Movements of radio-tracked American mink () in extensive wetland in the UK, and the implications for threatened prey species such as the water vole ()

Jenny L. Macpherson, Paul W. Bright

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ORIGINAL PAPER

Movements of radio-tracked American mink (*Neovison vison*) in extensive wetland in the UK, and the implications for threatened prey species such as the water vole (*Arvicola amphibius*)

Jenny L. Macpherson · Paul W. Bright

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Abstract In a number of countries around the world, introduced American mink are acknowledged to have had a negative effect on a number of native species, many of which are of particular conservation concern. In the UK, there has been an observed correlation between the spread of mink and the decline of the, once common and widespread, water vole. Large wetlands, such as extensive reed bed, appear to mitigate the impact of mink predation on water voles and some bird species. The present study was carried out to test the hypothesis that the observed refuge effect of reed beds arises from the way mink forage in this type of wetland. The results suggest that the interior of reed bed offers a spatial refuge for water voles, and other species, from predation by mink, because more than 60% of mink foraging activity occurred within 10 m of a main (>10 m wide) channel. Where mink ventured within the reed bed itself, they associated closely with scrub. The implication is that easily navigable channels and areas of scrub probably compromise the refuge effect of reed beds. This can be used to inform management recommendations at these sites.

Keywords *Neovison vison* · Reed bed · Refuge · Conservation · *Arvicola amphibius* · Habitat use

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J. L. Macpherson (✉) · P. W. Bright
Royal Holloway University of London,
Egham, Surrey TW20 0EX, UK
e-mail: jenny.macpherson@rhul.ac.uk

P. W. Bright
e-mail: p.bright@rhul.ac.uk

Introduction

In a number of countries around the world, introduced American mink are acknowledged to have had a negative effect on a number of native species, some of which are of particular conservation concern (see Macdonald and Harrington (2003) and references therein). In the UK, although numbers and distribution of the water vole began to decline before American mink became established (Jefferies 1989), there has been an observed correlation between the spread of mink and an acceleration in the rate of the water vole decline (Jefferies 2003; Lawton and Woodroffe 1991; Strachan and Jefferies 1993). This has been particularly pronounced where habitat loss has resulted in water voles being constrained to narrow linear strips of suitable habitat along a water course, in what has been termed 'the tightrope hypothesis' (Barreto and Macdonald 1998). However, in some areas, this has apparently been buffered by the effect of certain habitat types—in particular non-linear wetlands such as grazing marsh (MacPherson and Bright 2010) and extensive reed beds (Barreto et al. 1998; Carter and Bright 2003). Carter and Bright (2003) found that predation rate declined sharply with distance from a main water channel, suggesting that this type of habitat provides water voles with a refuge from predation. It has been demonstrated with real and artificial nests that reed beds also act as a refuge from predation for a number of bird species (Baldi and Batary 2005; Kristiansen 1998).

Spatial refugia occur as a result of the predator's patch use behaviour and foraging aptitude (Schmidt 2004) and have huge potential benefit as a practical method for the conservation of endangered prey as they can be enhanced by management. However, in order to mitigate predation by manipulating the physical environment, it is essential that managers first have an understanding of the way in which predators use that environment (Lariviere and Messier 2000). So, where there is an apparent refuge effect, it is important to understand the mechanism underlying this in order that its benefits can be maximised. Reed bed, wetland dominated by common reed (*Phragmites australis*), is an important habitat for species such as bittern (*Botaurus stellaris*), marsh harrier (*Circus aeruginosus*), Cetti's warbler (*Cettia cetti*) and bearded tit (*Panurus biarmicus*). In addition, it offers a spatial refuge from predation for the water vole (Carter and Bright 2003), a species of high conservation concern in the UK. In order to maximise the conservation benefits of reed bed, it was important to understand the underlying mechanism, which was likely to relate to the way in which mink utilise this type of wetland.

There have been a number of studies of mink habitat use within their native range (Arnold and Fritzell 1990; Stevens et al. 1997) as well as along linear waterways and in coastal areas in countries where they have been accidentally or deliberately introduced (Bonesi et al. 2000; Lode 1991; Niemimaa 1995; Previtali et al. 1998; Yamaguchi et al. 2003; Zabala et al. 2007b). However, there have been no published studies of mink habitat use in extensive wetlands in the UK.

The aim of the present study was to test the hypothesis that the observed refuge effect of reed beds for water voles from predation by mink (Carter and Bright 2003) arises from the way mink forage in this type of landscape.

Methods

Mink were radio-tracked at Shapwick Heath and Ham Wall (ST443, 401) in south west England. These two adjacent nature reserves are owned by Natural England and the Royal Society for the Protection of Birds, respectively. Together, the reserves form a contiguous wetland of approximately 500 ha comprising a mosaic of reed fen, marsh, wet heath and grassland.

From the end of March to the end of April, 2002, mink were trapped in single-entry commercial cage traps (Tomahawk Live Trap Co., WI, USA). Each animal was fitted with a waterproof radio transmitter attached to a collar (Biotrack Ltd, Wareham, Dorset, UK). Trapping was carried out in the main areas of reed bed at both sites under licence from DEFRA. Captured animals were weighed, sexed and approximately aged as either adult or juvenile. Males were aged by palpation of the baculum (Elder 1951) and females by the presence or absence of healed or recent mating bite wounds on the back of the neck (Ireland 1990; Yamaguchi et al. 2004).

After each animal was collared, it was then located every 2 h around the clock with a Telonics TR-2 VHF receiver (Telonics Inc., Mesa, AZ, USA) and three-element Yagi flexible antenna (Biotrack Ltd.). A minimum of 2-h spacing between fixes was to ensure independence of radiolocations. Each animal was followed intensively for a minimum of 5 days (Yamaguchi et al. 2004) or until at least 30 active fixes were recorded (Conner et al. 2003). Animals were located by homing in (White and Garrott 1990) and then taking bearings at close range from at least two locations. The position of fixes was determined to the nearest 10 m using a Garmin e-trex handheld GPS (Garmin Ltd., Romsey, Hampshire, UK). Mink were defined as active or inactive according to changes in the strength of the radio signal (Kenward 2001; White and Garrott 1990). When an animal was stationary for more than one fix at a location, it was defined as a lie-up or, if the animal returned to that location more than once, a den.

Radio-tracking data were plotted on to high resolution recent aerial photographs of the site and entered into a Geographic Information System (MapInfo v8) so that the distances to significant features could be measured.

Generalised linear models (McCullagh and Nelder 1983) were used to examine potential correlates of mink activity. The most parsimonious model was selected by first including all explanatory variables and then testing the significance of each (χ^2 statistic) by successive deletion. Explanatory variables considered were: distance from nearest tree or scrub, distance from track and distance from a main channel. A main channel was defined as being more than, or equal to, 10 m wide, as per Carter and Bright (2003).

A Poisson error structure with a logarithm link function was used in the model.

Table 1 American mink tracking periods and the number of independent locations

Animal	Sex	Weight at capture (g)	Radio-tracking period	Active fixes	Dens	Lie-ups
529	F	790	25/3/02–5/4/02	31	1	2
317	M	1,400	26/3/02–9/4/02	30	1	4
514	M	1,760	28/2/02–25/3/02	33	2	3
487	M	1,550	25/2/02–21/3/02	33	1	2
433	M	1,220	16/3/02–21/3/02	30	2	1
529[a]	M	1,450	2/3/02–3/3/02	6	–	–

[a] Animal 529 was not included in the analyses because of insufficient data

Table 2 Results of the generalised linear model using count of active fixes in each class as the response variable (Poisson errors, log link)

Explanatory variable	Parameter estimate	SE	Deviance	χ^2 probability
Constant	2.944	0.150		<0.001
10–20 m from channel	−1.609	0.367		<0.001
20–30 m from channel	−1.721	0.385		<0.001
30–40 m from channel	−2.156	0.465		<0.001
40–50 m from channel	−3.86	1.04		<0.001
>50 m from channel	−2.156	0.465		<0.001
<10 m from scrub	0.110	0.206		0.598
10–20 m from scrub	−1.258	0.319		<0.001
20–30 m from scrub	−2.944	0.670		<0.001
30–40 m from scrub	−3.86	1.04		<0.001
40–50 m from scrub	−3.86	1.04		<0.001
>50 m from scrub	−1.989	0.430	420.654	<0.001
	Total deviance explained			80.4%

Estimates and standard errors for the significant variables are shown. Parameters for factors are differences compared with the reference level: <10 m from channel. Regression χ^2 probability <0.001, deviance 420.7, residual deviance=102.4, total deviance=523.0

Results

Five males and one female were captured and radio collared. One animal, a mature adult male, disappeared after 2 days either as a result of the transmitter failing or because the animal dispersed out of receiver range, so this animal was excluded from the analysis. The remaining five animals were each tracked for a mean of 16.8 (±3.8) days and nights (Table 1).

A generalised linear model was used to test for significance the relationship between the number of active fixes and distance from track, main channels and scrub (Table 2). The number of fixes was negatively correlated with distances above 10 m from both main channels and scrub, suggesting that for mink in this type of habitat at this time of year (March–April), easily navigable channels and scrub are highly significant features. This is shown graphically in Fig. 1.

The mean distance of den sites from a main channel was 15±5.49 m, while the mean distance of lie-up sites to a main channel was much closer at 1.75±0.19 m. These were all in willow (*Salix* spp.), dense stands of rush (*Juncus* spp.) and bramble (*Rubus fruticosa*) scrub.

Discussion

The results of the present study support the hypothesis that the interior of reed bed offers a spatial refuge for water voles from predation by mink, because more than 60% of mink foraging activity occurred within 10 m of a main channel.

It is widely reported that there is a strong association between intensity of habitat use by mink and other mustelids and local prey availability (Arnold and Fritzell 1990; Erlinge 1977; Gerell 1970). Carter and Bright (2003) suggested that the refuge effect of reed bed for water voles with respect to mink predation could be a result of differences in the abundance of alternative prey along main channels or edges and within the reed bed itself. An alternative hypothesis is that predation rates are lower on water voles in reed because of the high availability of alternative prey and consequent refuge effect of relative low water vole density resulting in prey switching by mink. This is not supported by our data; if it were the case, then mink would still be active within the reed bed, hunting for alternative prey.

American and European mink are strongly associated with scrub (Yamaguchi et al. 2003; Zabala et al. 2003,

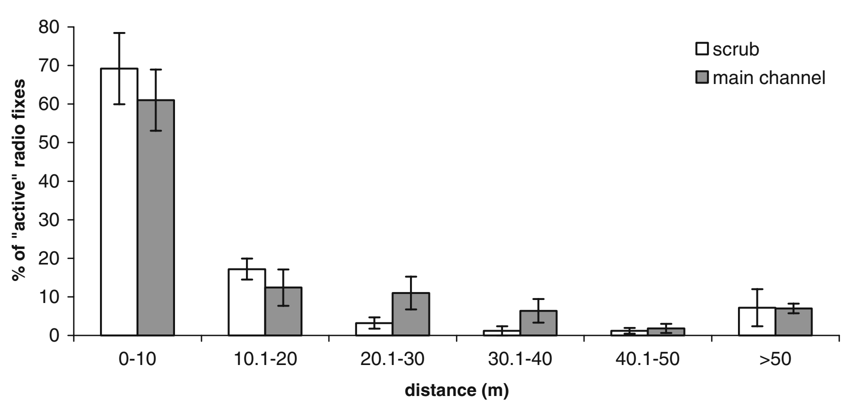

Fig. 1 Percentage of 'active' American mink radio fixes (mean ±SE) at different distances from a main (≥10 m wide) channel and scrub

2007b). This was supported by the present study. Where mink ventured within the reed bed itself, they associated closely with scrub. The implication is that easily navigable channels and areas of scrub probably compromise the refuge effect of reed beds. This can be used to inform management recommendations at these sites, although there will inevitably have to be a trade-off at many sites between what is optimal for water voles and the habitat requirements of other species, particularly birds.

Mink were radio-tracked during the rut in March because this is when trapping success, particularly of males, is likely to be highest (Ireland 1990); however, range use is not necessarily typical at this time of year as a result of mating behaviour (Yamaguchi et al. 2004). In a Scottish study of coastal mink, Ireland (1990) showed that there was seasonal variation in the length of linear home ranges, especially among males, and that they were highest in March at the peak of the rut. Therefore, it is probable that the males radio-tracked in the present study were extending their ranges in search of females with which to mate, but the type of habitat and features used for hunting and along which to travel are likely to be similar all year. The male bias of the sample must be considered when interpreting the results of the present study. It has been shown that female American mink radio-tracked on a river system utilised narrower streams than males (Zabala et al. 2007a); however, the females' home ranges still included sections of the main (>10 m wide) river. Sidorovich et al. (2001) also found that, in warm seasons, mink sometimes occupy marshy areas away from stream banks. Further study is required to determine if the apparent preference for wider channels in reed bed, observed in March, is affected by sex or season.

Because of their long, tubular body shape and high surface area-to-volume ratio, mink, like other mustelids, are vulnerable to extreme temperatures (Brown and Lasiewski 1972; Dunstone 1993). They have relatively large home range size and are not central place foragers. As a result of this, they require physical protection from the elements during periods of inactivity. It has been suggested that the availability of suitable den sites is a limiting factor in their abundance and distribution (Halliwell and Macdonald 1996). Availability of suitable den sites is of major importance to female mink when breeding, as protection for kits from predators and for shelter prior to their achievement of thermoregulatory competence. Mink are reported as using between two and ten den sites (Birks and Linn 1982) with most dens being located within 2 m of water (Schladweiler and Storm 1969). Rabbit burrows are particularly important as den sites (Yamaguchi et al. 2003), but mink will also use tree roots, rock piles, brush piles, culverts or bridge foundations (Birks and Linn 1982; Dunstone 1993). Dense stands of emergent vegetation may be used by mink as temporary lie-up sites (Arnold and Fritzell 1990; Birks and Linn 1982; Sargeant et al. 1973). In extensive wetland with a high water table, such as the sites used for the present study, rabbit warrens are scarce and in this case mink dens were all in cavities under waterside trees, scrub and other structural vegetation. Reed beds offer few suitable den sites.

Autocorrelation is a potential problem with radio-tracking data, resulting in an artificial inflation of sample size. However, locations obtained at t_1 and t_2 can be considered independent provided that sufficient time has elapsed between the two fixes for the animal to have moved from one end of its home range to the other (Salvatori et al. 1999; White and Garrott 1990). Mink are recorded as achieving mean speeds on land equating to 1.73 km/h walking and 9.4 km/h when 'bounding' (Dunstone 1993). The maximum distance between two points of any one of the radio-tracked mink in the present study was 2.755 km (mean 1.621). Therefore, the 2-h spacing of fixes that was used should be sufficient to ensure independence of locations.

The sample size used in the present study is equivalent to that of other published studies of habitat use by mink (Arnold and Fritzell 1990; Niemimaa 1995; Stevens et al. 1997; Zabala et al. 2003). However, this is still relatively low. Nevertheless, the present study provides some valuable insights into the way in which mink forage in reed bed habitat and the mechanism by which this type of habitat provides a refuge for water voles and other prey species from mink predation.

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