Evaluating nest boxes in attracting barn owls and kestrels for controlling voles in grass seed production systems

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Introduction

Voles are herbivorous rodents that are distributed throughout the mid-to-upper latitudes of the northern hemisphere. In many areas, vole species have become serious crop pests because of their ability to adapt to human-altered landscapes. Damaged crops include alfalfa, clover, potatoes, commercial forests, orchards, and row crops (Vertrees 1961, Myllymaki 1977, Getz et al. 1987, Jacob 2003).

Population fluctuations are famous for their regular cycles at northern latitudes, but at the middle latitudes of western Oregon, vole dynamics are much less predictable and the fluctuations vary in both frequency and amplitude. Vole population fluctuations may sharply influence other species in grassland communities (Sundell et al. 2004, Gervais et al. 2006, Howe et al. 2006). Their presence is particularly problematic in agricultural systems, because they are a native species whose populations support many other species of wildlife, including predatory birds, mammals, and snakes.

The species that is most responsible for crop damage in the Willamette Valley of Oregon is the endemic gray-tailed vole, *Microtus canicaudus* (Verts and Carraway 1998). Gray-tailed vole populations seem to reach high densities every 5 to 8 years, although this has not been carefully studied. They can, however, be associated with substantial crop damage. In 2005, the estimated losses to the grass seed industry alone were 35 million dollars, and damage was also sustained by nursery crops, orchards, and vineyards (Christie 2005). Recently, zinc phosphide baits have been registered for use in grass grown for seed in Oregon under Federal Fungicide, Insecticide and Rodenticide Act Section 24(c) Special Local Needs labeling.

The use of rodenticides to control gray-tailed vole populations in the grass seed fields of western Oregon has been controversial because of potential risk to non-target organisms such as over-wintering Canada geese. Currently, zinc phosphide is registered for broadcast baiting during the summer, when over-wintering migratory geese are not present. Otherwise, use of the bait has been restricted to below-ground application. Baiting below ground is a labor-intensive process requiring crews to walk through fields and manually push bait into vole tunnel entrances.

Voles are widely recognized to be important prey species for many predators (Korpimaki 1994, Taylor 1994, Hanski and Korpimaki 1995, Sundell et al. 2004, Gervais et al. 2006). Although decades of research into vole population dynamics suggests that predators are not responsible for vole population cycles, predators can impact the severity and frequency of population peaks

(Pech et al. 1992, Stenseth et al. 2001, Korpimaki et al. 2002, Korpimaki et al. 2005, Nie and Liu 2005). These peaks are when most agricultural damage occurs. Within the Willamette Valley, population peaks of voles appear to occur irregularly over a 3 to 8 year time span, and the peaks also vary widely in their magnitude. However, even localized high densities can cause substantial economic losses.

Natural predators may help substantially in reducing and controlling pest populations. The Willamette Valley supports populations of breeding barn owls (*Tyto alba*), American kestrels (*Falco sparverius*), red-tailed hawks (*Buteo jamaicensis*), northern harriers (*Circus cyaneus*), and other raptors. The winter population is even greater, with rough-legged hawks and other raptors arriving from outside the region. In addition to the raptors, herons and egrets occur in the valley and prey upon voles. Of all the avian predators, however, barn owls are the most focused on rodents in general and voles in particular. In addition, they have responded readily to habitat enhancement in the form of nest boxes in other countries and other regions of the U.S. This research was initiated to enhance barn owl activity in grass seed fields

The original objective of this research was to measure the impact of barn owls on vole population densities in grass seed fields, and to examine interactions between owl predation and field residue management. Eighty barn owl boxes were erected in 16 fields near Shedd and Coburg, Oregon in 2007 and 2008 (Figure 1). All fields were bordered at least in part with trees, which provided perch sites for raptors. It was hypothesized that barn owl populations might be limited by nest site availability, and providing suitable nest boxes would allow the birds to choose nesting and roosting sites in otherwise suitable areas.

Figure 1. Nest box installed along field border in Shedd, Oregon.

Because use was so much lower than expected, insufficient sample sizes existed to evaluate barn owl impacts on vole populations in the grass seed fields surrounding the boxes. Kestrels were also found utilizing the boxes on a number of occasions. Accordingly, objectives were modified to evaluate habitat characteristics of nest boxes that were selected for use by both barn owls and kestrels. In addition, information on nest box use from the primary literature was summarized, in hopes of better characterizing the best locations for barn owl and kestrel nest boxes for future attempts in recruiting natural predators for vole population control.

Methods

A total of 80 barn owl boxes were deployed on three growers' fields in the vicinity of Shedd and Coburg, Oregon (Figure 2). Nest boxes were made of plywood and mounted on posts 3 m from the ground (Figure 1). Boxes featured an interior wall that shielded occupants from daylight, and prevented great-horned owl predation of the nests.

Fields were chosen because they were in seed production at the start of the study, had well-defined borders, and offered borders with and without tree cover. Boxes were placed so that as much as possible, each field offered equal numbers of boxes in the open and along a wooded edge (Figure 3). Areas with known nesting great-horned owl pairs were avoided. Field management has been variable, although most fields were initially planted in perennial grass

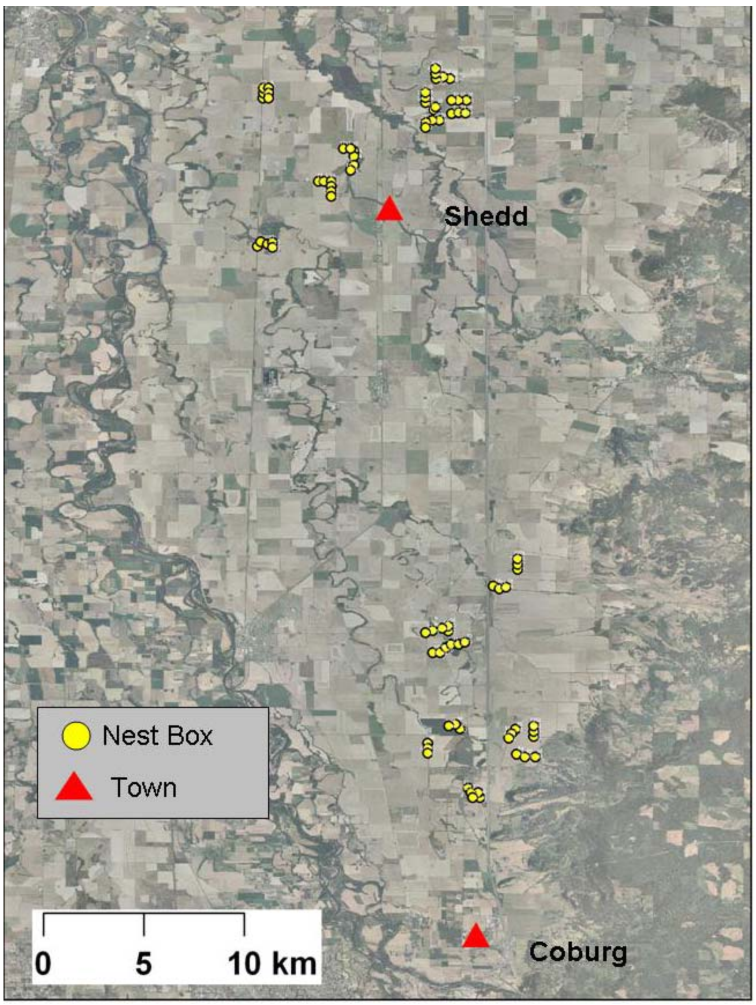

Figure 2. Nest boxes deployed near Shedd and Coburg, Oregon.

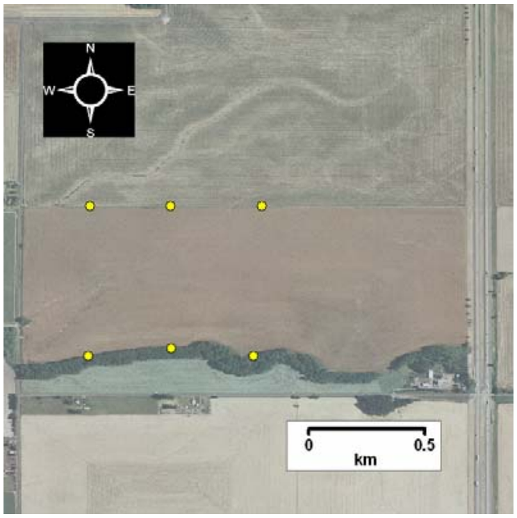

Figure 3. Detail of box placement in one field, showing boxes along the border of two adjacent fields (top) and along a wooded riparian area (bottom).

grown for seed. Minor crops included annual ryegrass, clover, wheat, and vegetables grown for seed. A few perennial grass fields have been replanted in annual ryegrass or wheat over the course of the study. None of the study fields were tilled. Residue management was variable although none of the study fields were burned, and most were left with crop residue following harvest.

Boxes were visited in late March-early May each year to assess breeding bird occupancy. Use was determined either with an infrared cavity probe or by opening the box briefly to determine contents. Boxes were also visited in December-February of each year, for maintenance and cleanout. One box post was broken by a tractor boom and not replaced, but all other boxes either remained erect or were reinstalled if damaged by field operations or flooding for the duration of the study period.

Nest box contents and signs of use were noted during all visits. Bird species using boxes were determined if possible, and all contents were carefully described. The ground below each nest boxes was also searched for pellets or droppings that might indicate use either as a roost or perch. Use by perching diurnal raptors also was recorded.

Nest box coordinates were estimated using a Garmin GPS76, and imported into a Geographic Information System (GIS) for analysis. We used the Willamette Valley Land Use/Land Cover geospatial data set (updated 2001, *http://www.nwhi.org/index/gisdata#Willamette%20Valley%20Specific%20GIS%20Data*) to estimate landscape vegetation characteristics. Landscape characteristics were selected based on previous studies of barn owls and the particular features of the study area. Landscape characteristics measured included distance to the nearest contrasting habitat edge in meters, the amount of forest edge along agricultural fields in meters within 100 meters, 1 km, and 2 km of the nest box, and amount of forest area measured in hectares within 100 m, 1 km, and 2 km of the nest box. Characteristics were compared between boxes that were used for either roosting or nesting by barn owls and all other boxes. Boxes used and not used by kestrels were compared similarly. Habitat features used in the analysis were selected based on reported habitat use by radio-tagged barn owls in other studies (Colvin 1984, Taylor 1994).

Results

Overall, box use by nesting kestrels and barn owls was low. Half the boxes were installed in winter of 2007. In the summer and fall of 2008, the remaining 40 boxes were installed in the Coburg region. No use was recorded in 2008. Subsequent monitoring revealed 3 barn owl nests in 2009 and 2 in 2010 (Figures 4 and 5). Two of the 3 nests in 2009 failed and were abandoned. One of these nests failed in the nestling period following the death of one of the adult owls. One of the 2 nests in 2010 also failed from unknown causes, although the remaining nest appeared to successfully fledge young.

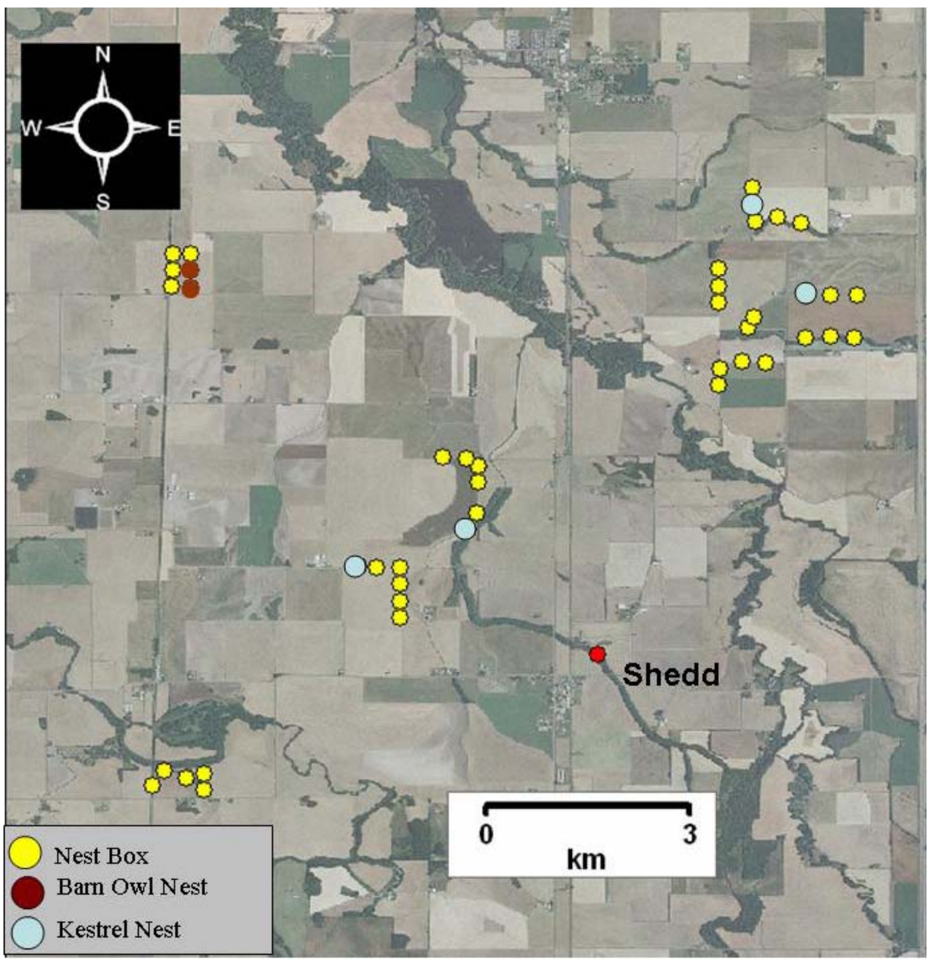

Figure 4. Box use by nesting barn owls and American kestrels near Shedd, Oregon, 2008-2010.

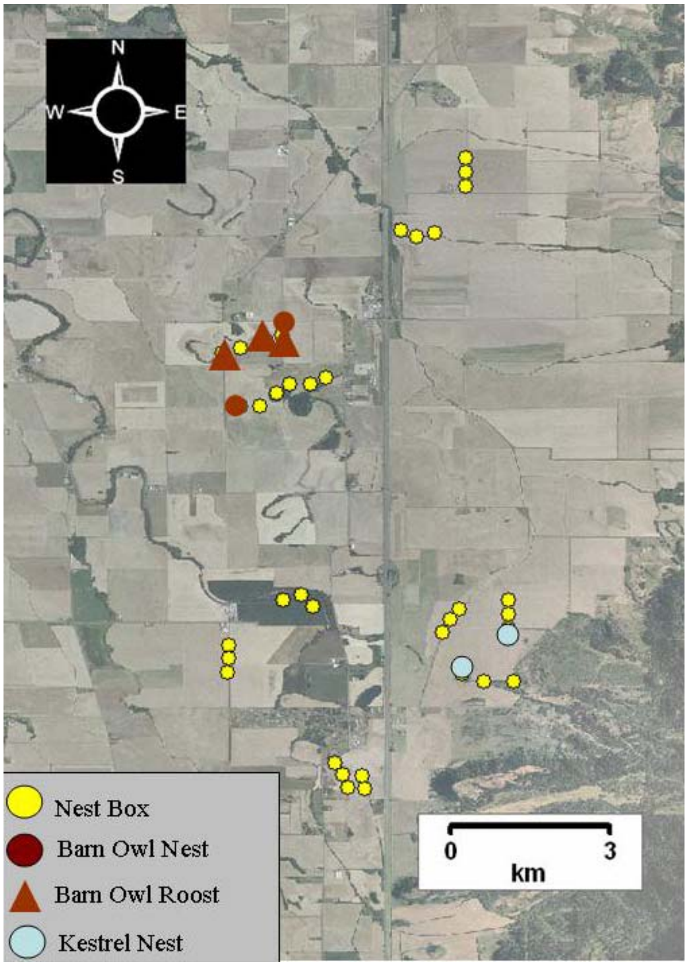

Figure 5. Box use by barn owls and American kestrels near Coburg, Oregon, 2008-2010.

A total of 5 kestrel nests were initiated during 2009 and 2010 (Figures 4 and 5). Three nests belonging to kestrels in 2010 all failed, although an additional 4 boxes appeared to be used as roosts. Two kestrel nests found in 2009 also failed. An additional 4 boxes were documented to be kestrel roosts in 2010. Because roosting may leave little sign, it is expected that roosting activity was greatly underestimated for both species.

Unfortunately, the biggest beneficiaries of the box network were European starlings (*Sturnus vulgaris*), which consistently used a quarter of the boxes for nesting each year. Two additional passerine nests whose builders were not identified were also found in 2010.

Of the boxes that were used by barn owls, most were located along open fencerows with no woody or shrubby vegetation or narrow field borders with little woody vegetation. One box along a fencerow bordering a forested patch contained a single barn owl pellet in 2009, and in 2010 a box along a hedgerow with isolated ash trees was used as a roost by a male owl. This box was 1050 meters away from an active nest. Sample sizes are too small to reveal clear patterns (Table 1); point estimates of habitat features are similar between the used and unused nest boxes.

Kestrels did use some boxes along forested edges; the forested edge in one case was that of a riparian wet area with small ash trees less than 10 m in height. The patch was roughly rectangular and measured 153 m long by 117 m wide. A second nest was located on a fence line between two fields. The fence line supported a hedgerow with some small ash trees that were also less than 10 m in height. The very small sample of used boxes leads to extremely imprecise confidence intervals, and none of the specific characteristics examined appear to have been selected by the kestrels.

Table 1. Summary statistics of GIS data for nest boxes used by barn owls near Shedd and Coburg, OR 2007-2010. Measured variables included the amount of linear forest edge habitat in meters within 100 m, 1 km, and 2 km of boxes, the distance to the nearest edge of different habitat type in meters, amount of forest area in hectares within 100 m, 1 km, and 2 km of the nest box. UCL and LCL refer to upper and lower bounds of 95% confidence intervals.

	Used			Not Used		
	Mean	LCL	UCL	Mean	LCL	UCL
Edge 100m	72	-128	272	117	79	154
Edge 1 km	3769	2247	5291	4906	4250	5563
Edge 2 km	11096	8663	15150	18796	16942	20649
Dist to edge	267	8	527	272	209	335
Forest 100 m	0.16	-0.29	0.61	0.29	0.19	0.39
Forest 1 km	11.98	1.86	22.09	14.14	11.13	17.15
Forest 2 km	35.54	21.81	49.27	65.09	54.94	75.25

Table 2. Summary statistics of GIS data for boxes used by nesting American kestrels near Shedd and Coburg, OR 2007-2010. Measured variables included the amount of linear forest edge habitat in meters within 100 m, 1 km, and 2 km of boxes, the distance to the nearest edge of different habitat type in meters, amount of forest area in hectares within 100 m, 1 km, and 2 km of the nest box. UCL and LCL refer to upper and lower bounds of 95% confidence intervals.

	Used			Not Used		
	Mean	LCL	UCL	Mean	LCL	UCL
Edge 100m	53	-94	201	118	80	156
Edge 1 km	4012	201	7823	4890	4250	5530
Edge 2 km	17408	8372	26445	18428	16569	20288
Dist to edge	369	-77	814	265	204	326
Forest 100 m	0.25	-0.44	0.93	0.29	0.19	0.39
Forest 1 km	8.36	-4.08	17.12	14.38	11.38	17.39
Forest 2 km	63.60	9.13	118.07	63.22	53.18	73.26

Discussion

Habitat changes within the Willamette Valley have included extensive loss of oak savannah habitat and bottomland forests. In addition, large barns with exposed beams and haylofts that once offered barn owls nesting and roosting opportunities have declined as farming practices have changed and livestock have largely disappeared. Land use in recent decades has likely favored the gray-tailed vole by creating large blocks of grassland habitat, while removing cover for many of the predators that might otherwise work to keep vole populations in check. In addition, use of tile drains has likely improved the habitat quality for this species of vole by creating even larger expanses of the drier grassland it selects. Prey for barn owls may not have been a limiting factor in this system. Loss of nesting habitat has been shown to affect barn owl populations elsewhere, such that providing nest boxes allowed populations to expand (Marti et al. 1979, Taylor 1994, De Jong 2009). However, this attempt in the Willamette Valley to attract barn owls by providing nest boxes was not very successful. Based on the low nest box occupancy during the study, nest sites do not appear to be limiting barn owl populations within the Willamette Valley.

There are a number of reasons that that may explain why the nest boxes in Shedd and Coburg only attracted a few pairs of owls. The boxes themselves may not have been entirely suitable, or the habitat in which they were placed was not optimal. Owls in the area may have chosen to reuse old nests rather than relocate into the boxes. The prey base may not have been sufficient for the duration of the breeding season or possibly over winter. Finally, the presence of predators or competitors may have prevented occupancy. Each of these hypotheses will be discussed in turn.

Patterns in nest-site use vary throughout the barn owl's range. The likelihood that the same owls will use a nest site in multiple years appears to vary from population to population. A long-term study in Switzerland found that owls rarely stayed in the same pairings or at the same nest box from year to year (Altwegg et al. 2007). However, fidelity to nest sites in Scotland was very high despite wide fluctuations in vole populations among years (Taylor 1994). It is not clear what factors may underlie site fidelity, as barn owls in Scotland moved primarily in response to the loss of a mate, and not to nest failure (Taylor 1994). In burrowing owls, adult dispersal in females occurred following the loss of the male, but both genders were prone to dispersing if the previous nest attempt had failed due to predation (Catlin and Rosenberg 2008). Barn owl nests seem most likely to fail because of lack of food, which in Scotland is a highly variable resource. It may be more advantageous in environments with highly dynamic food resources to remain on a known territory and wait for conditions to improve rather than relocate to a new territory; the reason for the difference in responses among studies in dynamic environments, such as Scotland and Switzerland, is not obvious.

Interestingly, the nesting attempts in the box network in the Willamette Valley occurred in the same or adjacent boxes between years. In New Jersey, barn owls shifted into nest boxes from trees and other sites over three years, from 30% to 68% of all nesting attempts. However, the number of nesting attempts remained stable through time (Colvin 1984). In contrast, most nest boxes in Scotland remained unused, as the owls seemed to continue nesting in outbuildings, silos, and other structures as they had before boxes were available (Taylor 1994).

Barn owls have been shown to adapt to a wide variety of human-provided nest sites, including hay bale piles, barns, church towers, and a wide variety of nest box types (Marti et al. 1979, Hegdal and Balaskiewicz 1984, Taylor 1994). The box design used on this project has been used successfully by owls in the Willamette Valley by other conservation projects and in this study. Although an eastern Oregon nest box project used boxes with shade structures attached, the cool spring climate of western Oregon would not seem to require the extra protection from heat gain. Barn owls have a metabolic neutral zone of 22.5-32.5 °C ambient temperature, or 73-90 °F (Edwards 1987, Taylor 1994). Even when clear weather develops over the western Willamette Valley in June and July, it seems unlikely that nest boxes become too warm for occupancy. In addition none of the boxes in the study that were along the forest edge were used as nests and they were used only rarely as roosts.

Barn owl fledglings seem to benefit from structure near the nest site that allows them to practice flying before they undertake the first real attempt. In Europe, researchers noted that nests in church steeples were less successful if these nests did not have access to the beams inside the building so that the maiden attempt at flight had to be straight out from the box entrance (Klein et al. 2007). However, barn owls do not seem to select nest sites based on nearby perches for owlets learning to fly, as none of the boxes placed near trees were used. Some of these nest boxes faced along the woodland edge, and would have allowed young owls the opportunity to hop from the box to a perch and back in the process of developing flight skills. Natural nests in tree hollows would have automatically afforded such an environment; no selection by the owls for perches near nest sites would have been necessary throughout most of their evolutionary history.

The boxes in this study were mounted on relatively short poles, whose height was selected based on success of nest boxes installed elsewhere, available materials, and for ease of installation, monitoring, and maintenance in addition to cost. Although potential for nest predation by raccoons has been suggested for the use of nest cavities well above the ground (Taylor 1994), boxes on short poles have been successfully used in eastern Oregon and in the Central Valley of California (*personal observation*). The height of the box alone therefore does not seem to be a deciding factor in use although it might possibly affect rates of nest success in some circumstances.

The boxes may have been too vulnerable to predators for the owls to use them, or predators caused nests to fail. Barn owls in North America must deal with predators that don't exist in many other parts of the species' range. In the Willamette Valley, raccoons in particular may be able to climb to a nest box. However, female barn owls attend eggs and young chicks nearly continuously until the male's ability to feed her and the young begins to decline, at about the time the oldest chick is roughly two weeks of age (Taylor 1994, Durant et al. 2004). Barn owls begin incubation at the onset of laying, so that young hatch at roughly 2-day intervals (Taylor 1994). The youngest owlet may be only a few days old when the female begins hunting, but the oldest chicks may have the ability to defend at least themselves from most intruders. No more specific information was found regarding nest predation. Raccoons and opossums would be the only two likely nest predators in this study area. However, it would seem that nest predation is more of a reason for nest failure rather than nest site selection.

Great-horned owls have also been recorded to be predators on barn owls, and could raid a nest and kill either the female or the young. For this reason, the boxes in this study had a small entrance hole and included an interior wall that shields the back of the nest box, so that a great-horned owl could not reach in and extract any barn owls inside. Great-horned owls may still attack adult owls, and one nest in this study failed apparently upon the death of the adult male.

The body was found on the ground below the nest box. It was too decomposed to determine cause of death, but attack by another owl or other large raptor is possible. Barn owls and great-horned owls rely on different prey bases, and although the potential for interspecific aggression exists, it is not clear how much of a threat this is, and whether barn owls respond to it while selecting nest sites.

Boxes may not be as attractive as natural nest sites, but barn owls have a long and clear pattern of adapting to and even selecting artificial structures for nesting and roosting. Barn owls use outbuildings within the Willamette Valley. There are relatively few large trees on the study area. The presence of natural cavities of sufficient size for a barn owl and young would be even less common, suggesting that the lack of adoption of the nest boxes is not a result of an abundance of nest site choices.

The boxes were installed along the edges of fields, so that in most instances each study field included boxes in the open and along the edge of a forested area, usually a riparian zone with relatively small, young trees. Barn owls appear to use forest edge habitat extensively for foraging in agricultural areas (Hegdal and Balaskiewicz 1984, Taylor 1994). Boxes were on average within 300 meters of such edge habitat (Table 1). Barn owls in North American have been shown to fly several kilometers from roost or nest sites to reach hunting sites (Hegdal and Balaskiewicz 1984). Distance to suitable foraging habitat does not seem to be prohibitive.

The presence and location of nest sites is only one of several requirements for barn owl population persistence within a region. An appropriate prey base must also be present. Barn owls prey mostly on small mammals, with a particular emphasis on voles (Taylor 1994, Arim and Jaksic 2005, Bernard et al. 2010). Barn owl population dynamics are linked to that of their main prey species, the voles, in that numbers of nesting pairs is correlated to vole abundance (Taylor 1994, Altwegg et al. 2003). When food is abundant, owls may produce multiple broods in a year. The likelihood that the owls will produce second broods in a year increases with the age of the adults (Altwegg et al. 2007). Although barn owls rely heavily on small mammals in general and voles in particular, seasonal and annual changes in prey abundance are reflected in their diet (reviewed in (Taylor 1994). Barn owls in Scotland took more shrews and mice when voles occurred in low numbers, and captured a wider range of prey in the absence of voles (Taylor 1994). All evidence suggests that the dynamics of this species are tightly linked to its main prey; alternate prey may sustain an established population but do not appear sufficient to allow barn owl numbers to increase in the southern Willamette Valley.

Gray-tailed voles appear to be the most numerous small mammals in dry grassland systems within the Willamette Valley, although house mice (*Mus musculus*), deer mice (*Permomyscus maniculatus*), and vagrant shrews (*Sorex vagrans*) have been captured in grids along with Townsend's vole (*Microtus townsendii)* (Wolff et al. 1996). In years when gray-tailed vole populations are low, owls would have to find adequate shrews, mice, Townsend's voles, which inhabit wetter grassland sites than gray-tailed voles (Verts and Carraway 1998), and other prey to meet energetic needs.

In order for these other species of prey to sustain barn owls in the absence of gray-tailed voles, their densities must be relatively high at times the voles are not available, and they must be found in sufficient numbers in habitats that are accessible to hunting barn owls. Grass seed fields are likely to support large populations of voles but not the other species, whose diets are made up of invertebrate prey and seeds. Further, concern over purity of grass seed crops has led to the practice of spraying herbicides on field borders and fence rows so that weed seeds do not contaminate the grass seed. This practice also removes vegetative cover and food such as seeds and insects for small mammals that might serve as alternate prey for barn owls. Uncultivated land is limited, and landscape configuration may not allow sufficient densities of alternate prey to make up the difference in the owls' diets in poor vole years. The lack of alternate prey remains a viable hypothesis for the low numbers of owls that selected nest boxes in the study area.

Gray-tailed voles can reach densities that cause economically significant crop damage, even if region-wide population outbreaks are relatively rare. Many growers respond to increases in vole activity with broadcast baiting of zinc phosphide in the summer after harvest, or by baiting individual burrows with this rodenticide. Although attempts at control rarely eliminate voles from the landscape, rodenticide use may prevent populations of voles building to densities necessary to form the basis of a barn owl's diet on the scale of a breeding territory. This may be compounded by the fact that alternate prey species may also be killed by the zinc phosphide bait.

Alternatively, prey may be available in the strict sense but foraging conditions may not be suitable. Barn owls forage by either coursing on the wing at low altitudes over grasslands or from low perches where they can hear their prey. It appears that in at least some situations, energetic costs are better met by sit-and-wait foraging rather than active searching (Taylor 1994). The grass seed production fields of the Willamette Valley frequently lack perches along field borders in the form of fence posts and no perches exist in the centers of the fields. This, along with the fields' large sizes (frequently 30 ha or greater), may make it difficult for barn owls to hunt away from the edges despite the fact many fields border riparian zones with small trees. Perches provided for American kestrels increased visitation to test enclosures (Wolff et al. 1999). A better understanding of the factors that influence foraging decisions in barn owls would be helpful, particularly because perches set up within or adjacent to fields incur greater costs to farming operations.

It was not possible to identify fences on the GIS layers available. Wire fencing for livestock still exists on the borders of some fields, although the posts are decaying and permanent fencing appears to being replaced by temporary electric fencing for sheep. The temporary fencing is unlikely to offer perch sites. Barn owls and kestrels used boxes that were along fence rows in some cases, but not in others.

Another reasonable hypothesis for low occupancy is simply that the Willamette Valley has a low density of owls and occupancy of new nesting structures would therefore be slow. If populations of barn owls are low in the Willamette Valley to begin with, few recruits into the breeding population would be expected even following very good years. Young owls may travel long distances between fledging and recruiting into a breeding population; distances of over 200 miles have been recorded (Stewart 1952, Marti 1999). However, major geographic features affected juvenile barn owl dispersal in Utah (Marti 1999). Whether owls from outside the Willamette Valley are likely to immigrate into this region is unknown. If topography limits the number of immigrants, then young produced by resident owls will have to be the source for increasing populations. Although a vole outbreak might well allow local barn owls to produce far more young than usual, these young birds must find sufficient food to survive after vole populations decline in order to be present for the start of the next increase in vole density

Nesting sites alone do not appear to be limiting barn owls within the Willamette Valley. Breeding pairs are known to exist, and they are capable of producing young in at least some circumstances. Given adequate hunting habitat and prey base in addition to suitable nest sites, the possibility to increase the Valley population of barn owls certainly exists. Adequate alternate prey in the absence of dense vole populations may not be available. Evaluating the alternate prey base, in particular its composition, density, and distribution, may greatly aid in determining what steps might be taken to enhance populations of barn owls and increase the use of nest boxes as one of several control mechanisms to reduce densities of voles that cause significant economic damage.

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