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Bird Damage to Fruit Crops: A Comparison of Several Deterrent Techniques

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ABSTRACT: Economic impacts, risk factors, and deterrent strategies related to fruit damage by birds were investigated in a four year study across North America. Here we focus primarily on bird management strategies tested in the Pacific Northwest, including visual deterrents such as hawk-kites, inflatable tube-men, and falconry. Fields protected by professional bird-abatement falconry showed less blueberry damage than non-falconry fields. Neither hawk kites nor kite-falconry combinations showed strong damage prevention. A pilot trial of inflatable tube-men in blueberries showed a potential deterrent effect in one of three blocks. Bird management strategies that are biodiversity-friendly, such as falconry and predator nest boxes, may also be useful in marketing fruit.

KEY WORDS: biodiversity, bird damage, deterrent, European starling, falconry, fruit damage, inflatable effigy, kites, Pacific Northwest, pest bird, raptor, *Sturnus vulgaris,* visual deterrents

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INTRODUCTION

Bird damage to fruit is a serious economic issue across North America (Anderson et al. 2013, Baldwin et al. 2013, Gebhardt et al. 2011) and globally (Somers and Morris 2002). A 2012 grower survey showed $189 million in annual losses to birds in cherries, "Honeycrisp" apples, blueberries, and wine grapes across five states, with aggregate benefits of bird management approaching $800 million annually (Anderson et al. 2013). Bird damage also makes fruit more susceptible to *Drosophila suzukii* and other pests (Ioriatti et al. 2015). In addition, European starlings (*Sturnus vulgaris*) have been implicated as animal and human disease vectors in livestock operations (Cernicchiaro et al. 2012, Gaukler et al. 2009, Kauffman and LeJeune 2011, Medhanie et al. 2014, Swirski et al. 2014, Williams et al. 2011). This is a special concern for fruit growers in close geographic proximity to livestock operations supporting starling populations.

The environmental impact of bird management methods and public perception of those methods may limit available options for growers (Anderson et al. 2013, Baldwin et al. 2013, Hernstadt et al. 2015, Oh et al. 2015). While trapping (Gorenzel et al. 2000), lethal shooting (Baldwin et al. 2014), and various chemical bird repellents (Askham 1992, Brugger et al. 1993, Socci et al. 1997, Tupper et al. 2014) sometimes provide efficacy, these methods are viewed less favorably by the public in comparison to use of falconry or native raptor nest boxes (Hernstadt et al. 2015, Oh et al. 2015). Netting, while effective (Pagay et al. 2013, Taber 2002), can be labor-intensive and may not be logistically feasible or cost-effective in large and/or machine harvested blocks. Acoustic and visual scare devices have shown some success as deterrents, although birds habituate to non-lethal threats over time if multiple techniques are not deployed (Berge et al. 2007, Gilsdorf et al. 2002).

As part of a multi-year North American study "Limiting Bird Damage to Fruit Crops," we examined bird damage in a variety of cultivars of cherries, blueberries, wine grapes, and "Honeycrisp" apples in Washington, Oregon, British Columbia, Michigan, and New York, and undertook a series of various deterrent trials based on regional considerations. Here we report from trials with visual deterrents in the Pacific Northwest including inflatable tube-men (effigies) and flying hawk-kites, as well as a technique with direct threat of lethality: bird-abatement falconry.

METHODS

Study Areas

Regions and crops for these trials included blueberries and "Honeycrisp" apples in Western Washington, and wine grapes in Oregon and Washington.

Bird Deterrent Trials

We tested various bird deterrents in each crop, including tube-men, falconry, and hawk-kites. While our fruit damage assessment methods were consistent across trials, our site set-up and plant selection methods for bird damage sampling varied.

Tube-Man Trials

In 2014 we deployed inflatable tube-men in three Washington blueberry fields (i.e., blocks A-C). Tube-men were placed about 10 m from field edges, leaving space for farm equipment traffic. Each tube-man was 7 m high and mounted on an electric fan. It had a "scary" face emblem on the head and was colored red, white, and blue with shiny silver streamers attached to head and arms. We ran the fans with electric power for at least 14 hours per day, from dawn to dusk, beginning 16-34 days pre-harvest.

We quantified bird damage by sampling six plants at each of the following distances from the field edge where the tube man was placed: 2, 5, 10, 20, 30, 40, 50, 75, 100, and 125 m. We took GPS coordinates for each plant location with Garmin GPSmap 78 units (Garmin Ltd., Olathe, KS) and calculated the distance from each sample to the tube-man using ArcGIS 10.2.2 for Desktop (Esri, Redlands, CA).

Hawk-shaped Kite Trials

The frequency with which some visual bird deterrents are moved throughout an orchard may influence their effectiveness. In 2013 in "Honeycrisp" apples, we tested whether moving the kites frequently led to reduced damage compared to leaving kites in a single location. We established two 1-acre plots in each of four blocks, leaving at least 65 m between plots. We deployed a single hawk-kite in each plot and randomly assigned treatments of "movement" or "no-movement" within sets of plots. In "movement" plots, we moved the kite to a new location within the one-acre area every 3-5 days. Kites in "no-movement" plots were left in place. We deployed kites 9-21 days before harvest by tethering them to 5-m-tall fiberglass poles with 5 m of fishing line. Kites resembled peregrine falcons and were supplied by Jackite Inc. (Virginia Beach, VA). We quantified bird damage in each plot according to the stratified sampling protocol described below.

In 2013, we also deployed kites in two Oregon vineyards and compared bird damage in these blocks to a block with no kites. One site used a kite prototype with fixed wings, while another site featured two of the previously described Jackites. At a third site we deployed no kites. Kites were deployed seven and 15 days pre-harvest respectively, and moved to new locations within the block every 2-3 days. We quantified bird damage using the protocol below but did not compare damage statistically.

Falconry Trials

In 2012 we encountered bird-abatement falconry in many of our blueberry blocks. To determine the effects of falconry, we compared damage in eight falconry blocks to eight randomly-selected non-falconry blocks (see bird damage assessment protocol below). Other management practices were employed in five non-falconry and one falconry block. Three non-falconry blocks were protected with a combination of cannons, a bird trap, and an active kestrel (*Falco sparverius*) nest box, and two blocks had audible distress callers and cannons. One falconry block had two audible distress callers.

Hawk-shaped Kite + Falconry Trials

In 2013, to further understand the effects of falconry in Washington blueberries, we compared use of falconry to use of hawk-kites, and to a combination of hawk-kites and falconry. In this trial, we deployed kites as previously described at roughly 1/2.5 acres and we limited bird damage sampling areas to <7 acres. We assessed bird damage in five blocks per treatment group (n = 15 blocks total). One falconry + kite block contained an audible distress caller, as did one kite block.

Fruit Damage Assessment

Fruit damage was assessed according to stratified sampling techniques established for grapes by Tracey and Saunders (2010), with modifications made for blueberries and apples. Each block was divided into five strata: four edge strata and an interior stratum. We sampled 12 plants per stratum in apples and blueberries and 20 vines per stratum in wine grapes. Plants were sampled systematically from a randomly chosen starting point within each stratum to achieve uniform coverage.

Branch Selection

We quantified fruit damage on one branch per sampled plant. In apples, we randomly chose the branch by selecting a height above ground from a pool of possible branch heights for the tree to the nearest 0.5 m, and by selecting a horizontal position relative to the tree trunk. Horizontal positions were drawn from the eight half-winds of the compass rose. The nearest branch tip to the selected location was designated for assessment. In blueberries, we selected canes for sampling based on horizontal position only.

Measuring Damage

In apples, we counted the total number of intact and damaged fruits on the entire branch, including appendages. If fewer than 50 apples occurred on the branch, we selected and counted fruit on another branch by moving clockwise around the tree to the next horizontal sector at the same height. We continued in this manner until we counted at least 50 apples or four total branches.

For blueberries, we conducted initial fruit counts up to five weeks prior to harvest while fruit was green. From the tip of each selected cane, we counted towards the base of the bush until we reached about 50 berries. We marked this location with a twist tie, and returned just prior to harvest to conduct the second count, this time noting any damaged fruit. By subtracting the total number of berries at the second sample from the first sample, we calculated the number of missing fruit, assuming birds ate these. Any damaged fruit were also subtracted from the initial count.

Prior to conducting damage counts, we consulted growers regarding how to differentiate between bird damage and damage from other causes such as hail, insects, or mammals. Generally, bird damage was distinguished by the presence of peck-marks or holes in the fruit, and by missing fruit in blueberries.

Statistical Analysis

We used damage count data to determine the percent of damaged fruit occurring on each sampled branch, and we calculated average damage occurring in each stratum from these values. We then calculated overall weighted average damage values for each field following methods described by Tracey and Saunders (2010).

In blueberries, we considered average loss per day at each site, because the number of days that elapsed between first and second counts varied across sites. We calculated loss per day by dividing overall weighted average damage by the number of days between counts.

In tube-man trials, we compared amounts of damage occurring on individual blueberry plants as a function of distance from the plant to the tube man. We used linear regression to look for a relationship between amount of damage and location of tube-man, running separate analyses for each site and transforming data to achieve linearity if necessary. In hawk-kite trials in apples, we compared overall weighted average damage in "movement" and "no-movement" plots with a paired t-test. For the 2012 falconry trials in blueberries, we compared loss per day in non-falconry and falconry blocks with a Welch's 2-sample t-test. In 2013, we used ANOVA to compare the loss per day in falconry, kite, and falconry + kite blocks.

RESULTS

In 2012 and 2013, average bird damage losses in Pacific Northwest fruit crops ranged from 1.54 +/- 0.48% in 2013 "Honeycrisp" apples to 7.14 +/- 12.81% in 2012 red wine grapes (Figure 1). In both years, apples exhibited the least amount of bird damage while grapes exhibited the most. Average bird damage was lower in 2013 than 2012 for all crops.

Tube-Man Trials

Regression analyses of blueberry sites with inflatable tube-men showed a significant positive relationship between the amount of damage on a plant and the distance to the tube-man in block C only (Figures 2 & 3). The relationship was not strong, with $R^2 = 0.16$. This block had the most bird damage overall, with a loss per day of 0.75% of the total crop, compared to 0.11% for block A and 0.22% for block B.

Hawk-shaped Kite Trials

We found no difference in overall weighted average damage for "no-movement" vs. "movement" kite treatments in "Honeycrisp" apple blocks (T = 0.11, DF = 3, P = 0.91, N = 8, Figure 4). In general, damage rates in the kite plots were similar to regional averages (Figure 1).

In wine grapes, we measured <1% overall weighted average damage in each of the three blocks used for the kite comparison (Figure 5). Although we measured higher damage in the no-kite block, the damage rates were low compared to regional averages (Figure 1).

Falconry Trials

We found loss per day in 2012 blueberries was significantly lower in blocks with falconry compared to non-falconry (T = 2.6, DF = 10.9, P = 0.022, N = 16, Figure 6). The percent of crop lost per day averaged 0.20 +/- 0.04 in falconry blocks and 0.42 +/- 0.07 in non-falconry blocks.

Hawk-shaped Kite + Falconry Trials

We detected no difference in the amount of damage occurring in 2013 blueberry blocks with treatments of falconry, falconry + hawk-kites, and kites only (F = 0.78, P = 0.48, N = 15, Figure 7). The average loss per day was 0.31 +/- 0.10% in falconry blocks, 0.55 +/- 0.17% in falconry + kite blocks, and 0.45 +/- 0.15% in kite blocks.

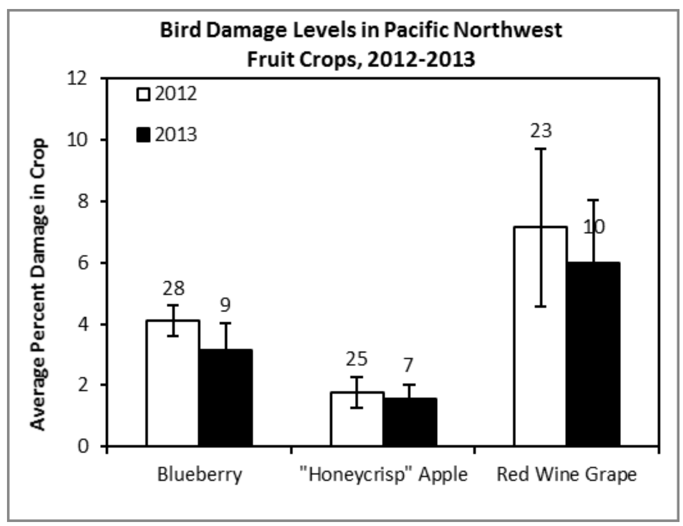

Figure 1. Average bird damage quantified in Washington and Oregon fruit crops, 2012-2013 with sample size and standard error.

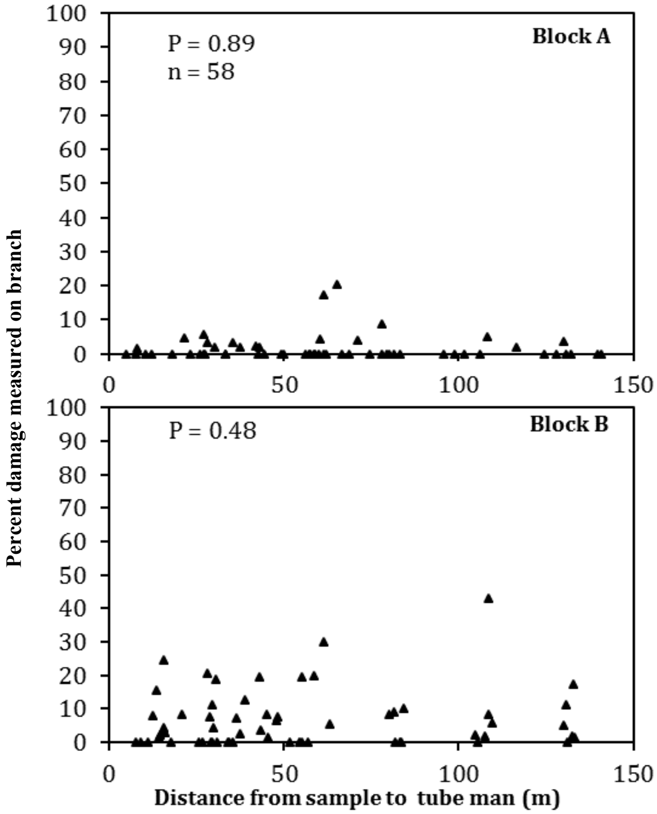

Figure 2. Percent damage on a branch against distance from the sample to the tube-man with linear regression results for blueberry blocks A and B, 2014.

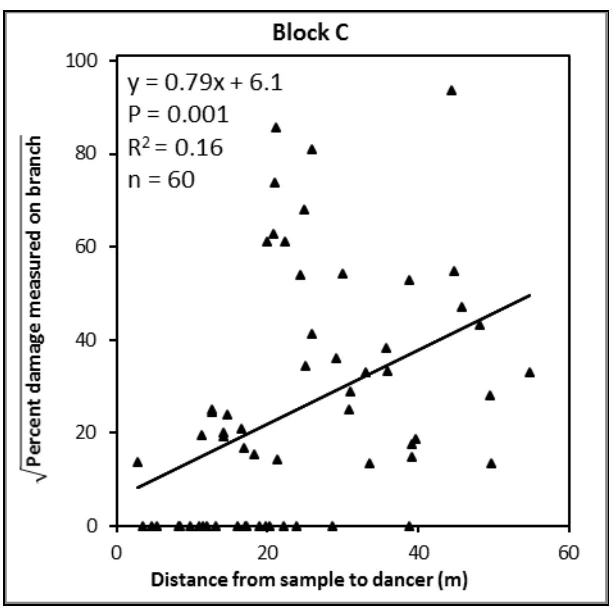

Figure 3. Linear regression of percent damage on a branch against distance from the sample to the tube-man for blueberry block C, 2014.

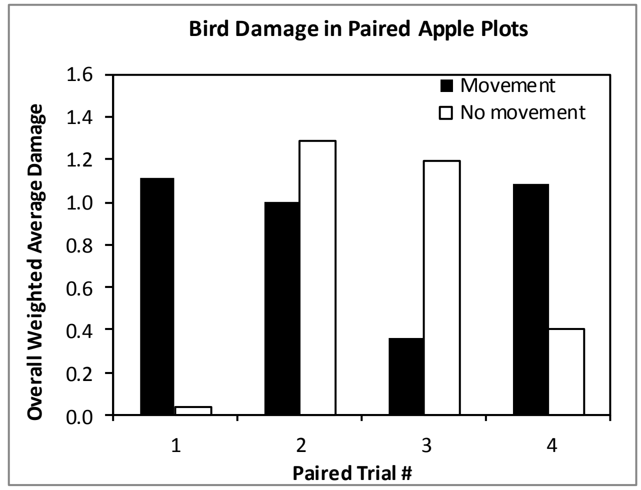

Figure 4. Overall weighted average damage in 2013 Washington "Honeycrisp" apple plots with hawk-kites that were moved throughout the trial or left stationary. Damage was statistically similar across treatments (T = 0.11, DF = 3, P = 0.91).

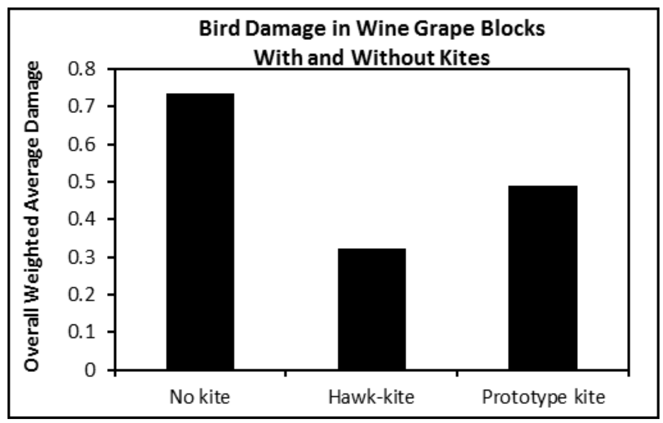

Figure 5. Overall weighted average damage in 2013 Washington wine grape blocks with or without kites.

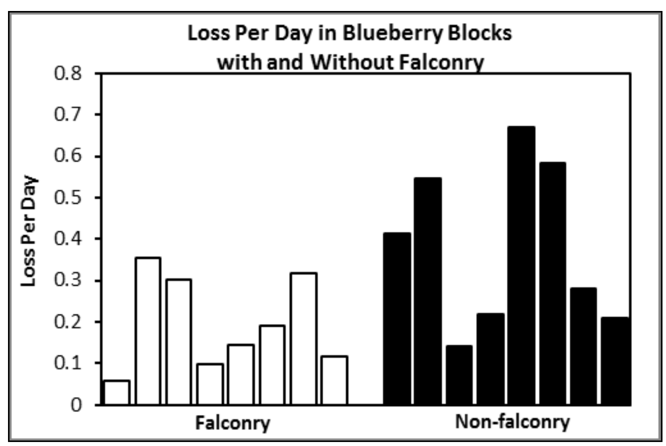

Figure 6. Crop lost per day to birds in 2012 Washington blueberry blocks with and without falconry. Damage was significantly lower in falconry blocks (T = 2.6, DF = 10.9, P = 0.022).

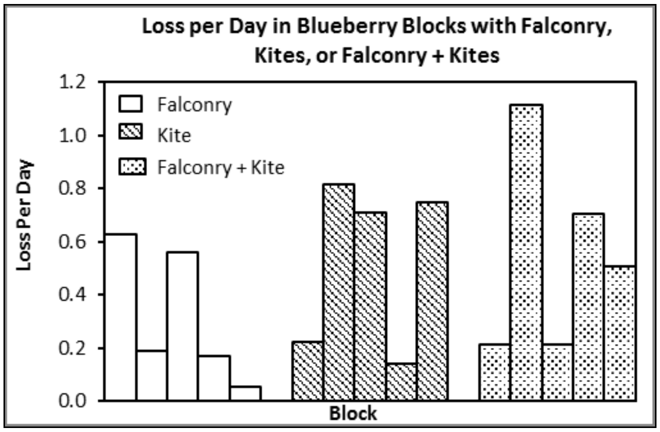

Figure 7. Crop lost per day to birds in 2013 Washington blueberry blocks with treatments of falconry, hawk-kites, or falconry + hawk-kites. Damage was statistically similar across treatments (F = 0.78, P = 0.48).

DISCUSSION

Tube-Man

Inflatable tube-men, while exhibiting startling random movements and sheer size effect (7 m fully inflated), provided no strong evidence of bird deterrence efficacy in our limited blueberry trial. Of three fields, one experienced extremely low damage and another had slightly more damage but no detectable effect of the tube-man; the third, with higher damage overall, did show an effect of greater damage at a greater distance from the device but distance explained only a small amount of variation in damage. The latter two blocks were small enough that most plants were near field edges and highly susceptible to damage; thus, lack of sample size plus inconsistent field parameters likely obscured patterns.

More extensive trials in Michigan blueberries and New York wine grapes may show greater efficacy of tube-men once analyses are complete (H. Henrichs, Dept. of Natural Resources, Cornell University, Ithaca NY; pers. comm. 2016). Use of this technique may be indicated in smaller fields and orchards where growers are willing to move the devices. The cost of fuel for generators and the inconvenience of refueling or placement near an electricity source, along with the somewhat cumbersome nature of the devices, should be taken into consideration by growers. The novelty of the technique in general, which has really only seen broader-scale adoption over the past two to three years, may help explain effectiveness currently perceived by growers (Loria 2014). Habituation patterns of birds in the presence of tube-men should continue to be studied in future years as bird exposure to the technique becomes more pervasive. Tube-men could also potentially deter deer or elk, given our anecdotal observations that dogs were frightened by this technique.

Hawk-shaped Kites

Hawk-kites used on their own, although possibly effective initially on dairies (Steensma et al. 2009), have not been previously studied in fruit. Our trials showed no difference in effects of kites regularly moved and those kept in one position. Laying our "movement" vs. "no-movement" trials aside, the kites fall into the category of active predator models because they fly with minimal wind. Such models may result in rapid habituation, especially if left in one place or in the absence of wind (Belant and Martin 2011, Rensel and Wilder 2012). We observed tree swallows (*Tachycineta bicolor*) mobbing hawk-kites within five minutes of kite placement, but the swallows lost interest and left the area within another five minutes, supporting the idea of extremely rapid habituation. Marsh et al. (1992) surveyed a variety of model types, concluding that active predator models are more effective than stationary models. Belant (1997) found fixed-predator models ineffective in deterring gulls; Belant et al. (1998) found that predator models did not deter European starlings from nesting. Fixed taxidermy effigies of both an owl and a hawk elicited mobbing behavior in crows preparing to roost for the night (Carroll and Garneau 2013). Whether the crows later habituated to the effigies is unknown. Devereux et al. (2005) noted that starlings increased vigilance after exposure to flying model predators in a captive setting, which may translate to a deterrent effect. Our results do not support the idea that moving predator models delays habituation of pest birds.

Falconry

Bird-abatement falconry in landfill and airport settings has been documented as one of the most successful techniques in reducing pest bird numbers (Baxter and Robinson 2007, Cook et al. 2008, Erickson et al. 1990), although habituation to falconry has also been found (Belant and Martin 2011, Soldatini et al. 2008). Falconry for fruit protection looks promising as a bird deterrent technique, but aside from a study in strawberries by Daugovish and Yamamoto (2008), evidence has been largely anecdotal to date (Hauser 2015). Prevalence of licensed bird-abatement falconers and grower awareness of the technique both appear to be higher in the western region of North America than in the east. In our discussions with cooperating growers, we found anecdotally that growers in Michigan and New York either had little knowledge of falconry bird abatement, or were interested but could not find licensed abatement falconers operating in the area. Proximity to open spaces, and the existence of larger contiguous blocks of agricultural and range land in the west in general, likely provide more area to operate and less risk to bird-abatement falconers of injuring or losing their birds. Large-scale growers are also more likely to have the resources to consider falconry. Where abatement falconry is available, it is likely that experienced falconers employed early in the season can prevent birds from establishing a foraging pattern in a particular block in the first place, but this hypothesis requires further research.

Falconry and Hawk-kites Combined

The combination of falconry with kites may actually be detrimental to the effectiveness of falconry. Pest birds may perceive increasing threat of lethality moving from hawk-kites, to kites plus falconry, to falconry alone. Targeted birds already habituated to kites may then view a mixture of kites and live falcons as less threatening than falconry alone (Soldatini et al. 2008). To reduce the risks associated with flying their birds, falconers often employ additional techniques including pyrotechnics, lasers, and shooting. Flying hawk-kites are less of a potential conflict with neighbors than noise deterrents, and could save growers money if falconry can be minimized. Further study focusing on bird response and habituation to the falconry + hawk-kite combination would be useful.

Biodiversity and Ecosystem Services

Benefits of falconry bird abatement and other biodiversity-friendly bird management (e.g., raptor perches and kestrel falcon nest boxes) extend beyond fruit damage protection to other ecosystem services. Awareness of the relationship between higher bird diversity and increased ecosystem services in agricultural areas has received much recent attention (Tremblay et al. 2001, Mols and Visser 2002, Jones and Sieving 2006, Haslem and Bennett 2008, Whelan et al. 2008, Puckett et al. 2009, Bouvier et al. 2011, Sinu 2011, Luck 2013, Maas et al. 2013, Garfinkel and Johnson 2015, Kolecek et al. 2015, Puech et al. 2015,). Insectivorous birds, for example, may forage from riparian vegetation and shelterbelts throughout both edges and interiors of an agricultural crop, thus potentially providing great benefit to crop health (Puckett et al. 2009). Jedlicka et al. (2011) found dramatic increases in insectivorous birds in California vineyards without corresponding increases in omnivores (potential frugivores) when growers placed nest boxes to encourage western bluebirds (*Sialia mexicana*) rather than placing netting to exclude all birds. Witmer et al. (2008) found increased overall raptor presence in a Colorado location with introduction of raptor perches. Kross et al. (2012) and Saxton (2010) studied reintroduction of a threatened native falcon (*F. novaeseelandiae*) to the wine-growing Marlborough region of New Zealand. Falcon diets included a high proportion of non-native frugivores and omnivores such as finches and European starlings, indicating the benefit of falcons to the wine grape growers in preventing bird damage. Suhonen et al. (1994) and Norrdahl and Korpimaki (1998) found occupied European kestrel (*F. tinnunculus*) nest boxes depressed the adjacent breeding bird population in open farmland in Finland, although orchards and vineyards may not show this effect because taller foliage structure provides greater protection for prey birds.

Ecosystem services provided by birds may be at risk when all birds are excluded from a fruit crop via any deterrent technique, including use of bird-abatement falconry. Yet use of "natural" birds of prey to protect fruit ranks highest in consumer surveys of willingness to pay more for fruit (Hernstadt et al. 2015, Oh et al. 2015), and this may be useful as a marketing strategy for growers. In rural-urban fringe areas with denser human population overall, the marketing benefit of eliminating neighbor-unfriendly techniques such as propane cannons, pyrotechnics, and audible distress callers might also be exploited by growers, given that consumers of fruit may show increased willingness to pay for amenities such as increased presence of raptors and decreased use of noise (Stobbe 2009).

Management Recommendations

Deterrence of pest birds in fruit will require ongoing refinement and adaptation based on regional and individual grower needs. Most visual scaring devices pose little threat of lethality and this leads to habituation of pest birds unless multiple, varied techniques are used. Further study of such combinations of techniques, as well as use of raptor habitat enhancements and falconry, are warranted. Growers should also consider positive public perception of biodiversity-friendly bird deterrent techniques (including habitat enhancement for raptors, perch and nest box placement, and use of falconry) when making decisions about overall bird management and marketing strategies for their crops.

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