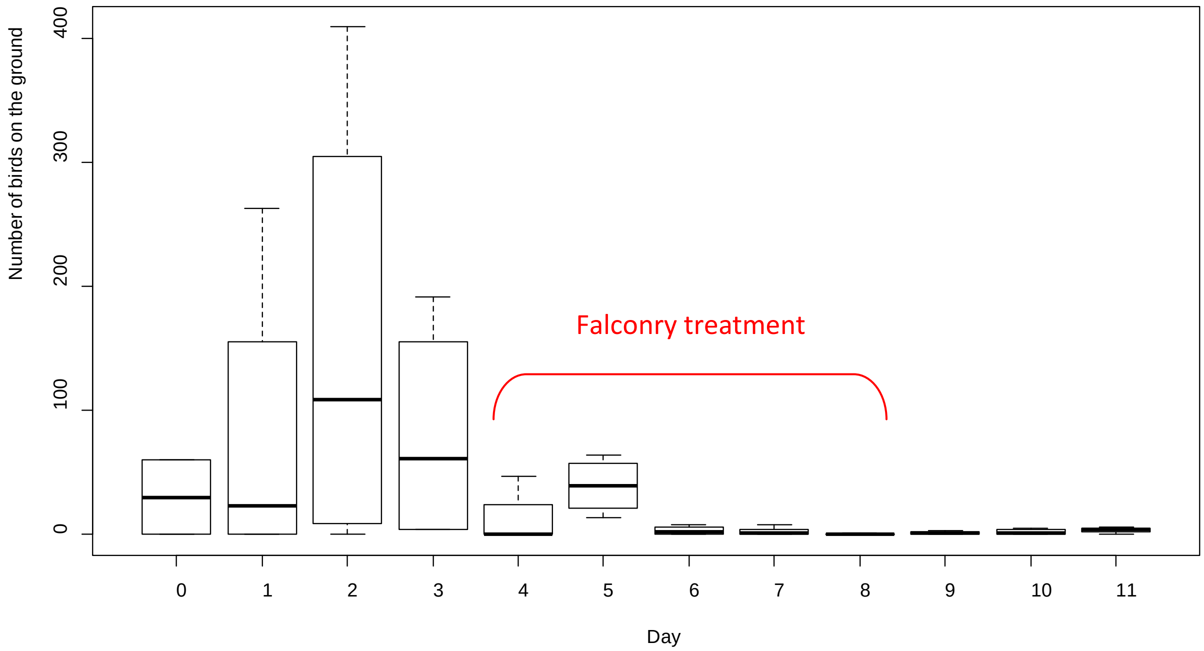

Figure 4. The number of birds seen on the ground in Treatment lettuce field (Fall trial #2). Falconry treatment lasted from Day 4 to 8.

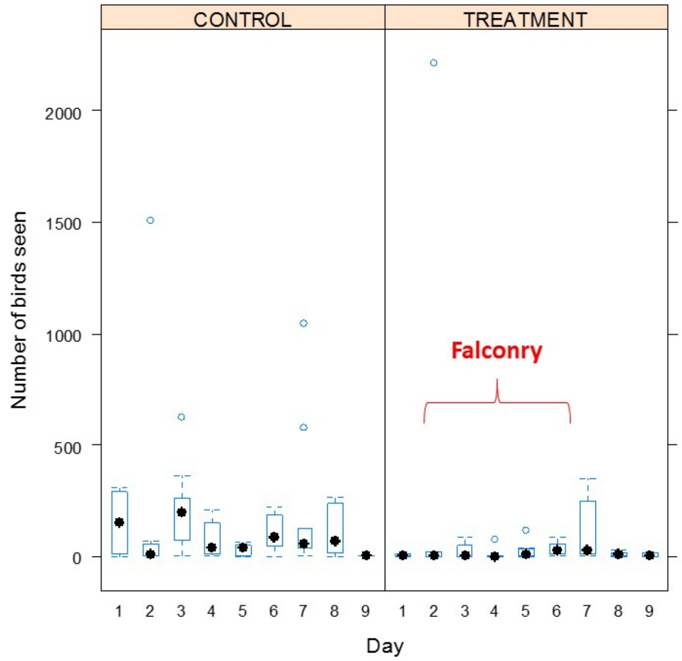

Figure 5. Boxplot showing the number of birds seen in the control and treatment blocks throughout the trial period (Fall trial #3).

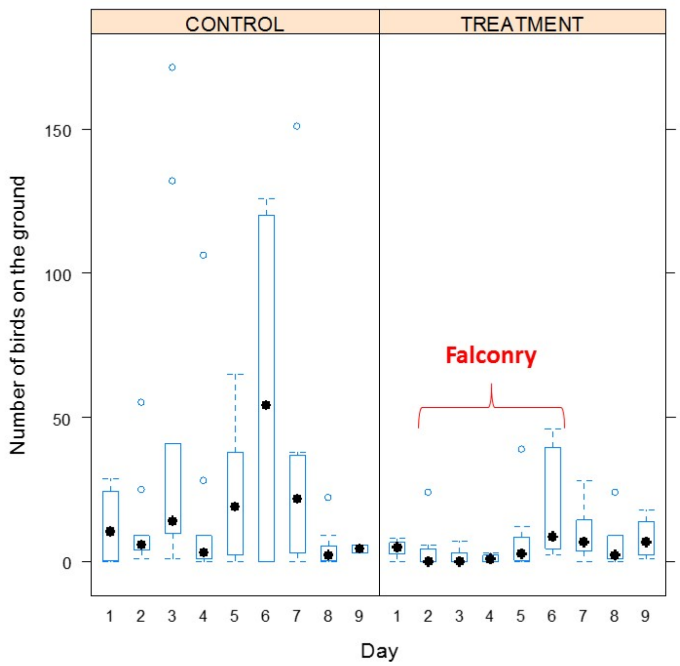

Figure 6. Boxplot showing the number of birds seen on the ground in the control and treatment blocks throughout the trial period (Fall trial #3).

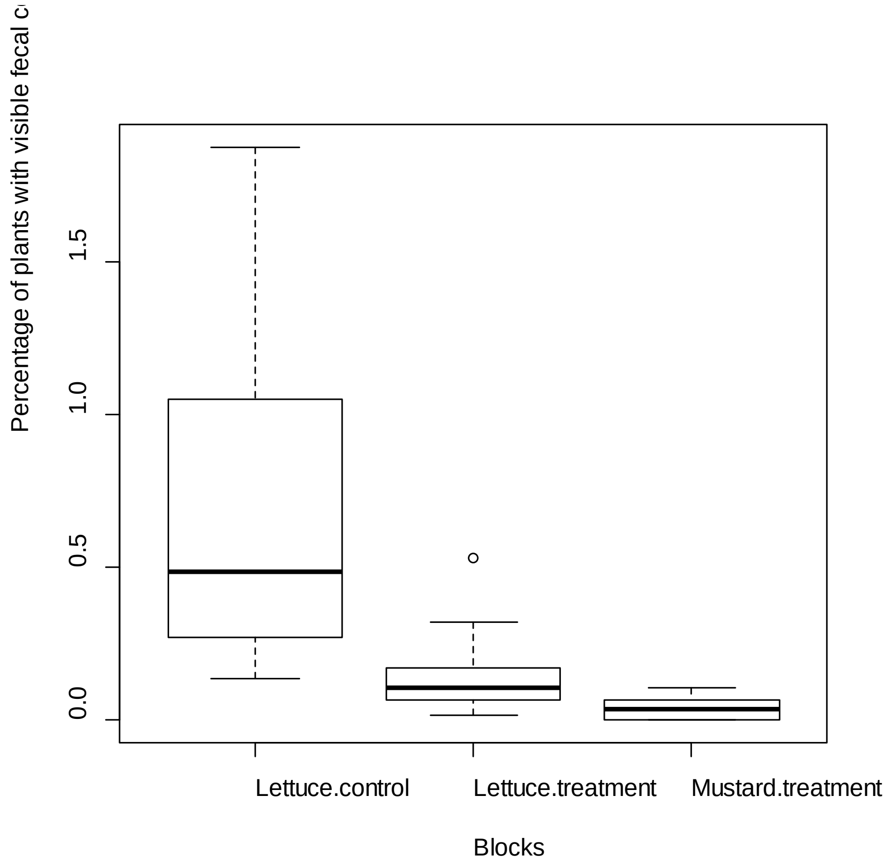

Figure 7. Boxplot showing the percentage of plants with visible bird fecal contamination in each of the study blocks, based on surveys performed on the transects of the Fall trials.

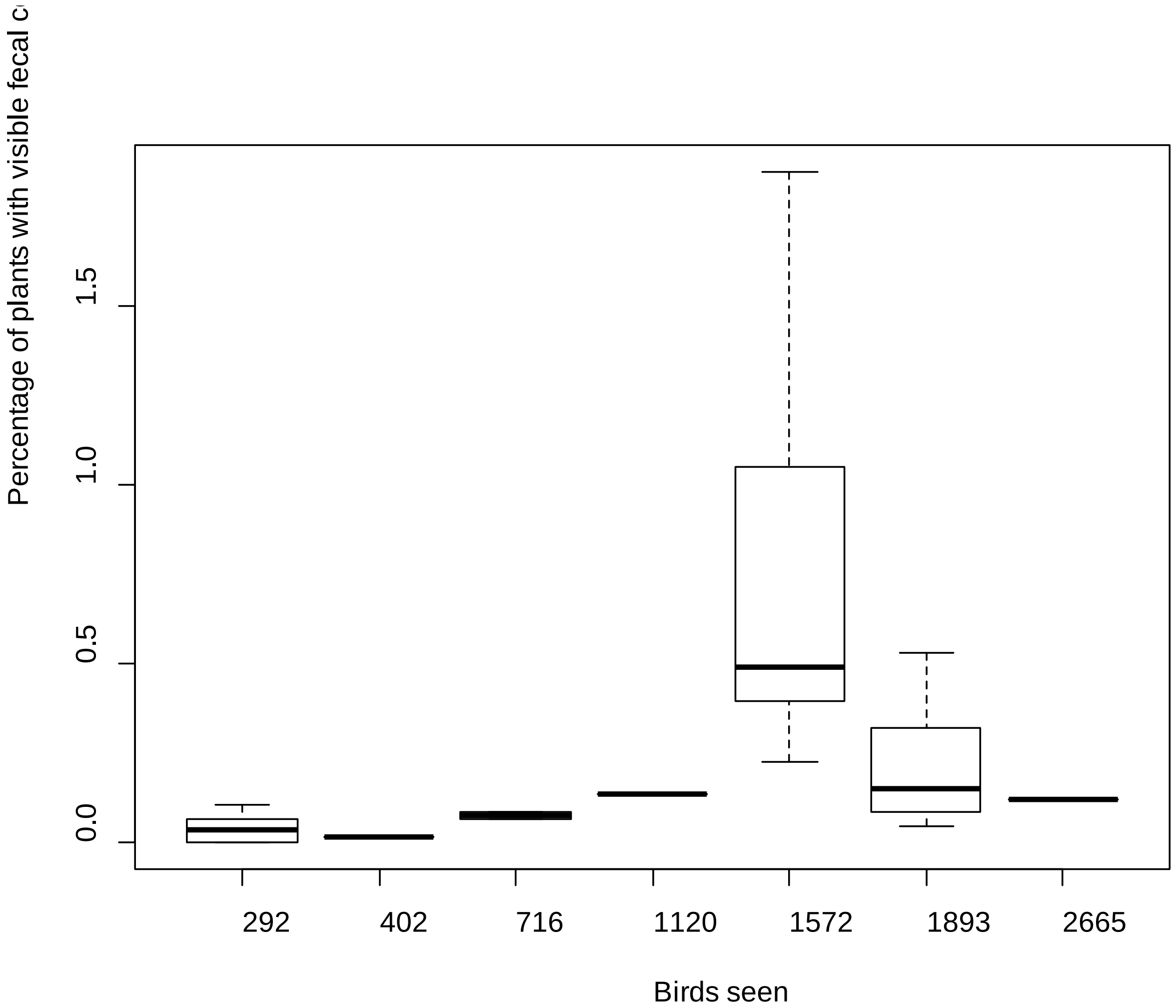

Figure 8. Boxplot showing the percentage of plants with visible bird fecal contamination as a function of the number of birds seen in a specific transect during the Fall trials, as a categorical variable.

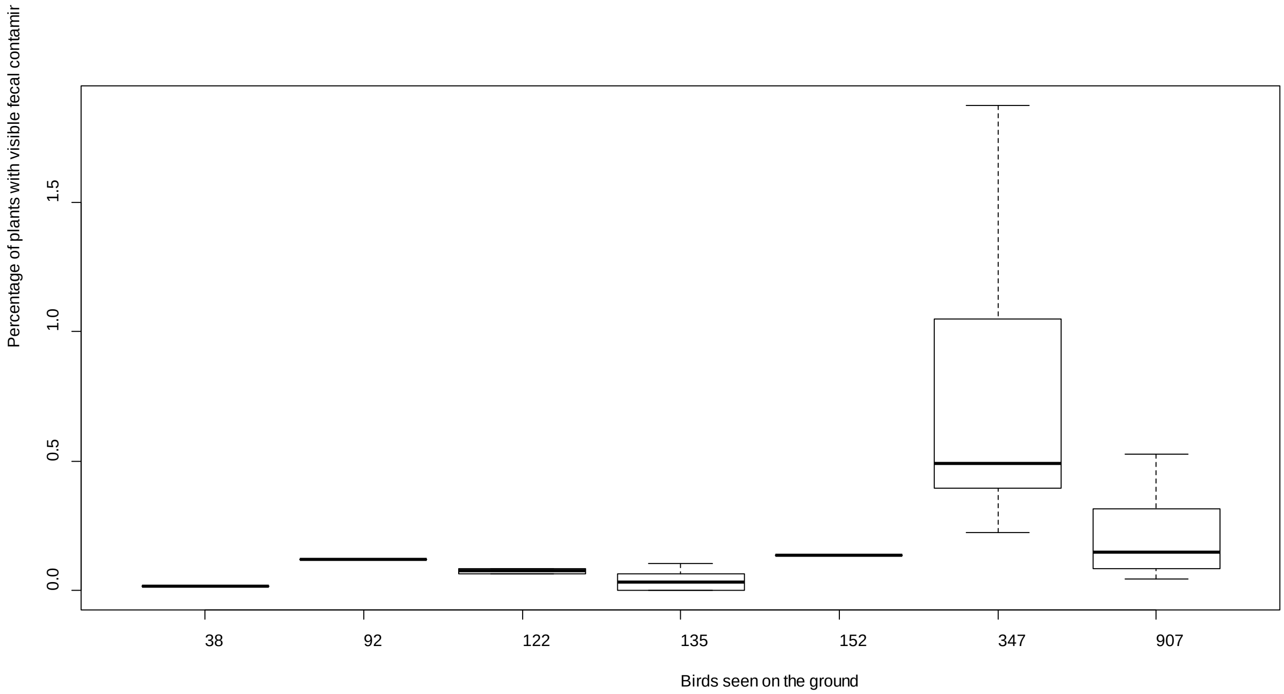

Figure 9. Boxplot showing the percentage of plants with visible bird fecal contamination as a function of the number of birds seen on the ground in a specific transect during the Fall trials, as a categorical variable.

Acknowledgments

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