PROJECT REPORT

This is a final project report submitted
to the Organic Farming Research Foundation.

Project Title:

Integrating songbird conservation and insect pest management in organic California vineyards

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ORGANIC FARMING RESEARCH FOUNDATION

Project Summary

By establishing nest boxes in vineyards, organic growers may provide good breeding habitat for native songbird populations, particularly the Western Bluebird. Bluebirds rely on insects for food and may be important natural predators of vineyard pest species. My study used natural field comparisons where bird populations were experimentally increased by the establishment of songbird nest boxes (nest box treatments) and compared with control areas of California vineyards without nest boxes. I then mimicked a pest outbreak by placing sentinel pests (caterpillars/larvae) throughout the vineyard and measured how efficiently birds removed the prey in the different treatments. Providing songbird nest boxes in vineyards increased the abundance of insectivorous birds, most notably the Western Bluebird. Data from the mimicked pest outbreak indicate significant predatory effect of insectivorous birds not only immediately adjacent to occupied nest boxes but at randomly selected points throughout the nest box treatment of the vineyard. Consequently the presence of occupied nest boxes benefits the vineyard and is providing ecosystem services to winegrape growers in the form of pest control.

Introduction

Referred to as a "vast and fertile land" by Governor Schwarzenegger, California (CA) agriculture produces half of the fruits, nuts and vegetables consumed by United States citizens (CDFA 2006). In 2008 an estimated 844,000 acres in California were devoted to grape cultivation (USDA 2009), only approximately 1% of which were certified organic (Daane et al. 2005). Despite the overwhelming acceptance of Integrated Pest Management (IPM) in California vineyards, 24 million pounds of chemicals were applied annually to control winegrape pests in 2007, increasing 2.6 million pounds from 2006 (CDPR 2009). However, winegrape growers throughout the California North Coast have begun to install nest boxes within their vineyards, a practice that may provide a secondary service besides that of avian conservation: insect pest control. The winegrape-growing season overlaps with the migratory bird breeding season when, due to avian reproductive activities, the strongest predatory pressures occur (Holmes 1990). The goal of this research was to assess the potential of songbird enhancement in vineyards as an integrated pest management (IPM) tactic that meets the needs of farmers and promotes wildlife.

On the forefront of integrating avian biological control into modern IPM systems, the Organic Farming Research Foundation funded a project by Jo Ann Baumgartner in 1999 documenting avian biological control of codling moths in apple orchards (Baumgartner 1999). Birds significantly reduced numbers of lepidopteran larvae on coffee plants (Perfecto et al. 2004) and lower coffee's most significant pest (the coffee berry borer, *Hypothenemus hampei*) by 1-14%, resulting in increased quantities of saleable fruit creating an additional US$44-105 per hectare (Kellermann et al. 2008). Mols and Visser (2002) found that avian predation of lepidopteran pests significantly increased apple yields by 60% compared to sites where birds were excluded from foraging. The authors concluded that the small initial cost of erecting nest boxes in apple orchards may result in increased yields and large profits. However, more focused research on the effects of bird predation in agroecosystems is needed to determine if avian biocontrol can be a reliable and cost-effective management tactic for IPM more generally.

Establishment of songbird nest boxes in vineyards has been a grassroots response to a strong conservation need by some concerned winegrape growers (Heaton et al. 2008). Since 1950, over 1,000,000 acres of California oak woodlands and savannahs have been converted to agricultural and urban land (Merenlender and Crawford 1998). As oaks are removed, many cavity-nesting songbirds are left without nesting sites (CalPIF 2002) in an agricultural landscape increasingly composed of vineyards and as a result their populations are declining (Heaton and Merenlender 2000). Recently the American Bird Conservancy included California oak savannahs on their list of the 20 most threatened bird habitats in the United States (ABC 2007).

By establishing nest box programs, California vineyards may provide good breeding habitat for native songbird populations, particularly the Western Bluebird (*Sialia mexicana*) (Fiehler et al. 2006). In 2008, three bird species were the predominant occupants of nest boxes at my vineyard sites: Western Bluebirds (36.8%), Tree Swallows and Violet-green Swallows (*Tachycineta bicolor* and *Tachycineta thalassina* respectively, 17.8% combined). Because swallows primarily eat flying insects over great distances (Brown et al. 1992, Robertson et al. 1992), they are likely not consuming pest insects within the vineyard. Bluebirds, however, forage by perching in low vegetation and strike insects on the ground, air, or vegetation (Guinan et al. 2000), potentially acting as an important natural predator of many vineyard pest species.

My study used natural field comparisons where bird populations were experimentally increased by the establishment of songbird nest boxes (nest box treatments) and compared with control areas of California vineyards without nest boxes. I then mimicked a pest outbreak by placing sentinel pests (caterpillars/larvae) throughout the vineyard and measured how efficiently birds removed the prey in the different treatments.

Objectives Statement

Test the hypothesis that biological control of cicadellid and lepidopteran vineyard pests is enhanced through conservation of insectivorous birds via the establishment of songbird nest boxes.

Materials and Methods

<u>Study sites</u>

Two certified organic vineyards chosen for this experiment were located in Mendocino County, California: in Hopland (38°59'N, 123°06"W) and near Ukiah (39°04'N, 123°09'W). Both were planted between 1985 and 1988 and managed identically by the same manager, David Koball. Chardonnay grapevines are grown on trellises forming rows. Tilling occurred in every other tractor row, alternating with cultivated cover crops - 97% clover (*Trifolium spp.*) and 3% Queen Anne's Lace (*Daucus carota*). Grapevines were pruned to 6 buds per lineal foot of cordon with yields averaging 6 tons per acre (Koball 2010). Harvest is largely climate-dependent, but usually occurs between September and October each year.

Nest box management

Each vineyard was divided in half such that a bird enhancement (nest box treatment) and control treatment could be randomly assigned and located at least 250 m from each other. Nest boxes were constructed from redwood following recommendations of the North American Bluebird Society (13.9 cm by 10.2 cm by at least 23.8 cm tall with entrance hole opening of 3.8 cm diameter, NABS 2008). In Jan. 2008, vineyard nest boxes were erected back-to-back in pairs within nest box treatments to maximize bird densities by reducing interspecific competition for nest sites (Figure 1).

Figure 1. Pair of songbird nest boxes mounted back-to-back in a vineyard.

Pairs were spaced 85 m from each other based on nearest-neighbor distances measured by Dickinson & Leonard (1996) in a study where a 68% nest box occupancy rate was achieved. At each site, 23 to 24 nest box pairs were established in a grid pattern in 5 to 6 rows (Figure 2). Each row consisted of 3 to 6 pairs of boxes on 10-m t-posts placed 2 m into the ground along grapevine trellises. All boxes were cleaned of previous nesting materials in February 2009 and checked weekly for breeding activity during the

2009 avian reproductive season from March through July. Once bluebird nests were found to contain eggs, Noel predator guards made of wire mesh hardware cloth were attached to the outside of the boxes to prevent predation by raccoons or cats (Toops 1994).

Figure 2. One vineyard site illustrating treatments and nest box spacing. Stars indicate one pair of nest boxes mounted back-to-back. All numbers are distance in meters.

<u>Avian Observations</u>

In order to document how the bird populations differed between treatments, I conducted bird observations of nest box and control treatments every other week (alternating sites between weeks) from mid-April through mid-July 2009. All observations were conducted between 6:00 am and 10:30 am on days without rain. Control and nest box areas were sampled on consecutive days, if weather permitted, but within at least one week of one another. Nest boxes were monitored to assess bluebird reproductive activity. A nest was defined as active if it contained eggs and/or live nestlings. Abandoned nests with eggs were no longer considered active if eggs had not hatched in three weeks and no adults appeared to be entering the box. All active bluebird nests located at least 85 m from riparian vegetation were selected for avian observations, averaging about 5 nests per week. At 5-minute intervals for 30 min. durations, a scan sample was performed to quantify all birds seen or heard in vineyard vegetation (not flying overhead) within an 85-m radius around the active nest box. Observations and species identification were made from a camouflaged ground hunting blind (Ameristep one-person chair blind #403580, gandermountain.com) located approximately 10 – 20 m from the entrance hole of occupied bluebird nest boxes. Avian observations were replicated at five randomly selected points in no-nest box control areas of vineyards. Each control point was positioned at least 85 m from each other, mimicking the nest box design layout.

Sentinel Pest Study

The University of California Division of Agriculture and Natural Resources recognizes several lepidopteran species, such as beet armyworm (*Spodoptera exigua*, ~12 mm), as California vineyard pests (UC ANR 1992). Fifth instars of *S. exigua* larvae were purchased from Bio-Serv and were used as sentinel pest experiments run at each vineyard site on consecutive days in June 2009. *S. exigua* larvae were placed in transects containing five individuals pinned through their last abdominal segment to brown cardboard squares, immobilizing but not killing the insect (Figure 3). Each insect was placed 2 m apart with cardboard squares staked into the ground in vineyard tractor rows not containing cover crops. Larvae were pinned directly before placement in transects, and all sentinel pests were set out before 7:00 am. Each transect was established at 15 different locations in the vineyard: adjacent to five active bluebird nest boxes, at five randomly selected points in the nest box treatment, and at five randomly selected vineyard control points (same as the avian observation points above). Larvae were recollected approximately 6 hours later the same day and recorded as either present (dead from sun exposure) or missing, signifying consumption from natural enemies strong enough to remove prey from pins. No vineyard workers or machines were present during the duration of the experiment.

Figure 3. Larvae of beet armyworm (*Spodoptera exigua*) pinned to cardboard squares.

Data analysis

Mean avian activity was calculated as average abundance of all birds and bluebirds per 5-minute observation interval. Total avian abundance was square root transformed to meet normality assumptions. Three-factor mixed ANOVAs were used to analyze the square root of avian abundance where time and site were fixed factors and treatment (nest box or control) was random. Observations were categorized into one of three 4-week long time periods during the breeding bird season corresponding to early (22-Apr - 22-May: birds finding territories, building nests, some with eggs), middle (23-May - 20-Jun: first broods are fledging, other nests with eggs), and late (21-Jun - 19 Jul: second broods fledging, less singing). Differences between treatments were evaluated via Tukey's hypothesis tests. Other observational data did not conform to normality assumptions; however variances between treatments were similar and were analyzed via one-tailed Mann-Whitney-Wilcoxon tests, lumping sites and time intervals where appropriate.

Number of larvae removed from the sentinel pest experiment were normally distributed with similar variances and analyzed with mixed model ANOVAs where site was fixed and treatment the random factor. Differences between treatments were evaluated via Tukey's hypothesis tests.

Project Results

Avian observations

Avian abundance doubled in nest box areas early in the season and experienced a 2.6 factor increase late in the breeding season when fledglings were seen foraging with adults throughout the vineyard. Square root of avian abundance had a significant time by treatment interaction ($df=1$, $F= 3.84$, $p=.054$) where abundance was greater in nest box areas of vineyards early (Tukey's dif= -0.51, $p<0.001$) and late (Tukey's dif= -0.89, $p<0.001$) in the season but did not differ significantly in the mid-season (Figure 4, Tukey's dif= -0.29, $p=0.11$).

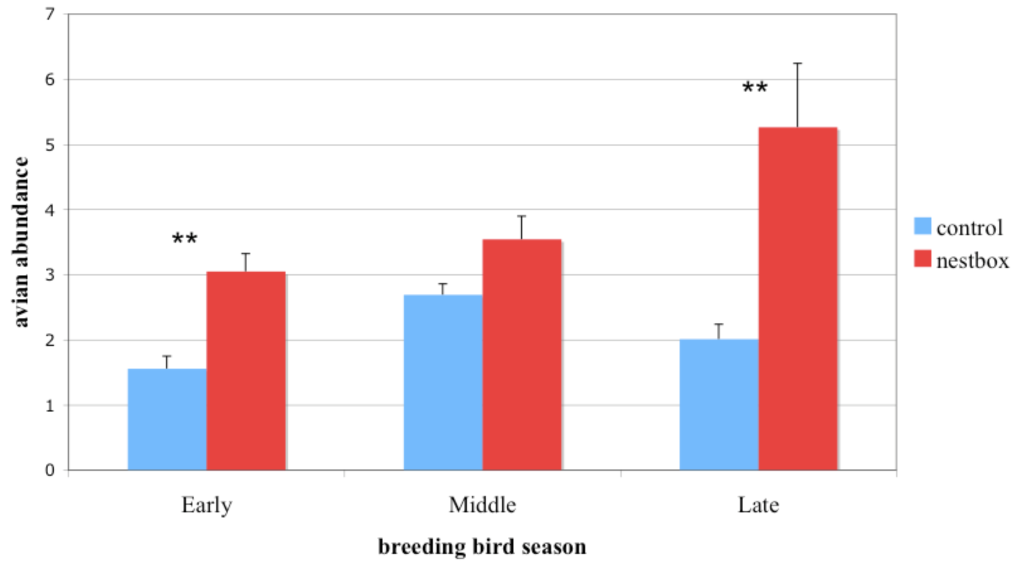

Figure 4. Means and standard error of avian abundance per 5-minute observation interval. Double asterisks indicate significant differences at p<0.01 via Tukey's post hoc tests.

The increase in total avian abundance is mostly due to one species. Western Bluebird abundance significantly increased by a factor of 9 in nest box treatments throughout the breeding season, averaging 1.73 ± 0.08 SE individuals surveyed every 5 minutes compared to 0.18 ± 0.05 SE individuals in control areas (Figure 5, N_c=44, N_n=36, Mann-Whitney U=15, p<0.001).

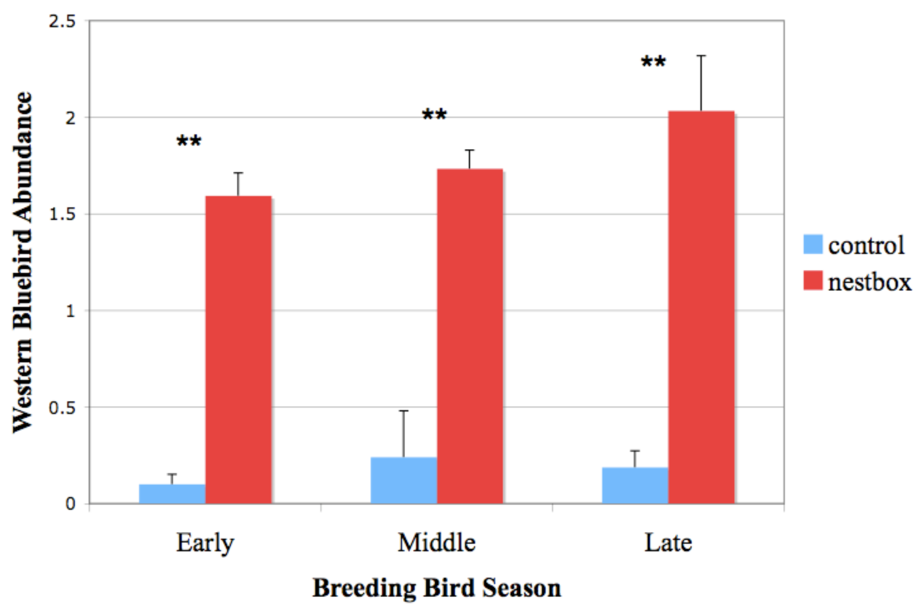

Figure 5. Means and standard error of Western Bluebird abundance per 5-minute observation interval. Double asterisks indicate significant differences at p<0.01 via Tukey's post hoc tests.

Bluebird distance results

In nest box treatments, bluebirds were observed close to active nests and seen traveling long distances (over 65 m) to return with prey items for nestlings. While there is some variability (early in the season bluebirds were more commonly observed close to the nest than later on), bluebird observation distance from the nest box is relatively consistent and demonstrates active foraging both close and far (over 65 m) from nest boxes (Figure 6).

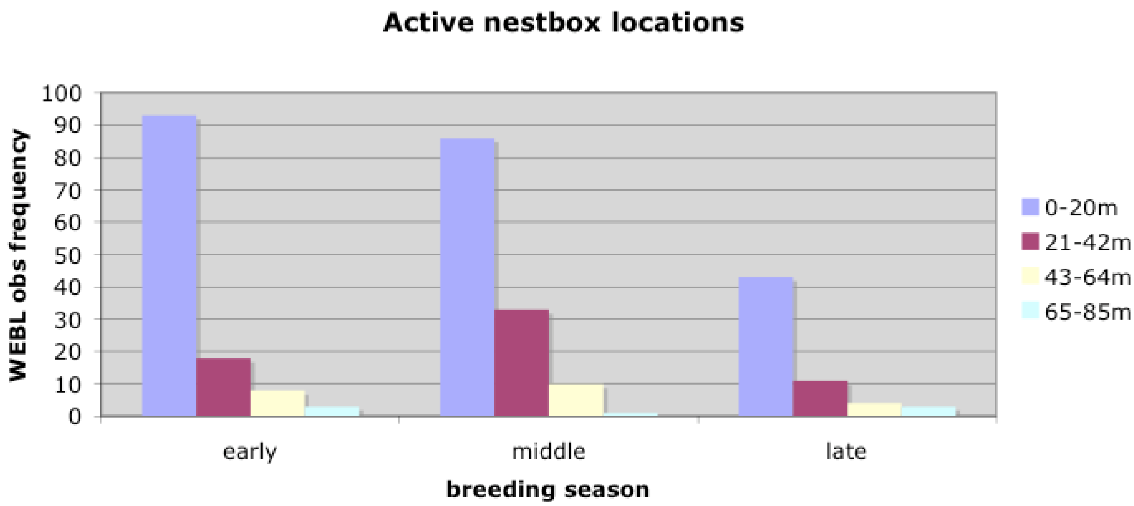

Figure 6. Western Bluebird observations at both sites categorized as distance from observed nest box during breeding season.

Sentinel Pest Data

Number of larvae removed was consistent across sites and varied by treatment (Table 1). Transects in front of active bluebird nest boxes experienced the highest predatory effects with 83% of larvae removed, on average (n=7 transects, mean=4.14 out of 5, SE=0.55). This removal rate did not significantly differ (Tukey's diff = 1.24, p=0.25) from the 58% of larvae removed from randomly selected areas within the nest box treatment (n=10 transects, mean=2.9, SE=0.62). However, removal rates from both nest box treatments were significantly greater than the 24% of larvae removed from control vineyard points (n=10, mean=1.2, SE=1.03). Significant differences were found between control and active nest box locations (Tukey's diff = -2.94, p=0.002), as well as between control and random points in nest box treatments (Tukey's diff = -1.7, p=0.054, Figure 7).

Table 1. Results of two factor ANOVA comparing number of larvae removed from three treatments (active nest box, random nest box, control) across two sites.

Factors	df	F-ratio	p-value
Treatment	2, 2	30.97	0.03
Site	1, 2.8	0.25	0.65
Treatment by Site	2, 21	0.22	0.81

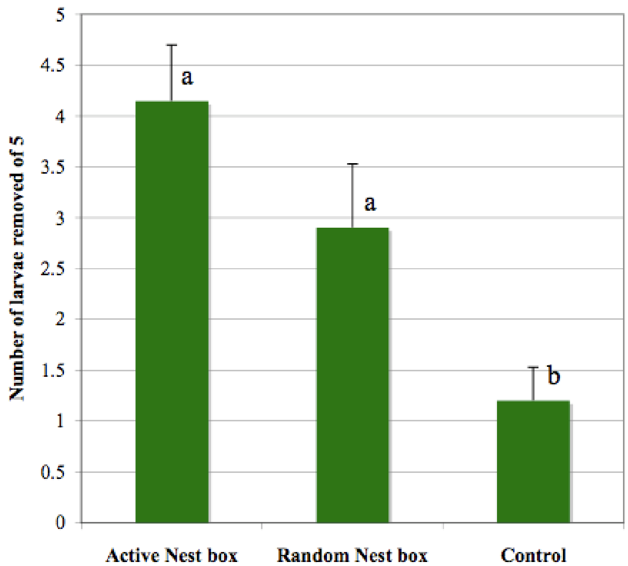

Figure 7. Mean number of lepidopteran larvae removed out of five per transect in control and nest box treatments. Error bars signify one standard error. Letters indicate significant differences ($p<0.05$) via Tukey's post-hoc hypothesis tests.

Conclusions and Discussion

Conservation practices may be a win-win scenario for organic winegrape growers. Providing songbird nest boxes in vineyards increased the abundance of insectivorous birds, most notably the Western Bluebird. Bluebirds maintain large territories that they actively patrol, increasing pest control services in vineyards. Data from the mimicked pest outbreak indicate significant predatory effect of insectivorous birds not only immediately adjacent to occupied nest boxes but at randomly selected points throughout the nest box treatment of the vineyard. Consequently the presence of occupied nest boxes benefits the vineyard and is providing ecosystem services to winegrape growers.

The sentinel pest experiment produced strong results in mid-June but took several attempts to succeed. Pinning live caterpillars to cardboard was a last resort after earlier attempts failed. Initially, live mealworms were placed in wooden nests (purchased from Petco™) on the vineyard floor, but many of the insects were able to burrow through the nesting material and escape into the earth. Later I tried placing mealworms in clay drip pans whose edges were smoothed with petroleum jelly, however many insects were able to climb over the slippery edge. With such high numbers escaping in both situations, it was impossible to determine the number of mealworms consumed as opposed to missing. Finally I tried a methodology that accurately measured predation, pinning beet armyworm larvae. However, this experiment was performed too late in the season to be replicated. I was lucky to get the data I did. As a result, I cannot show how birds respond to a mimicked outbreak throughout the growing season. I can state that in mid-June birds responded quickly to the pests and the avian predatory effect was large in the nest box treatments.

While the sentinel pest experiment was successful, these data only address part of my original objective, to monitor both lepidopteran and cicadellid pests in response to avian predation. Unfortunately, cicadellid populations occur in patches throughout the vineyard and monitoring those patches yielded data describing the clumpy distribution of insects, making any predatory effect of birds undetectable. I am now convinced that other methods are necessary to document the predatory effect of bluebirds on cicadellids. For example, one could test bluebird fecal matter and count the number of cicadellids consumed. Because exoskeleton fragments of cicadellids break apart, the most effective method for quantifying cicadellid predation is molecularly testing the fecal matter using Polymerase Chain Reaction techniques. I have research plans to study this in the future, but it requires specific equipment and laboratory techniques.

Avian biological control may appear to be a novel step for IPM; however, this research resurrects a strong area of study within the United States Department of Agriculture before the advent of DDT and other cheaply produced materials for pest control. From 1885 to 1940 a division of the Bureau of Biological Survey (part of the USDA) called Economic Ornithology was devoted to researching avian biocontrol (Kirk et al. 1996). My research is important because it connects economic ornithology with avian conservation practices. Growers can benefit from conservation practices by increasing pest predators on their agricultural land. It should be noted, however, that I did not monitor the conservation impact of nest box placement, rather documented how conservation practices are benefiting growers. In order to show that nest boxes are important for avian conservation, one would need to know how many nestlings from vineyard nest boxes survive each year to become adults and breed the following year. If the number of young produced from vineyard boxes is enough to create breeding populations year after year, then the practice of providing vineyard nest boxes could be considered beneficial for bird conservation. Thus I cannot say that providing nest boxes leads to a sustainable increase of songbird species. However, it is evident that the conservation practice of providing nest boxes increases the abundance of insectivorous predators who respond rapidly to lepidopteran pest outbreaks. Perhaps avian biological control of pests may decrease insecticide use and be a viable IPM strategy for vineyards.

Some growers might be concerned about bluebirds posing a threat to the grape crop. Might they consume the grapes and become a pest themselves? Actually, bluebirds are not a threat to agricultural crops. They are strictly insectivorous during the breeding season (which corresponds with the grape growing season). They rely on the energy they receive from insects to feed themselves and their nestlings. They will not eat grapes during the summer, and the grapes are not ripe at this time, so no birds are eating grapes then. Bluebirds are short-distance migrants and their migration paths, overwinter sites, and departure and arrival times vary by region and population. In the study areas in the North Coast of California, bluebirds generally leave the vineyards in late July and don't return until March of the following year. Consequently they are not around during veraison or harvest and do not eat the grapes. It was reported that in Southern California (Santa Barbara County), bluebirds are still around during veraison and occasionally pluck grapes. However the winegrape grower thought this was minimal and unimportant to overall yields. Bluebirds are not considered a pest on any manual or website describing bird pests in vineyards and forage quite differently than pest birds.

Another consideration is the potential for bluebirds to be displaced from their nesting boxes by predatory bird species that would then eat the grapes. Of the birds considered to be pests in winegrapes, none of the species will use bluebird nesting boxes (assuming proper woodpecker management, see below).

European starlings are too big for the entrance hole in western bluebird boxes so long as woodpeckers do not enlarge the entrance hole. Woodpecker guards come in many forms and are easy to construct to prevent entrance hole enlargement.

Brewer's blackbird is a ground nester and will not use boxes.

American robins and house finches are open cup nesters (meaning they build a cup nest in a shrub or tree), and will not use boxes.

Bird-friendly viticulture practices are necessary to maintain breeding populations of birds in vineyards. This study was performed on organic vineyards in the North Coast of California where bird populations responded quickly to the nest boxes, however other vineyard landscapes and cultural practices may not be able to recruit such high abundances. On the other hand, there are three different species of bluebirds (Western, Mountain, and Eastern Bluebirds) whose combined ranges basically cover the continental United States. So where there are suitable environments, growers will likely be able to attract breeding bluebirds. It is important that growers monitor nest boxes once a year and discard old nests to encourage continued use of the boxes and diagnose any potential problems. For example, raccoons and cats can become problematic by killing songbird adults and young in vineyard boxes, hurting avian conservation. Growers should opt to use nest box predator guards (as in this study) to protect the nests from mammalian predators (Heaton et al. 2008) and increase avian wildlife on farms. With a little effort, growers can reap the benefit of having many hungry bird mouths to feed just when insect pests may be emerging.

Outreach

I am committed to discussing and distributing these results to as many growers as possible. On January 22, 2010 this research was presented at the Ecological Farming Conference in a symposium entitled “Bat, Bird and Owl Nest Boxes”. On May 5, 2010, I presented these findings to the Napa Growers Vineyard Association at a meeting organized by University of California Cooperative Extension. I am in the process of submitting the research to Ecological Applications for a peer-reviewed publication. If the paper is accepted I will notify the Organic Farming Research Foundation. Finally, I have a research brief in preparation for the Center for Agroecology and Sustainable Food Systems at the University of California, Santa Cruz. Once this brief is published, I will actively distribute the publication to winegrape growing associations such as the California Sustainable Winegrowing Alliance, Mendocino Winegrape and Wine Commission, Sonoma County Winegrape Commission, and Lodi-Woodbridge Winegrape Commission. Last year, I presented preliminary results of this research to an audience of approximately 200 at the Wine and Wine Grape Research Conference at the University of California, Davis. I plan to present these data at both the 2011 American Ornithological Union and the Ecological Society of America Conferences.

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