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Title

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Journal

Proceedings of the Vertebrate Pest Conference, 27(27)

ISSN

0507-6773

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Publication Date

2016

DOI

10.5070/V427110543

Insect Pest Control and Bird Damage as a Function of Distance from Riparian Habitat in a California Vineyard

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ABSTRACT: Farmers have few tools with which to objectively assess the true impact of avian species on crop production, partly because ecologists and conservationists have been slow to quantify the role of birds within agricultural settings. At an annual value of over \$5.5 billion dollars, vineyards are the third-most-valuable agricultural crop produced in California. Vineyard area has rapidly expanded in California and now covers at least 820,000 acres. Encouraging growers to retain existing natural habitat around vineyards or install new habitat, such as hedgerows, is likely to have positive effects on biodiversity. However, viticulturists are often wary of actions that could increase wildlife numbers on their land, particularly birds, since they are considered one of the most damaging pests to vineyards worldwide. In California, over 67% of vineyard acres have some degree of bird damage, with estimates ranging from between 5.4% and 16.1% of crops damaged. Conversely, birds may provide vineyards with valuable pest control services by consuming insects in high numbers in the spring and summer. Quantifying these costs (bird damage) and benefits (insect pest control) for vineyards from birds as they relate to natural habitat is an essential step in understanding the net value of nature in vineyard ecosystems. In July 2015, I used a sentinel prey experiment in a California vineyard to measure the relationship between insect pest-control, bird damage, and distance from a riparian corridor. I found that over 40% of sentinel prey were consumed at the edge of the vineyard, and that birds damaged 12% of grapes. Depredation of sentinel prey and grape damage dropped at a similar rate with increasing distance from riparian habitat. These results suggest that birds may remove insect pests at a rate that could offset the damage caused by avian foraging once grapes are ripe, but further studies are needed to confirm this.

KEY WORDS: biological control, bird damage, California, conservation, ecosystem services, human-wildlife conflict, sentinel prey, vineyards

Proc. 27th Vertebr. Pest Conf. (R. M. Timm and R. A. Baldwin, Eds.)
Published at Univ. of Calif., Davis. 2016. Pp. 204-208.

INTRODUCTION

Over 25% of California's land area is used for agriculture (USDA 2015), and in many areas of the state farmland is virtually the only habitat available for wildlife. Agricultural lands are therefore a critical but often overlooked opportunity for conservation efforts. Intensification of agricultural practices has been identified as a major threat to many avian species globally (Green et al. 2005) and in areas where agriculture utilizes the majority of land, such as the California Central Valley, conservationists often advocate for wildlife-friendly farming practices to offset the negative impact of farming on birds. Establishing and protecting agroecosystems that take advantage of functional diversity to provide ecosystem services at the farm and landscape levels is seen as a way to simultaneously decrease chemical inputs and increase biodiversity (Cumming and Spiesman 2006, Perrings et al. 2006, Tschardt et al. 2007). To this end, there have been calls for biodiversity conservation to be expanded beyond the reserve system (Edwards and Abivardi 1998, MacLeod et al. 2008, Chazdon et al. 2009).

At an annual value of over \$5.5 billion dollars, vineyards are the third-most-valuable agricultural commodity produced in California (USDA 2015). Vineyard area has rapidly expanded in California and now covers at least 820,000 acres (USDA 2015). Early vineyard expansion occurred along river edges and floodplains, but recent vineyard expansion has focused on hillside areas and is encroaching upon grassland, savannah, and oak woodland habitats (Merenlender 2000). Encouraging growers to

retain existing natural habitat around vineyards or install new habitat, such as hedgerows, is likely to have positive effects on biodiversity (Viers et al. 2013). However, viticulturists are often wary of actions that could increase wildlife numbers on their land, particularly birds, since they are considered one of the most damaging pests to vineyards worldwide. In California, over 67% of vineyard acres have some degree of bird damage, with estimates ranging from between 5.4% and 16.1% crop damage (Shwiff et al. 2009). On the other hand, birds have been shown to provide valuable pest-control services in a number of crops globally, including coffee (Perfecto et al. 2004, Borkhartaria et al. 2006, Kellermann et al. 2008, Karp et al. 2013), apples (Mols and Visser 2002), and kale (Garfinkel and Johnson 2015). Birds may provide valuable insect pest-control services for vineyards, which may offset the damage done by birds. Only two studies thus far have quantified the potential for birds to provide pest control services: Jedlicka et al. (2011) used sentinel prey to measure the importance of active bluebird boxes for providing California vineyards with insect pest-control services; and Howard and Johnson (2014) used sentinel prey in Mendocino and Sonoma Counties (CA) vineyards to measure the effects of distance from oak woodland on avian depredation of the sentinel larvae. However, no studies have any studies measured both the potential for pest control services and the potential for causing damage within the same vineyard.

I used a sentinel prey experiment in the summer to measure the relative ability of birds to control insect pests

in a vineyard at varying distances from a natural riparian habitat, and I estimated the amount of damage from birds to the grape crop at the same locations in the fall just prior to harvest. Sentinel prey have been used in a number of experiments to measure the relative ability of birds to remove potential pest species from plants (Jedlicka et al. 2011, Howard and Johnson 2014, Garfinkel and Johnson 2015).

METHODS

Study Site

This pilot study was conducted at the RH Phillips Vineyard in Yolo County, California. The vineyard is located between the Dunnigan Hills and the Northern Coastal Range. I collected data from two different blocks of Chardonnay wine grapes (*Vitis vinifera*), both of which were managed using a quadrilateral spur pruning method. The two blocks bordered opposite sides of a narrow (~20-m) remnant riparian habitat.

Sentinel Prey Experiment

For the sentinel prey, I used small (0.64 to 1.28-cm) mealworms (*Tenebrio molitor*). Fresh mealworms were purchased before each trial and stored at 4°C until the morning of each sampling period. I ran the sentinel prey experiments over three different trials, each starting when mealworms were placed in the vineyard between 0630 and 0830, and finishing 24 hours later. Trials took place on July 8-9, 15-16, and 21-22, 2015. On the first sampling date, mealworms were placed at 10, 17, 26, 35, and 44 m distance from riparian habitat along five different vineyard rows. On the second and third sampling dates, mealworms were placed at 12, 19, 28, 37, 46, 73, 100, 145, and 190 m from riparian habitat along two different vineyard rows. In all trials, the first distance was for the first vine in the row. At each distance, two mealworms were pinned to the trunk of the vine and one mealworm was pinned to each of two representative grape bunches, with the exception that no mealworms were pinned to the trunk of vines on two of the five rows in the first trial. Mealworms were pinned approximately through the middle of their abdomen using size 17 dressmaker pins (27 mm). Pinned mealworms remained mobile, and most mealworms that were not depredated during the trials were still moving when they were collected 24 hours later. All mealworms were pinned to the east-facing side of the rows to avoid direct sunlight in the afternoons. When I returned to the vineyard 24 hours after setting out the mealworms, I returned to each sampling location and recorded how many mealworms were depredated and how many were untouched. I considered a mealworm to have been depredated if all or some of it was missing.

Bird Use of Vineyard and Habitat

On July 9, 2015, starting at 0635, I conducted a single 20-minute transect between the vineyard and the riparian habitat. I identified all birds using the riparian habitat and the vineyard using visual and auditory identification methods (see Bibby et al. 2000). For birds observed within the vineyard, I estimated the perpendicular distance from the riparian habitat to where the birds were

seen. Birds were recorded for the habitat in which they were first observed, so a bird observed in the vineyard that then flew into the riparian habitat was recorded within the vineyard only.

Bird Damage

Just prior to the Chardonnay harvest, I returned to the vineyard to collect data on bird damage to the grape crop. I sampled bunches in rows adjacent to the two rows used for the final sentinel prey experiment, on the east side of the vines, and at the same distances as for the sentinel prey experiment. At each distance, I sampled ten representative grape bunches for bird damage using the methods described in Kross et al. (2012). Briefly, each bunch was examined visually, and I estimated the number of grapes that were pecked, the number that were removed, and the number that were undamaged.

Analyses

I calculated the proportion of mealworms removed from trunks, bunches, and total for all sampling locations, and also calculated the proportion of each sampled bunch that had pecking damage, removed damage, and total damage (pecked and removed combined). All data were then analyzed using generalized linear models in JMP Pro (v. 12.0.1; SAS 2015).

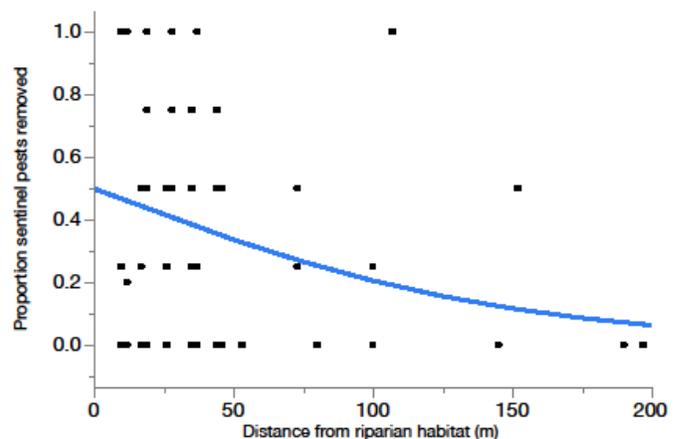


Figure 1. The relationship between the proportion of all sentinel prey (mealworms pinned to grapevine trunks and grape bunches) removed over a 24-hour period and the distance of those prey from riparian habitat.

RESULTS

Sentinel Prey Experiment

Birds removed 49.85% of sentinel prey at locations closest to riparian habitat; however, this prediction was not significant because of the wide spread of the data at locations closest to riparian habitat ($\chi^2 = 0.0002$, $p = 0.99$, Figure 1). These results were driven by depredation of the sentinel prey on both the grape bunches (37.85% depredated at vineyard edge, $\chi^2 = 1.12$, $p = 0.29$) and the vine trunks (65.0% depredated at vineyard edge, $\chi^2 = 0.35$, $p = 0.13$). There was a significant negative relationship between distance from riparian habitat and removal of sentinel prey, with our model predicting a

0.34% reduction in sentinel prey predation with every meter in distance from riparian habitat ($\chi^2 = 5.53$, $p = 0.02$, Figure 1).

Bird Use of Vineyard and Habitat

I observed nine species of bird utilizing the riparian habitat and three species utilizing the vineyard itself. In the riparian habitat, I observed one American robin (*Turdus migratorius*), one ash-throated flycatcher (*Myiarchus cinerascens*), five mourning doves (*Zenaida macroura*), five house finch (*Haemorhous mexicanus*), three Nuttall's woodpeckers (*Picoides nuttallii*), four Western kingbirds (*Tyrannus verticualis*), one Bullock's oriole (*Icterus bullockii*), two Northern mockingbirds (*Mimus polyglottos*), and two tree swallows (*Tachycineta bicolor*). In the vineyard, I observed 16 house finch (12 were <10 m, one was between 10-25 m, one was between 25-50 m, and two were between 50- 100 m from the vineyard edge); one mourning dove (10-25 m from the vineyard edge), and two Northern mockingbirds (one <10 m, and one 10-25 m from the vineyard edge).

Bird Damage

Bird damage was also highest at the vineyard edge (12.0% damage, $\chi^2 = 9.00$, $p = 0.003$), which was primarily driven by pecking damage (9.74% damage, $\chi^2 = 10.51$, $p = 0.001$), and not by removal of grapes (4.42% damage, $\chi^2 = 1.84$, $p = 0.18$; Figure 2). Bird damage also declined as distance from riparian habitat increased, with our model predicting a 0.31% reduction in damage with every meter in distance from riparian habitat ($\chi^2 = 5.64$, $p = 0.02$; Figure 2).

DISCUSSION

My results show that birds are likely to provide valuable pest control services in vineyards, especially close to riparian habitat. Interestingly, the models for both removal of sentinel prey and for grape damage had similar slopes with respect to increasing distance from riparian habitat, which suggests that the pest control services from birds in summer may directly offset the costs associated with bird foraging prior to harvest. However, because these results come from a small-scale pilot study, they support the need for further studies to confirm the potential for birds to provide valuable pest-control services. Without quantifying actual insect damage to grapes at varying distance from riparian habitat, I am not able to convert the results of the sentinel prey experiment into actual changes in yield, so cannot directly compare the ecosystem services from birds (insect pest control) with the disservices (grape damage). I recommend that future research attempt to measure the direct impact of birds on insect pests through the use of avian exclusion experiments.

The result that removal of sentinel prey tapered off with increasing distance from riparian habitat opposes the findings of Howard and Johnson (2014), who did not observe a distance effect in their similar sentinel prey study in vineyards in Mendocino and Sonoma Counties. This may be explained by the vastly different landscape heterogeneity of the two studies: In my study, natural woody vegetation is limited to thin strips along a riparian

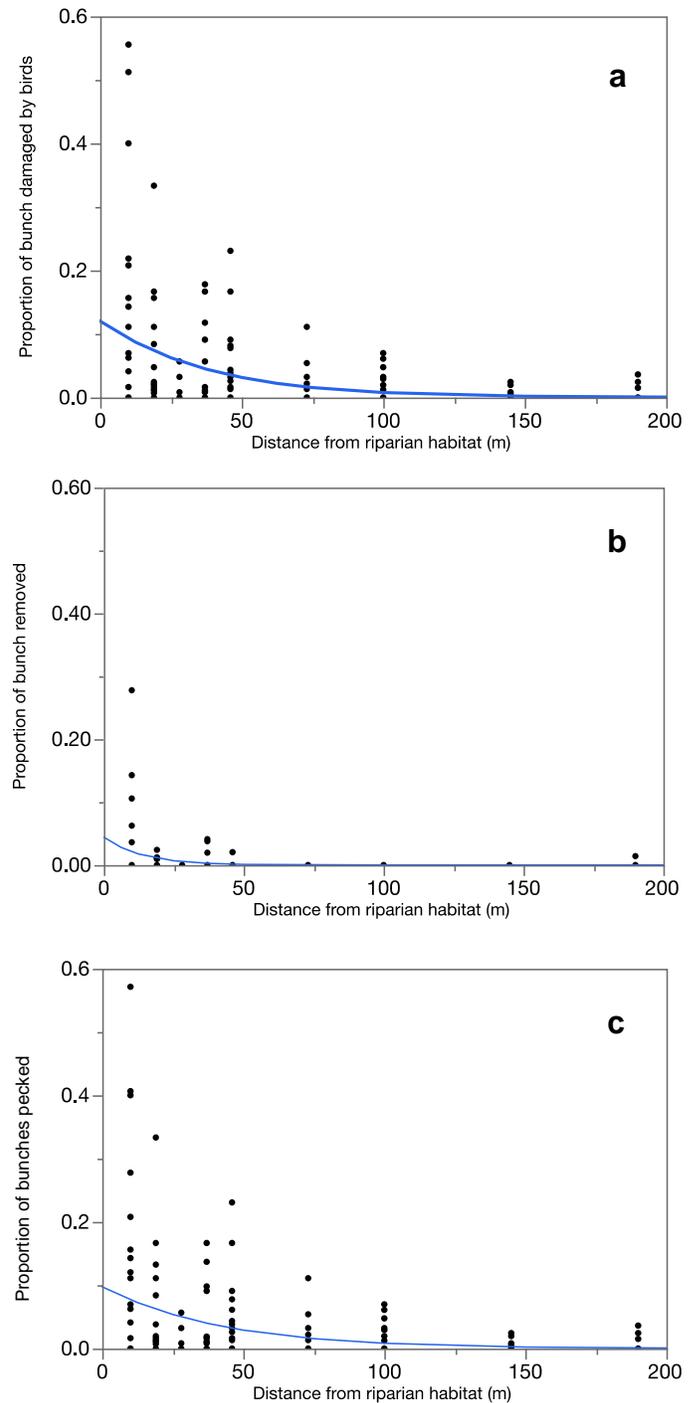


Figure 2. The relationship between the distance of grape bunch sampling locations from riparian habitat and a) the total (removed + pecked) proportion of bunches damaged; b) the proportion of bunches removed; and c) the proportion of bunches pecked by birds. Lines show the estimated relationship between damage categories and distance from a generalized linear model.

corridor within a large homogenous vineyard landscape, whereas the Howard and Johnson (2014) study took place in small vineyards embedded within a more forested landscape. In the small vineyards, birds may have been

more willing to venture further into the vineyard than in my large vineyard, where less cover was available once birds left the riparian corridor.

The sentinel prey portion of this experiment took place in July, which is later in the summer than would be ideal for quantifying the maximum potential for birds to control pest insects. This is because birds will consume the most insects during the breeding season while raising their chicks on protein-heavy diets, and therefore almost all species are all or partially insectivorous during the breeding season (De Graaf et al. 1985). Most birds in California have completed breeding by July and are transitioning into fall diets, when more species are omnivorous or frugivorous (De Graaf et al. 1985). The single bird count that I conducted is not enough to draw conclusions of the overall bird assemblages using both the riparian habitat and the vineyard, but it does indicate that the riparian habitat housed a diversity of avian species and foraging guilds. Future studies examining the role of birds for pest control should take place in spring and early summer and should have multiple bird counts conducted.

While birds were the most visible vertebrate species within the vineyard, other predatory vertebrates may have consumed the sentinel prey. Western fence lizards (*Sceloporus occidentalis*) and western toads (*Anaxyrus boreas*) were also observed within the vineyard, and may have consumed the sentinel prey, especially mealworms pinned to the trunks of vines. Furthermore, while vertebrates are likely to have been responsible for the majority of the depredated sentinel prey, I cannot be sure that invertebrate predators (such as spider, ants, and predaceous beetles) were not responsible for some of the depredation. Future studies utilizing video monitoring of a subsample of sentinel prey would be useful to identify which species consume the sentinel prey. Similarly, while the pecking damage to grapes was almost certainly from birds, grapes may have been removed by other vertebrate species including raccoons (*Procyon lotor*), Virginia opossum (*Didelphis marsupialis*), or rodent species.

Farmers have few tools with which to objectively assess the true impact of avian species on crop production, partly because ecologists and conservationists have been slow to quantify the role of birds within agricultural settings. Here, I have taken a step towards understanding both the benefits and the costs of utilizing wildlife-friendly viticulture to encourage bird conservation in an intensively farmed landscape, and I encourage future research to further explore and describe the role of birds in vineyards.

ACKNOWLEDGEMENTS

Thank you to Constellation Brands USA, and to Ricky Mendoza and Rod Schaeffer from the RH Phillips Vineyard for giving access and advice for this project. This work was funded by the David H. Smith Conservation Research Fellowship and Selma Herr Fund for Ornithological Research. I was hosted by John Eadie in the Department of Wildlife, Fish and Conservation Biology at UC Davis.

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