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Journal
Proceedings of the Vertebrate Pest Conference, 24(24)

ISSN
0507-6773

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Publication Date
2010

DOI
10.5070/V424110631

Barriers, Traps and Predators – An Integrated Approach to Avoid Vole Damage

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ABSTRACT: Voles (*Microtus* spp. and *Arvicola* spp.) are the most abundant rodent species in open European landscapes. Due to their preference for agricultural habitats and their enormous reproductive potential, they are often regarded as pests. Several attempts have been made to reduce vole densities using rodenticide baits, gasses, or traps. No matter what method is used, they all bear the problem of voles reinvading from adjacent habitats. We tested a combination of fence and a new kind of trap that enabled terrestrial vole predators to take the captured prey. The combination of fence and traps was tested in a field trial and compared with mesh wire fences and an obstacle-free control line. This three-line setup was installed at each of three locations in Switzerland. Movement patterns of terrestrial predators were recorded by video observation during a 2-year period. Within this period, we made 1,224 observations of mammals; about ¾ of them, 951, were terrestrial predators and 157 were others like hares or hedgehogs. Due to their smaller size, only 116 voles were observed during the same time. Fences with traps were clearly preferred by predators, and their activity was significantly higher along fences with traps, as compared to the two other types. Predators seemed to check traps actively as they moved significantly more often close and parallel to fences with traps. Voles were not only removed from the traps but also caught while moving in the vicinity of the fences. The observed vole movements were ended by a predator in 11% of all instances. We found that barriers with additional trapping devices attracted predators, which started to patrol these fences regularly. Such a physical barrier in combination with its natural guard is a suitable device to protect high-value crops like orchards. As an integrated tool, it will reduce efforts, costs, and environmental impacts of vole control measures. Subsequent to this study, a new H-shaped double wall fence was constructed. This new type gives additional benefits, as it is easier to maintain and allows both terrestrial and avian predators to take captured voles.

KEY WORDS: *Arvicola* spp., crop protection, fence, *Microtus* spp., orchards, organic farming, rodent management, Switzerland, traps, wildlife damage

Proc. 24th Vertebr. Pest Conf. (R. M. Timm and K. A. Fagerstone, Eds.)
Published at Univ. of Calif., Davis. 2010. Pp. 222-227.

INTRODUCTION

Old church archives told us, long before Charles Elton (1924) founded modern population ecology, that voles have an enormous reproductive potential and they can reach disastrous population densities. Reaching peak populations is disastrous for the voles, as a crash is likely to follow within a short time period, and it is disastrous for agricultural habitats, where population outbreaks may cause considerable damage. Therefore, the focus on voles is ambivalent: they are a favourite species group for population biologists (Stenseth and Ims 1993, Krebs 1996), while at the same time are in the crossline of plant protectors (Witmer et al. 2000).

In Europe, different species of *Microtus* and *Arvicola* usually conflict with human interests. They can present more-or-less regular population cycles, with peaks every 3 to 5 years for *Microtus* (Niethammer and Krapp 1982, Schlund 2005), and every 4 to 7 years for *Arvicola* species (Fröschle 1991, Giraudoux et al. 1997). There is no doubt that voles cause severe economic losses, especially during population outbreaks, but good estimations of these losses are rare. For Switzerland, Stutz (2002) calculated that a single vole species (*Arvicola scherman*) causes costs of 3,50 CHF (€2.30) per year in grassland for fodder production. Walther et al. (2008) calculated the losses caused by voles in German apple orchards at up to €117 per tree. The annual losses in a country like Germany can only be estimated, but they definitely run into millions of euros.

Consequently, vole control is an important issue of plant protection. Several devices and methods have been applied with different success. Mechanical traps are the oldest among these tools but nevertheless still in use. Trapping takes time and needs specific skills, but the trapping success is directly visible and a skilled trapper can be very efficient. In organic orchards in Europe, it is still the method of choice to reduce vole damage. Chemical solutions, on the other hand, are commonly used in integrated farming. Chemicals can be fumigant gasses or repellents, but usually they are applied as rodenticide baits. Broadcast baiting can be effective to reduce vole numbers, but populations recover within a short time (Witmer and Fantinato 2003). In many European countries, however, broadcasting baits is restricted to some cultures and specific conditions. Alternatively, baits have to be placed hidden inside vole burrows. In this case, the use of rodenticides can be as time-consuming as trapping, but the success is less easy to control.

Voles are also an important prey for carnivorous species. Foxes, stoats, and weasels prey heavily on voles (Dieterlen 2005) and so do raptors (Pugh et al. 2003) and owls. The role of predators in cyclic vole populations is discussed controversially (Oli 2003, Korpimäki et al. 2003), but predator abundance (Korpimäki and Norrdahl 1998) or even their scent marks (Barreto and MacDonald 1999, Fuelling and Halle 2004) clearly influence vole numbers and behaviour. However, natural predators will not drive their prey to extinction, but they can effectively support other vole control methods (Saucy 2004). Predator density and activity can be increased by habitat management, additional perches, nest boxes, or other structures (Witmer et al. 2008).

No matter what method is used to reduce vole densities, they all bear the same problem. Removing voles creates a source-sink system and voles will soon move in from adjacent areas. In arable fields, voles might invade from fallow lands or other suitable refugia. In comparatively small orchards, lying side by side, farmers can hardly control vole populations if their neighbours do not devote the same attention to the issue. Stopping or minimising these movements from adjacent areas into the agricultural land seems to be a logical consequence. Husistein (1986) reported the use of a mesh wire fence to protect an orchard in Switzerland. Drift fences and traps have been used to study vole dispersal (Hansson 1987). The idea of fences was put forward when Saucy (2002) found that dispersal of water voles occurred above ground, usually during dark and rainy nights. During the last decade, vole fences have been studied intensively in European orchards. Walther and Pelz (2006) compared fenced and unfenced orchards in several enclosure and field studies and found a strongly reduced risk of tree damage in fenced orchards. Similar observations were made by Malevez and Schwitzer (2005) in a fruit farm in Switzerland.

Trapping or the application of rodenticides are reactions to high vole densities, whereas the support of natural predators and the use of fences are preventative measures to keep vole numbers in agricultural areas at low levels. It was the aim of this study to analyse the combination of predation pressure with dispersal barriers, by testing a new kind of vole trap and by concentrating predator activities along a vole fence.

MATERIALS AND METHODS

Locations

It was our goal to conduct this study in a realistic agricultural environment but still with a repeated experimental design. Therefore, three different agricultural grassland locations in Switzerland were chosen. The first location (47° 14' 58" N; 7° 00' 46" E) was near Saignelégier in the Jura Mountains of Western Switzerland, 952 m above sea level. The grassland was used for silage production and as pasture land in autumn. The second location (47° 17' 03" N; 7° 44' 04" E) was near Oensingen at the foot of the Jura Mountains, 454 m above sea level. At this site, grassland was used for silage production and surrounded by arable land of different uses. The third location (47° 07' 37" N; 8° 17' 45" E) was near Eschenbach in Central Switzerland, 526 m above sea level. This grassland was used for silage production and as pasture land.

Fences

At each location three different types of fences or observation lines, each 150 m long, were built. In cooperation with the local farmers, we found three suitable places and decided randomly if it became a trap fence, a simple fence, or a control line. Individual vole home ranges should not include more than one fence type, therefore the minimum distance between each line was 70 m. Maximum distance between the lines was about 500 m to allow individual predators a choice between the lines. The first line or fence type was made of 12-mm 'Casanet' mesh wire (Bekaert AG, Baden, Switzerland). It was 40 cm high and reached 20 cm into the ground. Along the fence we placed 20 special-made live traps (description see below), 10 on each side of the fence, at a distance of 15 m between. This was the 'trap fence' type. The second fence type was built in the same way but without traps; this was called 'simple fence' or just 'fence'. Both types of mesh-wire fences were designed to constrain the aboveground dispersal of voles. The third line was not a fence or obstacle at all; rather, it was built as a control to observe predator and prey behaviour in open grassland. To make the traps accessible to terrestrial predators, we had to clear a 40 to 50-cm-wide strip along both sides of the fence from vegetation. During the study, we used a herbicide (Roundup® Ultramax, Monsanto Co., St. Louis, MO) to achieve this. As a vegetation-free strip may be attractive to predators or voles, we treated the simple fences and the control lines in the same way.

Traps

The trap fences were equipped with so called standby-traps (Andermatt Biocontrol AG, Switzerland). The traps used were hand-made and still under development. These traps were multi capture live traps with an entrance door on each side. An additional feature made them self-service stations for terrestrial vole predators: the top of the box-like trap could be opened to take a captured vole out. After being opened by a predator, the top closed and the trap was ready to catch voles again. Video observations preliminary to our field study showed that terrestrial predators like foxes, cats, or mustelids were able to open the traps and take voles out. Predators learned fast to use the trap, but they never tried to open an empty trap. During the study, the traps were equipped with magnetic switches to record all openings day and night for the whole study period. The data were stored by custom-made data loggers (EPSA GmbH, Saalfeld, Germany).

Predator Observations

During the field study, two different methods were applied to observe predator behaviour. Most information was collected by digital infra-red video equipment (Panasonic, John Lay Electronics AG, Switzerland), observing each fence in Eschenbach and Oensingen for 10 five-day periods during the two years. In Saignelégier, only 9 five-day periods could be recorded, as the power supply once was destroyed by lightning. Digital recor-

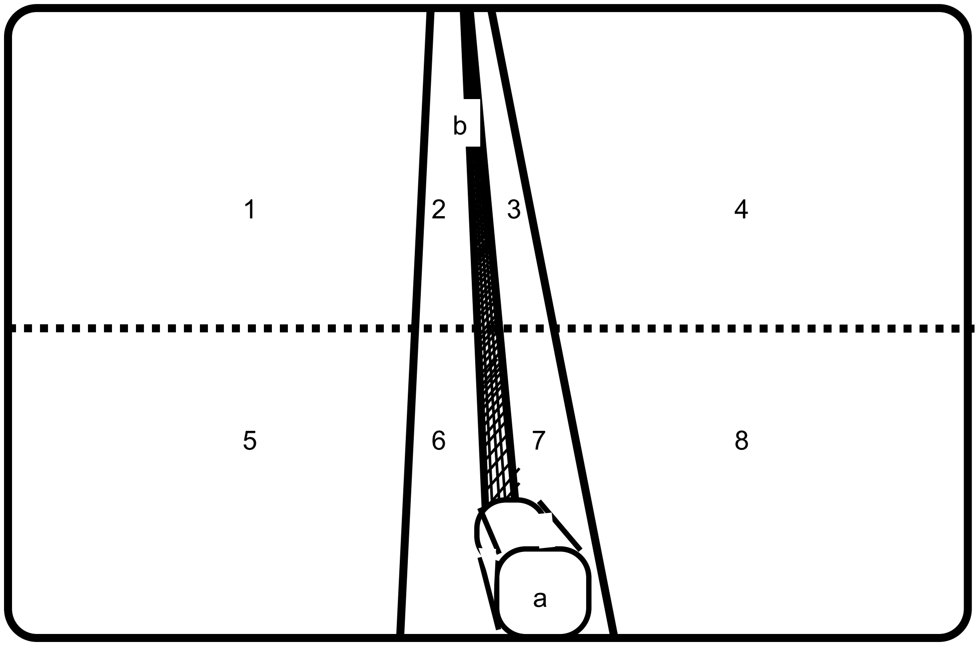

Figure 1. Partition of the field of camera vision for behavioural analysis of predator movements. The camera is marked with a) and the fence in the centre with b). The dotted horizontal line is only a virtual partition of the lower (closer) and upper (more distant) field of vision. The fields 1, 4, 5 and 8 mark the surrounding grassland and 2, 3, 6 and 7 represent the vegetation free strips on both sides of the fence. Only predator movements along these strips from the fields 2 or 3 towards 6 or 7 and vice versa were considered as "patrolling" a fence or control line. All other movements were treated as randomly captured in the field of vision.

ding was activated each night from 6:00 pm to 6:00 am and analysed the following day. Each mammal occurring on the screen was recorded by species, locality, and fence type code, as well as date and time. Furthermore, the pattern of movement was recorded. For this purpose, the screen (field of camera vision) was divided into 8 parts: upper and lower screen, outer left and right, inner left and right parts (Figure 1). The fences appeared in the centre of the screen from top to bottom. Therefore, animals moving across the virtual screen centre line from top to bottom or vice versa were counted as "patrolling" a structure. Animals crossing from left to right (and vice versa) and animals appearing only at the outer left or right screen were counted as "moving randomly".

As a second method, beside the periodical video observation, a permanent automatic registration of trap use was applied. For this purpose, each trap was equipped with a magnetic switch to register when the lid was opened. Each event was recorded with time and date by EPSA data loggers. Due to preliminary video observations, we knew that predators only tried to open a trap when a vole was inside. Therefore, we treated a recorded trap opening as a removal of a vole by a terrestrial predator. Additionally, movements of voles above and below ground were recorded. These data will be analysed and presented elsewhere.

Statistical Analysis

To compare the general pattern of predator occurrence and behaviour along the two types of fences and the control line, we pooled the data from all replicates, i.e., locations. We used only 9 out of 10 5-day observation intervals from all locations, as the tenth period at Saignelégier was not recorded due to technical problems. The data were analysed by the computer software PERMANOVA (McArdle and Anderson 2001, Anderson 2001). It does a permutational multivariate analysis of variance, using permutation procedures to obtain p-values for the tests with interactions included. Permutation p-values (p(perm)) and p-values based on Monte Carlo sampling (p(MC)) are calculated. The latter are slightly more conservative and will therefore be taken into account here. By this means, we compared the number of predator observations using locations, fences, and the kind of movement as factors.

RESULTS

From March 2007 to October 2008, we recorded and analysed 5,220 hours of video. A total of 1,224 observations were recorded, including 951 terrestrial predators, 116 voles, and 157 other mammals like hedgehogs, hares, or roe deer. Among predator observations, foxes (588) and cats (344) were by far the most frequent ones (Table 1). Most predator observations, 409, were made in Saignelégier, followed by 345 observations in Eschenbach, and just 197 in Oensingen.

There was a significant difference between the three locations (Permanova df = 2, 144; F = 6.8201; p = 0.0015; p(mc) = 0.0015) and between the three different structures (Permanova df = 2, 144; F = 6.0325; p = 0.0030; p(mc) = 0.0036). Predator movements occurred more often along fences with traps than along simple fences (pairwise comparison p(mc) = 0.03) or along control lines (pairwise

Table 1. Number of mammal observations during 5,220 hours of video survey.

Species	Location 1 Eschenbach	Location 2 Oensingen	Location 3 Saignelégier	All Locations
Badger (*Meles meles*)	5	0	7	**12**
Domestic cat (*Felis catus*)	197	23	124	**344**
Fox (*Vulpes vulpes*)	203	173	212	**588**
Stoat (*Mustela erminea*)	0	1	2	**3**
Stone marten (*Martes foina*)	4	0	0	**4**
Voles (*Arvicola* and *Microtus*)	37	50	29	**116**
Other mammals	41	81	35	**157**

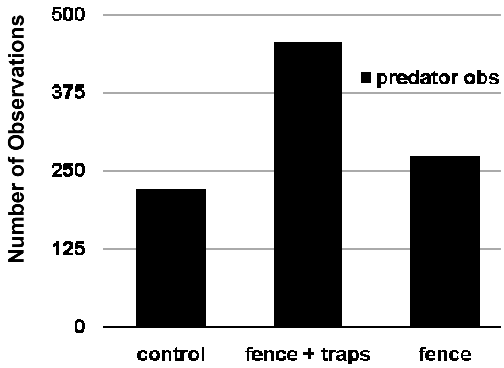

Figure 2. Total number of predator observations in the vicinity of three vole defence structures. The combination of fences and traps attracted significantly more predators.

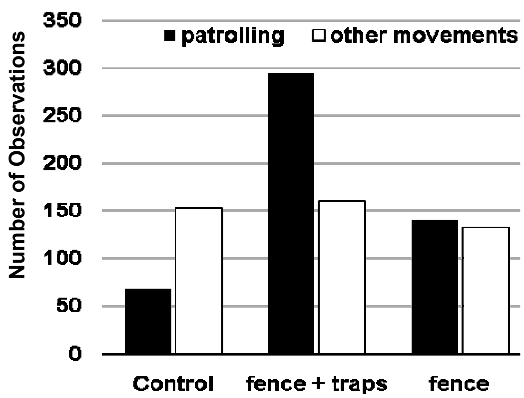

Figure 3. Predator observations along the three vole defence structures. Predators were counted as "patrolling" if they moved close and parallel to a fence or line (black columns). Other movements (white columns) were crossing the structure, approaching and moving from it, or keeping their distance. We interpreted "patrolling" as "interested" and other movements as "not interested".

comparison p(mc) =0.009). The difference is shown in Figure 2. When analysing the kind of movements (Figure 3), we found significantly more predators "patrolling" fences with traps than along the two other types (Permanova df = 2, 144; F = 4.9715; p(mc) = 0.008; pairwise tests: trap fence vs. simple fence p = 0.04; trap fence vs. control p = 0.001). A total of 116 movements of voles along the line structures were recorded; 51 of these movements occurred along fences with traps, 55 along simple fences, and 10 were observed at the control lines. During these 116 vole movements, 13 predators were observed catching the vole. Eight of these captures were made at fences with traps, and five at simple fences. No captures were observed at the control lines.

The automatic recording of opened traps counted 1,042 actions from November 2006 to December 2008. There was no significant difference between night and day activities. While 1,042 openings were automatically recorded, none of these actions was captured on video.

DISCUSSION

During our 2-year study in Switzerland, we observed significantly more terrestrial predators in the vicinity of fences equipped with self-service-traps than near simple fences or control lines. Analyses of the movement patterns showed that these differences were due to patrols along the fences, whereas other random movements did not differ between fences or lines. We conclude that the mammalian predators were especially attracted by the easy prey from the self-service-traps, and by the increased chance of catching a dispersing vole along a fence. At the control lines, their chance to catch a vole was not higher than elsewhere in the surrounding grassland habitat. Consequently, voles perceived a higher predation risk along fences, an assumption which was supported by increased vole activities measured along control lines (vole activity analyses of this study will be published elsewhere).

Almost all terrestrial predator species expected to occur in the study areas could be observed along the fences, but foxes and cats were by far the most frequent ones. As video recordings were only made from 6 pm to 6 am, diurnal predators such as stoats might be under-represented. Analyses of the automatically recorded trap openings, however, revealed no significant difference between day and night, suggesting that there is a round-the-clock predation risk for voles.

A predator opening a trap was never captured on video during the study, even if preliminary video observations showed their ability to do so. Nevertheless, the automatic recording of trap activities revealed 1,042 openings during the study period. This is not necessarily an inconsistency of our data, as automatic recordings were conducted permanently day and night for the whole study period, whereas video observations could be done during 10 (respectively 9) sessions, each session covering 5 consecutive 12-hour nights. Furthermore, on video a maximum of 4 out of 20 traps could be observed, whereas the permanent recording was connected to all traps.

Taking the relatively short time span of video observation into account, it is remarkable that recordings enabled us to capture 13 successful predator attacks on voles. These are 11% of 116 vole observations made in total. The majority of these 13 attacks could be observed along fences with traps, showing that predators did much more than just empty traps.

The study shows that self-service traps in combination with physical dispersal barriers were suitable to attract natural terrestrial predators. High diversity of predators in agricultural landscapes has a negative effect on vole populations (Erlinge 1987), and their abundance influences the amplitudes of vole cycles (Klemola et al. 2000). Therefore, natural predation can be a useful tool supporting farmers in vole control (Myllymäki 1970, Saucy 2004). To achieve maximum support, farmers should try to enhance a wide range of predators, specialists, and generalists, terrestrial and avian (Fuelling 2008).

The trap model used in the present study could only be opened by terrestrial predators, whereas avian predators had no access. Birds, like raptors and owls, however, also prey heavily on voles (Halle 1988). To include aerial predation, a new type of vole fence was designed subsequent to this study (Walther and Fuelling 2010). The fence is made of H-shaped profiles with the horizontal line at ground level, the two "legs" pushed into the ground, and the two "arms" building a double-wall fence aboveground. Each H-profile is 1,150 mm long and made of recycled polypropylene. Profiles can be connected to fences of any length. Through one-way doors, voles can enter the space between the two walls where they are trapped. Initial field tests have shown that terrestrial and avian predators can be attracted, and all were able to remove captured voles from the system. An additional benefit of the new construction is its easy maintenance without the application of herbicides for vegetation-free strips.

We think that vole-trapping fences can be of multiple uses in integrated vole control. The most obvious application of such systems is a full enclosure of high-value crops like orchards. The immigration of voles into the orchard will be stopped. Consequently, the damage to trees will decrease and the farmers' efforts for vole control can be minimised. It is, however, not always practical to enclose a whole orchard. In such cases, vole-trapping-fences might be used to draw protective lines between orchards and identified vole refugia. Setting vole-trapping fences as protective barriers might also be a solution for the protection of arable fields against voles invading from adjacent fallow land.

ACKNOWLEDGEMENTS

We would like to thank the people who promoted this project with their ideas, work, and general support: Jean Malevez started the project with his initial idea and supported it during the construction of the fences. This construction would have been impossible without the help of Rafael Gago and Cornel Stutz from Agroscope Reckenholz Tänikon. Esther Bühler diligently carried out part of the field work and analysed the huge amount of vole activity data. Urs Gantner represented the coordination centre of our financial support, provided by the Swiss Federal Office for Agriculture, the Federal Office of Environment, the plant protection department of Kanton Luzern, Profi-Lait, Topcat GmbH, and the plant protectors of Kanton Schwyz and Bern. And last, but not least, we are grateful to the farmer families Ingold, Kipfer, and Koller, who allowed us to install weird technical constructions on their land and supported our work during the whole study period.

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