Use of Falconry to Deter Nuisance Birds in Leafy Greens Fields in Northern California

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ABSTRACT: Some species of birds form large flocks that forage on agricultural fields and frequently damage the crop, resulting in significant economic losses. Additionally, by defecating they potentially contaminate the crop and farm equipment with pathogens, which is of special concern for leafy greens that are consumed uncooked. There is a need to find an effective deterrent that is also environmentally friendly, and falconry is an ideal candidate for this purpose. To evaluate falconry as deterrent of nuisance birds in leafy greens field in northern California, we performed a set of trials on a control ranch and a treatment ranch of similar production and landscape characteristics. We identified avian species, counted individuals, and recorded flock size in daily surveys pre-treatment, during treatment (falconry), and post-treatment. Bird abundance was lower in spring than in fall, probably because many fields were fallow in spring. In both seasons, we observed a large daily variation in the bird abundance and their use of the fields in the surveys pre-treatment. In fall, the first trial was interfered by the activity of a falconer in an adjacent vineyard and the harvest of the grapes. Importantly, in the second trial, use of the field (e.g., foraging, etc.) decreased during five days of treatment and continued to be low for three days post-treatment, suggesting a “memory effect” after hazing by falconry. Interestingly, the third trial coincided with the end of the leafy greens growing season and showed that falconry successfully minimized use of the field by nuisance birds during peak activity. These results indicate that falconry is an effective measure to protect leafy green crops from fecal contamination and damage, but further research is needed at more farms in different regions, and the effect of using falconry in combination with other non-lethal bird abatement approaches (e.g., audio-visual deterrents) should also be evaluated.

KEY WORDS: bird damage, falconry, food safety, hazing, leafy greens, pest bird, produce

INTRODUCTION

Disease outbreaks linked to produce consumption are common in the U.S., and efforts are being made to reduce this risk. Wildlife including avian species are a potential source of foodborne pathogens in the produce production environment (Jay-Russell 2013). E. coli O157 has been detected in several bird species in the California Central Coast (Jay et al. 2010, Gordus et al. 2011). These results indicate a risk of foodborne pathogen contamination of leafy greens from bird intrusions; therefore, measures to avoid pre-harvest contamination should include efforts to decrease pest bird abundance in produce fields and subsequent fecal contamination.

Leafy green growers report that controlling nuisance birds [e.g., American crows (Corvus brachyrhynchos); red-winged and Brewer’s blackbirds (Agelaius phoeniceus and Euphagus cyanoccephalus); European starlings (Sturnus vulgaris); and Canada geese (Branta canadensis)], 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. Co-management is defined as an approach to conserving soil, water, air, wildlife, and other natural resources while simultaneously minimizing microbiological hazards associated with food production (Anonymous 2016). Surprisingly, 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 it 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 some toxicants) 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 by delays in approval for registration with regulatory agencies.

Trained raptors have been used for biological control of nuisance birds at airports, stadiums, agricultural fields, and garbage dumps (Baxter and Allan 2006). Commercial falconers offer their services throughout the U.S. for the protection of valuable crops from pest birds, but their efficacy at controlling detrimental birds needs to be scientifically evaluated in different agricultural settings. In California, Daugovish and Yamamoto (2008) evaluated the use of falconry to reduce strawberry damage by pest birds, and they concluded that the efficacy depended on proximity of safe shelter, bird species, and availability of other food sources.

The purpose of this study was to evaluate commercial falconry as a co-management approach to reduce food safety risks from bird intrusions in leafy green fields. The specific aims were to 1) identify the main avian species...
and assess their abundance in leafy greens fields in spring and fall in the California Central Coast, and 2) evaluate the efficacy of falconry in reducing bird abundance and intrusions in leafy greens fields.

METHODS

General Methods
Two commercial ranches growing leafy greens in Monterey County, California were enrolled confidentially in the study. In each ranch, four blocks (20-40 acre) were selected based on similar production practices and farm landscape. 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 three hours. Observers used binoculars to count and record the species and number of birds flying over transects, or birds on the ground, on plants, or on sprinkler heads in the field. The observers also recorded if the birds were seen in flocks or individually, and the size of the flock, the date and location, crop, weather parameters (wind, temperature), irrigation, and presence of workers and equipment in the study block.

Commercial falconers from Tactical Avian Predators (Reno, NV) were hired for bird abatement. Figure 1 shows two of the raptors used in this study location: a lanner falcon (Falco biarmicus) and a saker falcon (Falco cherrug).

Specific Methods

Spring Survey and Pilot Trials
Two surveys were performed in spring 2015 (May and June) using four blocks from the Treatment Ranch (560 acres) and Control Ranch (350 acres). We conducted a one-day and a three-day pilot trial of falconry to refine methodology. Avian species presence and abundance were monitored pre- and post-treatment for two consecutive days. 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 to Sept 28 (10 days) and comprised two days of surveys pre-treatment, five days of falconry treatment, and three days of surveys post-treatment. In the Treatment Ranch, two blocks with four transects each were monitored (one with mustard and one with lettuce). Six transects were established at the Control Ranch 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 to 20 (12 days) and comprised four days of surveys pre-treatment, five days of falconry treatment, and three days of surveys post-treatment. The Control Ranch was taken out of production in October, and we had to identify new control blocks in the Treatment Ranch. Because of the size of the ranch, control blocks were found far enough from our treatment site (1.54 km) to expect no interference with the effect of falconry.

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 (nine days). We performed one day of surveys pre-treatment (additional pre-treatment days were not possible due to wet roads), five days of treatment, and three days of surveys post-treatment (extended by one day because of the rain). Only two blocks at this ranch still had leafy greens (lettuce), which were used as treatment and control blocks, respectively. Due to the small amount of blocks included in this trial, the transects were more closely monitored by conducting surveys both in the morning and in the afternoon, coinciding the end of the counts with the sunset (~30 min). 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 the ranch.

Statistical Analyses
The average number of nuisance birds observed during the counts pre-treatment was assigned to each transect as a baseline of bird abundance. Then, each transect was assigned a value “1” (success) if the number of birds was less than its average before the treatment, and a “0” otherwise (failure). We expected a large number of “successes” in the treatment field, and a small amount of “successes” in the control field (due to the natural variability of bird abundance from day to day). We counted the number of failures and successes in each the treatment and the control field, and performed a binomial test to detect statistically significant differences (Crawley 2007). We assumed that the probability of success and failure were equal (50%). The binomial test was performed with R Software 3.2.0 (R Development Core Team 2015).

RESULTS

Avian Species Abundance
Table 1 shows the avian species observed during the spring and during each fall trial in the treatment and control ranches combined. The average number of birds
Table 1. Average bird numbers and maximum flock size during spring and fall trials in treatment (falconry) and control ranches, Monterey County, 2015.

| Common name              | Scientific Name           | Spring Survey Average (max. flock size) | Fall Survey #1 Average (max. flock size) | Fall Survey #2 Average (max. flock size) | Fall Survey #3 Average (max. flock size) | Total Daily Average |
|--------------------------|---------------------------|----------------------------------------|------------------------------------------|------------------------------------------|------------------------------------------|---------------------|
| American crow            | *Corvus brachyrhynchos*   | 22.4 (7)                               | 4.5 (4)                                  | 12.3 (60)                                | 6.1 (50)                                 | 11.25               |
| American kestrel         | *Falco sparverius*        | 0                                      | 0.1 (1)                                  | 0                                        | 0.1 (1)                                  | <0.1                |
| American robin           | *Turdus migratorius*      | 0.22 (2)                               | 0                                        | 2.25 (25)                                | 0                                        | 0.7                 |
| Barn swallow             | *Hirundo rustica*         | 9.5 (5)                                | 2.5 (10)                                 | 0                                        | 0                                        | 2.8                 |
| Blackbird, Brewer's      | *Euphagus cyanocephalus*  | 47.7 (37)                              | 195.6 (>100)                             | 420.6 (>150)                             | 276 (>500)                               | 247.9               |
| Blackbird, red-winged    | *Agelaius phoeniceus*     | 14.9 (30)                              | 25.7 (80)                                | 8.4 (32)                                 | 0                                        | 0.4                 |
| Blackbird, unidentified  |                           | -                                      | 38.9 (13)                               | 67.7 (50)                                | 37.7 (50)                                | 19.8 (37)           | 41.4                |
| Other: mixed blackbirds  |                           | 0                                      | 110.1 (200)                              | 54.75 (200)                              | 31.4 (>100)                              | 51                  |
| and starlings            |                           |                                        |                                          |                                          |                                          |                     |
| Black phoebe             | *Sayornis nigricans*      | 0                                      | 0.7 (1)                                  | 0.5 (2)                                  | 0.2 (1)                                  | 0.4                 |
| Brown-headed cowbird     | *Molothrus ater*          | 0                                      | 0.5 (4)                                  | 0                                        | 0                                        | 0.1                 |
| California towhee        | *Pipilo crissalis*        | 0                                      | 0.2 (1)                                  | 0                                        | 0                                        | <0.1                |
| Common raven             | *Corvus corax*            | 0                                      | 0.1 (1)                                  | 0                                        | 2.3 (6)                                  | 0.6                 |
| European starling        | *Sturnus vulgaris*        | 1.6 (6)                                | 55.2 (>90)                               | 213.5 (>300)                             | 423.9 (2200)                             | 173.6               |
| Horned lark              | *Eremophila alpestris*    | 0                                      | 18.1 (33)                                | 0.7 (8)                                  | 0                                        | 4.7                 |
| House finch              | *Carpodacus mexicanus*    | 1.7 (7)                                | 0.8 (2)                                  | 0.4 (1)                                  | 0.3 (2)                                  | 0.8                 |
| House sparrow            | *Passer domesticus*       | 0                                      | 7.2 (11)                                 | 0                                        | 0                                        | 1.8                 |
| Killdeer                 | *Charadrius vociferous*   | 0                                      | 8.2 (12)                                 | 0.7 (2)                                  | 0.1 (1)                                  | 2.3                 |
| Mallard                  | *Anas platyrhynchos*      | 0.7 (3)                                | 0                                        | 0                                        | 0                                        | 0.2                 |
| Mourning dove            | *Zenaida macroura*        | 3.6 (3)                                | 2.9 (6)                                  | 0.3 (3)                                  | 0                                        | 1.6                 |
| Northern flicker         | *Colaptes auratus*        | 0                                      | 0                                        | 0.1 (1)                                  | 0                                        | 1                   |
| Northern mockingbird     | *Mimus polyglottos*       | 0.4 (1)                                | 1 (1)                                    | 0                                        | 0                                        | 14                  |
| Red-tailed hawk          | *Buteo jamaicensis*       | 0.11 (1)                               | 0                                        | 1.7 (1)                                  | 0                                        | <0.1                |
| Say's phoebe             | *Sayornis saya*           | 0                                      | 1.1 (2)                                  | 2.2 (1)                                  | 1.4 (2)                                  | 1.3                 |
| Sparrow, unidentified    |                           | -                                      | 0                                        | 3.7 (5)                                  | 24 (15)                                  | 19.1 (25)           | 12.4                |
| Turkey vulture           | *Cathartes aura*          | 1.8 (1)                                | 0.5 (3)                                  | 0                                        | 2 (2)                                    | 0.6                 |
| Western meadowlark       | *Stumella neglecta*       | 0.33 (1)                               | 2.3 (6)                                  | 10.5 (8)                                 | 48.4 (25)                                | 14.7                |
| White-crowned sparrow    | *Zonotrichia leucophrys*  | 0                                      | 0.1 (1)                                  | 0.7 (1)                                  | 0.3 (3)                                  | 0.3                 |
| Yellow-rump warbler      | *Dendroica coronate*      | 0                                      | 0                                        | 0.4 (4)                                  | 0                                        | 0.13                |
| **Daily average of total numbers** |                       | 143.8                                 | 508.8                                    | 790.1                                    | 829.9                                    | 583.3               |

*In bold:* three highest average and flock size per survey.
counted per day is given, as well as the maximum size of flock observed. It is remarkable how the bird abundance in spring was lower than in fall for most of the observed species. Maximum flock size was also lower in spring, with the largest flocks recorded being 37 Brewer’s blackbirds and 50 red-winged blackbirds. Interestingly, the most abundant species in spring were the Brewer’s blackbird and the American crow, along with groups of unidentified blackbirds (mostly because they were flying over the fields) that could be Brewer’s blackbirds, red-winged blackbirds, or a mix of both species. However, the American crow was considerably less abundant overall in the fall, although larger flocks of up to 60 individuals were observed compared with spring. Inversely, both the abundance and flock size of Brewer’s blackbirds increased strongly in the fall. In that season, the most abundant birds were the Brewer’s blackbird, the European starling, and mixed flocks of those species, along with unidentified blackbirds that may have included red-winged blackbirds. The largest flocks in fall comprised European starlings (max 2,200) and Brewer’s blackbirds (>500). Certain species were observed frequently but in fall only, for example, killdeer (Charadrius vociferous), horned lark (Eremophila alpestris), and several species of sparrows [shown here as unidentified sparrows because of the uncertainty of the identification, but most probably comprising song sparrows (Melospiza melodia), savannah sparrows (Passerculus sandwichensis), and Lincoln sparrows (M. lincolni)]. The low number of brown-headed cowbirds (Molothrus ater) detected suggests that they may have been reported as unidentified blackbirds or as mixed flocks, because this is an abundant species in the area, and in the adjacent vineyard in particular.

Spring Trial
As noted above, bird abundance was low at the ranches during the spring trial, so we used this period to optimize the survey protocol. A slight reduction in nuisance bird numbers following the three-day trial was documented mostly related to blackbird fly-overs (data not shown). The number of transects in the spring treatment field with less bird observations (success) was statistically significant (22 out of 28, p = 0.03). However, in the control field the difference was not significant (12 out of 18 transects had less bird abundance, p = 0.24).

Fall Trial #1
Our first fall trial was complicated by the presence of another commercial falconer at the vineyard adjacent to our treatment fields. The activity of this falconer interfered with the activity of the falconer hired by us; therefore, we deemed that the efficacy of the treatment in this trial was not complete. Specifically, the number of pre- and post-treatment days were marked with events that highly interfered with our trial. In particular, during our days pre-treatment we observed a very low abundance on birds, probably because of the presence of a falconer in the adjacent vineyard. For example, we observed the trained falcon from the vineyard (recognizable because marked with a GPS device) flying over the transects where we were performing bird counts. Thus, we could not establish a reliable pre-treatment baseline abundance. During the days post-treatment we observed a peak in the bird abundance, which we believe was related to the departure of the falconer in the adjacent vineyard. The presence of ripe grapes in the vineyard strongly attracted large numbers of nuisance birds that visited the vineyard regularly and our leafy greens field as a secondary location for water, perching pole lines, etc. In the vineyard, the first day post-harvest of the grapes coincided with the first day the falconer was absent. The large flocks of birds, noticing that the danger was gone, visited the vineyard to forage but their source of food (grapes) had disappeared too, forcing them to forage somewhere near. Probably because of this, that day an unprecedented numbers of birds visited our treatment blocks when we were at the stage of counts post-treatment.

As part of co-management, it is important to approach nuisance bird control in a holistic way that takes into account the activities happening in neighboring properties and the control methods used there. It is important that produce growers in a similar situation be able to anticipate such an event, especially when close to harvesting dates, as it can potentially drastically increase fecal contamination of the crop. Also, growers should take into account that if they wish to use falconry abatement in their properties, they should coordinate with neighbors that are also using this method and probably avoid situations where two falconers work in proximity.

Fall Trial #2
Figures 2 and 3 show the boxplots of bird numbers in the treatment and control blocks throughout the second fall trial period. In the days pre-treatment, bird abundance (Figure 2) and the use of field (birds counted on the ground, Figure 3) are both highly variable from day to day. However, it can be noted too that the control blocks had a lower baseline abundance and use of field. Therefore, there are some limitations when comparing the treatment and the control blocks to detect a decrease in bird abundance due to falconry in the treatment blocks. Among the two treatment blocks, bird abundance was greatest in the lettuce block compared with the mustard block. Thus, the effect of falconry is better observed in the boxplot showing the number of birds counted on the ground in the lettuce block only (Figure 4). The median and the quartiles decreased during the falconry treatment, and these low levels persisted until the end of the survey. The fact that both total bird numbers (Figure 2) and birds counted on the ground (Figure 3) in the treatment blocks remained low for three days after falconry suggests some “memory” following the treatment even after the falconers left. These results also suggest that falconry is effective in decreasing intrusions into the fields and potential fecal contamination by nuisance birds.

In this fall trial, a statistically significant high number of counts in the treatment field had a lower bird abundance than the corresponding baseline abundance (59 out of 64, p-value < 0.01, 95% CI Probability of success = 0.83-0.97). However, in the control field the difference was also significant (28 out of 42 transects had less bird abundance, p-value = 0.04, 95% CI Probability of success = 0.50-0.80), suggesting that the falconry treatment had an effect on our control field despite the distance, or that bird abundance
Figure 2. Boxplot showing the number of birds seen in the control (two lettuce blocks) and treatment blocks (one mustard, one lettuce block) during fall trial #2. Harvesting in the control blocks started on day 9.

Figure 3. Boxplot showing the number of birds counted on the ground in the control (two lettuce blocks) and treatment blocks (one mustard, one lettuce block) during fall trial #2. Harvesting in the control blocks started on day 9.
Figure 4. Boxplot showing the number of birds seen on the ground in the lettuce treatment block during the surveys (fall trial #2). 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 5. Boxplot showing the number of birds seen in the control and treatment blocks (two lettuce blocks) in fall trial #3. Harvesting in both blocks started on day 8.
was naturally low in those days in our study site.

**Fall Trial #3**

Figure 5 shows that the number of birds in the treatment block was consistently lower than in the control block. This can be seen not only through the median values (black circles) but also through the small number of extreme values (clear circles). It is remarkable that the variability in bird numbers is higher in the control block than in the treatment block, as shown by the height and the whiskers of the boxes. When comparing the number of birds counted on the ground (Figure 6), the effect of falconry can be more clearly observed, especially with regards to day five. That day, the number of birds counted on the ground peaked in the control block, as can be seen by the height of the box. In the treatment block, the counts were more highly distributed than in previous days; however, the values continue to be low, with <50 birds counted on the ground in all of the transects. Therefore, we consider that the falconer managed to mitigate the number of birds, and the usage of the field by the birds in particular. Although on day six there was a peak of birds counted in the treatment block, this did not reflect an increase in the number of birds counted on the ground. It is also interesting to note that on day eight the harvest started in both blocks. The number of birds (both in total and counted on the ground) remains variable and is not consistently different from what was observed on a non-harvest day. This suggests that birds habituate to the disturbance caused by the crew (noise, human presence, machinery), and we have observed that birds forage on the ground of the beds immediately after the field crew has passed. If so, this would mean that crops are also vulnerable to fecal contamination from birds during harvest, and deterrence measures including falconry should be considered. To assign a baseline abundance for the statistical analysis of this trial, we had to consider the one day pre-treatment of this trial and the counts pre-treatment of the corresponding transects of fall trial #2 to calculate the average. Only morning counts were included in the binomial test. Out of 34 transects, 24 had a lower number of birds than their corresponding baseline, while seven had more birds, this difference being significant (p-value<0.01, 95% CI \textit{Probability of success} = 0.59-0.90). In the control field, the number of successes (transects with less bird abundance) was not significantly different from the number of failures (transects with equal or more bird abundance): p-value = 0.26, 95% CI \textit{Probability of success} = 0.42-0.79).

**DISCUSSION**

Until the 1990s, the use of falconry in agricultural settings was very limited (Erickson et al. 1990). Today it can be considered an emerging approach to co-manage the damage and potential fecal contamination caused by nuisance birds in agricultural settings, according to conversations with growers and the amount of commercial falconers offering their services to protect crops. Previous studies on the efficacy of falconry to deter nuisance birds in agricultural fields have been difficult to compare,
due to differences in geographical locations, different pest bird species, and different crops. For example, Kenward (1978) reports how the attacks of a trained goshawk (Accipiter gentilis) were as effective in scaring wood-pigeons (Columba palumbus) as pedestrians and cyclists. However, we have observed that blackbirds and American crows do not modify their activity in proximity to the field crews and the equipment, and thus these pest birds seem to be habituated on the leafy green farms; discussions with leafy green produce growers confirm our observations. It can be concluded from the available studies that the efficacy of falconry depends on many factors related to the bird species (e.g., food preferences, ability to habituate) and the site (e.g., crop and alternative food sources, availability of shelter). Even in agricultural fields in the same county and with the same crop, the success of falconry was found to be site-specific (Daugovish and Yamamoto 2008). In addition, the specific needs of the affected ranch need to be considered to strategically protect the crops. The belief that birds just move to the nearest field and continue to be a problem may be not true if there is a buffer zone around the field, or if the crop needs protection for a short period of highest vulnerability, e.g., when seeding, at the emerging stage, or immediately before harvest. Although we did not have enough farms enrolled to conduct a cost-effectiveness analysis in this pilot study, the eight-day period encompassing treatment (five days with falconer costs) and posttreatment (three days without falconer costs) should be economically viable, especially for larger growers of high value crops such as lettuce and spinach. Smaller operations could work together to hire commercial falconers during the most vulnerable growth state, thereby sharing costs.

CONCLUSIONS

In summary, controlling pest birds is challenging, and growers must take into consideration the specific bird species and its behavior and biology in the context of each agricultural scenario. As well, we wish to highlight that bird control with falconry requires mastery of the technique, which the commercial falconer may use in combination with other measures like auditory deterrents (blowing the horn, pyrotechnics) to increase the effectiveness of their services.

In this study, we demonstrated that falconry was effective in reducing bird counts and intrusions in leafy green fields during and after treatment, but the results were dependent on inter-related factors including season and bird abundance. In California’s 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. 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 (more than five days) and follow-up post-treatment for more than three days to determine the duration of the effect.

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