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A multi-scale analysis of the habitat associations of European otter and American mink and the implications for farm scale conservation schemes

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Abstract Establishing relationships of species occurrence with environmental variables is important to define and develop species conservation schemes. The character of the riparian environment which supports populations of otter (*Lutra lutra*) and mink (*Neovison vison*) was investigated across spatial scales. Both species were positively associated with increased habitat diversity, the provision of natural land cover and a reduced level of urbanisation. However, mink were most closely associated with immediate riparian conditions whereas otters were associated more strongly with broad scale environmental characteristics. We argue that the benefits of habitat improvements may be seen more quickly in the occurrence of mink, a non-native pest species, than in the occurrence of the native otter. This has implications for the perceived benefits of conservation schemes which are applied at a fine scale, with particular relevance to farm-based conservation prescriptions such as agri-environment schemes. We show that mink presence is associated with higher levels of riparian bird diversity, a pattern which was not observed with occurrence of otter. It may be inevitable that conservation schemes benefit populations of both desirable and undesirable species. The present study demonstrates the importance of considering scale in animal ecology when developing conservation strategies. The use of specialist species with large home ranges to reflect the success of conservation schemes which are applied on a farm scale should be avoided. Effective conservation schemes may require specific pest species monitoring and management.

Keywords Agri-environment schemes · *Lutra lutra* · Mustelid ecology · *Neovison vison* · Spatial scale ecology

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Introduction

In Europe, the otter (*Lutra lutra*) is a species of conservation concern, due to population declines linked to habitat destruction and farming practices (Chanin and Jefferies 1978; Mason 1995; Macdonald 1996). The otter is listed In Annex II and IV of the European Habitats Directive (Council Directive 92/43/EEC). Analysis of public 'willingness-to-pay' for conservation show that otter command significantly higher values than a range of other species including the red squirrel (*Sciurus vulgaris*), brown hare (*Lepus europaeus*) and water vole (*Arvicola terrestris*; White et al. 2001). In contrast, the non-native mink is regarded as a pest species due to negative impacts on native species (Halliwell and Macdonald 1995; Ferreras and Macdonald 1999; Nordström et al. 2002**).** In Ireland, signs of otter presence are found at more than 70% of aquatic sites, although population fluctuations have been shown (Bailey and Rochford 2006). Given its charismatic public appeal, it is potentially an ideal figurehead for conservation schemes across Europe.

Human activities have transformed up to half of the Earth's land surface (Vitousek et al. 1997), and habitat destruction due to human activity, is the most pervasive anthropogenic cause of biodiversity loss (Myers 1988; Perfecto et al. 1997; Myers et al. 2000; Loreau et al. 2001; Williams et al. 2002). Habitat conversion to agriculture is implicated in the loss of biodiversity in many taxonomic groups (Downie et al. 1999; Donald et al. 2001; Wickramasinghe et al. 2003). In Western Europe, many wild species are threatened with extinction as agricultural production intensifies (Delbaere 1998). However, wild species can persist where low intensity traditional farming continues and natural or semi natural habitats comprising refugia survive (Marsh and Luey 1982; Bignal and McCracken 1996). Conservation of wild species in agricultural systems is commonly attempted through Agri-Environment Schemes (AESs). AESs promote agricultural extensification and reinstating refugia, by offering incentives to farmers to implement conservation and management prescriptions.

AESs cost the EU more than €1.6 billion annually (Donald and Evans 2006). However, the success of AESs is debatable (Kleijn and Sutherland 2003; Knop et al. 2006; Donald and Evans 2006; Kleijn et al. 2006; Reid et al. 2007). Assessing efficacy of AESs has been constrained by a lack of tailored monitoring schemes (Kleijn et al. 2006). At present, AES frequently rely on implementation by individual farmers. Whittingham (2007) suggests that the benefits for biodiversity are limited using approaches which result in the protection of small fragmented areas. Reid et al. (2007) found that AESs may benefit populations of common species but not necessarily rare species. Whilst charismatic species are often used to galvanize public support for such conservation projects, if benefits are not seen in these species, such schemes may lose support.

The present study uses multi-scale analyses to assess how otter and mink, species of diametrically opposed conservation priority, are associated with aspects of the riparian zone and the wider landscape. Additionally, their occurrence is compared to riparian bird community diversity. Riparian areas within permanent grassland agricultural landscapes are examined. These habitats represent significant refugia for both specialists and obligate riparian species. We expect that otter presence will be associated strongly with larger scale environmental character than the mink, given their larger home ranges (Roche et al. 2006). Given the smaller home range and broader ecological niche of minks (Dunstone and Birks 1985; Ward et al. 1986; Bueno 1996), its presence will be promoted by increased fine scale habitat diversity which in turn is expected to be related to diverse bird communities. The observed habitat associations of otter and mink can also be used in addressing the habitat requirements for their favourable conservation status (Hinsley and Bellamy 2000).

Methods

Faunal surveys

Fifty hydrologically independent rivers, of second and third hydrological order, were surveyed for presence of mink and otter. River sites were randomly selected across all seven major basins of Northern Ireland, below 150 m in altitude and situated in permanent grassland agricultural landscapes. At each site, a 600 m length of river course was surveyed for signs of mink and otter presence (Lenton et al. 1980). Due to their cryptic behaviour and low densities, obtaining occurrence and abundance estimates for many mammal species can be difficult using direct observations (McAlpine et al. 2006). Therefore, tracks and signs for otter and mink were the preferred survey method. A site was attributed as 'positive' for presence using records of spraints/scats, prints or direct observation. All surveys were conducted when rivers were at base level flow for at least a 3 day period. Surveys were carried out from August to October during 2004 and repeated in 2005. Caution is required when using tracks and signs in areas where similar species co-occur (Harrington et al. 2009). Track monitoring devices, such as mink rafts (Reynolds et al. 2004), were not used in this study as the geographical nature of the study area with its frequent high rainfall events concentrated in small catchments, results in rivers with highly variable flow levels which do not facilitate the use of rafts (Reynolds et al. 2004).

Point counts of all breeding bird species present in the riparian area were made at each site between April and July 2005. Two surveys were made at each site, an early and late season visit. Species occurrence from six 5 min point counts, 200 m apart, were summed. Surveys were carried out between 30 min pre-sunrise and 2 h post-sunrise. All non-corvid passerines species observed were recorded and visual identification was augmented by identification of species by song (Bibby et al. 1998). The bird communities at each site were characterised using the Shannon diversity index.

Environmental variables

The average farm size in Ireland is 32 ha (Eurostat; http://ec.europa.eu/eurostat). Variables were calculated over four spatial scales, with the survey site central to each corridor of increasing scale: (1) within-farm scale; 600 m river corridor with a width of 100 m, (2) farm scale; 1.8 km river corridor with a width of 200 m, (3) multi-farm scale; 10 km river corridor with a width of 2 km and (4) regional scale; calculated for the entire area of land hydrologically above the survey point, delineated using ArcSWAT (Di Luzio et al. 2004).

Three classes of explanatory variables were collected: (1) river character variables, (2) land cover variables and (3) landscape metrics. A full list and description of all variables is presented in Table 1. Regional level and multi-farm corridor habitat maps were obtained from existing land cover maps (LCM2000; Fuller et al. 2002). Habitats at within-farm and farm scales were mapped in the field, using phase one habitat survey techniques (JNCC 1993). Landscape metrics, Shannon's diversity and Shannon's evenness, were calculated at each spatial scale using Patch Analyst 3 for ArcGIS 3.3 (ESRI). Riparian boundary diversity was calculated using an Interspersion and Juxtaposition index using within-farm habitat maps (McGarigal and Marks 1995). River character was represented by river width and water quality. Water quality scores were obtained for each site (NIEA; www.ni-enviroment.gov.uk). Water quality was measured in terms of biological and chemical quality on a six point scale and represented an average value across the preceding 3 year period; both chemical and biological metrics were combined and an average valued calculated.

Table 1 A summary of explanatory variables used in the analysis of the occurrence of otter and mink

Variable type	Explanatory variable	Description
Land cover variables	Permanent grassland^{S}	Area of all classes of permanent grassland taken from the land cover 2000 database (Fuller et al. 2002) for regional and multi-farm corridors and field habitat maps following phase 1 land cover categories (JNCC 1993). Arcsine square-root transformed
	Scrub^{S}	Area of all classes of scrub taken from the land cover 2000 database (Fuller et al. 2002) for regional and multi-farm corridors and field habitat maps following phase 1 land cover categories (JNCC 1993). Arcsine square-root transformed
	Urban^{S}	Area of all classes of building and urban areas taken from the land cover 2000 database (Fuller et al. 2002) for regional and multi-farm corridors and field habitat maps following phase 1 land cover categories (JNCC 1993). Arcsine square-root transformed
Landscape metrics	Shannon diversity index^{S}	Shannon's diversity index—a composite measure of richness and evenness of land cover classes (McGarigal and Marks 1995)
	Shannon evenness index^{S}	Evenness—a measure of the relative abundance of different land cover classes (McGarigal and Marks 1995)
	Riparian diversity	An Interspersion and Juxtaposition index for the river land cover class as a measure of the diversity of riparian land cover (McGarigal and Marks 1995)
River character	Historical biological water quality	Biological and chemical water quality measures for each site were obtained (NIEA, 2008). Higher values correspond to better water quality (0–12).
	River width	Average river width (m)

Variables recorded over a range of scales are marked (^{S})

Models of species occurrence

Pair-wise Spearman's rank correlation showed that no explanatory variables were correlated strongly ($r_s < 0.5$) and all were retained (Booth et al. 1994). To allow comparison between regression coefficients, explanatory variables were standardised to a mean of 0 and a standard deviation of 1 (McAlpine et al. 2006). All variables were transformed for normality, where required (Table 1). Statistical analyses were performed using the R statistical package (http://www.r-project.org).

Univariate logistic regression models were constructed for variables with a scale component (Table 1), with species presence as the binary independent (McCullagh and Nelder 1989). Presence of field signs, during either survey, defined presence. The most relevant scale for each variable was assessed using Akaike's Information Criterion corrected for sample size (AICc) and Akaike weights (AICω; Burnham and Anderson 2002). Variables shown to have a consistent effect across spatial scales were retained, i.e. the AICω pattern reflects the same pattern as the variable mean across analysis scales (McAlpine et al. 2006; Fig. 1). This was based on the assumption the greatest effect of a variable is observed when the extreme value of the variable occurs. If the variable has a consistent effect on the dependent, the AICωs of models should mirror the pattern of the variable mean across spatial scales.

All possible generalized linear models combinations were built for occurrence of each species using selected spatial scale variables and all variables without a scale component. Model-averaged regression coefficients were calculated, together with unconditional standard errors for each variable across all models (Gibson et al. 2004). The models were

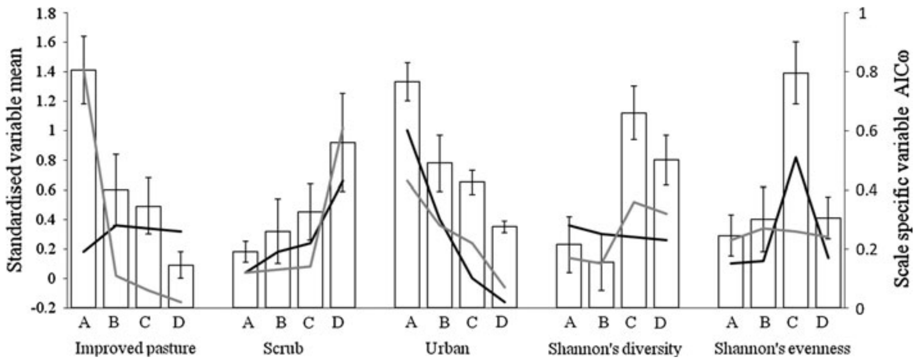


Fig. 1 Standardised variable means (*open bars*) and standard errors (*error bars*) of five environmental characters across four spatial scales *A* regional; *B* multi-farm; *C* farm; *D* within-farm. The relative Akaike weights (AICω) for univariate model of presences of otter (*black line*) and mink (*grey line*)

ranked by AICc and variable specific AICωs were calculated (McAlpine et al. 2006). Hierarchical partitioning was employed to identify the relative importance of each variable in models (MacNally 2002). Hierarchical partitioning allows variables to be ranked in order of their independent explanatory power and assesses multicollinearity amongst predictor variables. The independent effect of variables and their significance were tested using *Z*-scores (Walsh and MacNally 2003). Comparison of variable specific AICω, hierarchical partitioning ranking and regression coefficients provide confidence that the results are valid (Stephens et al. 2005).

Results

Surveyed rivers had an average depth of 30 ± 5.3 cm with average width 7.4 ± 0.8 m. Otter were recorded as present at 36 and 37 sites in 2004 and 2005, respectively. Mink, correspondingly, were present at 18 and 20 sites. An ANOVA was applied to investigate differences between bird community diversity at sites with: (1) neither species present, (2) only otter present, (3) only mink present and (4) both species present ($F = 7.86$; df = 3,46; $P < 0.001$). Greatest bird community diversity was recorded at sites where only mink occurred. A Tukey HSD post hoc test revealed significantly greater bird diversity in all conditions that mink were present in comparison with sites where only otter or neither species was recorded (Table 2).

From models of species occurrence no single spatial scale was identified as consistently most important for either species (Fig. 1). Within-farm scrub cover, regional scale urban land cover and farm scale Shannon's evenness index, were selected as explanatory variables for the presence of otter (Table 3). Mean values of improved grassland and Shannon's diversity index were not deemed relevant for the occurrence of the otter based on examination of the pattern between AICω and the variable means (Fig. 1). Regional scale permanent grassland and urban land cover, Shannon's diversity index for farm scale river corridors and within-farm scale scrub were selected as explanatory variables for presence of mink. Shannon's evenness index was not deemed relevant for occurrence of the mink, based on the pattern of AICω and variable means (Fig. 1).

Table 2 Results of Tukeys HSD post hoc test of difference in Shannon diversity of the riparian bird community between sites of different otter and mink occurrence

	Neither	Otter only	Mink only	Both
Average Shannon diversity	2.13 ± 0.14	2.26 ± 0.06	3.04 ± 0.19	2.71 ± 0.17
Otter only	$P = 0.895$	–	–	–
Mink only	$P < 0.001$	$P < 0.001$	–	–
Both	$P < 0.05$	$P = 0.080$	$P < 0.05$	–

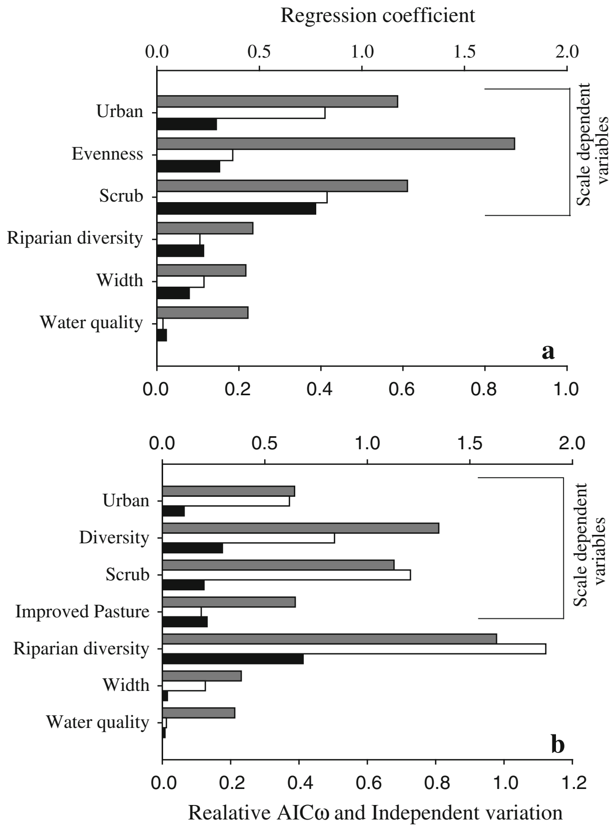
Table 3 Environmental variables selected for predicting the occurrence of otter and mink on differing spatial scales, 'na' denotes variables which are independent of scale

Variable	Selected scale (AICω of selected scale)	Multivariate model AICω	Regression coefficient ± s.e.	Independent contribution (%)	*Z*-score
Otter					
Urban	Regional (0.602)	0.587	−0.82 ± 0.23	14.5	7.92***
Riparian diversity	na	0.234	0.21 ± 0.01	11.4	7.41***
Scrub	Within-farm (0.432)	0.611	0.83 ± 0.06	38.7	11.43***
Shannon's evenness	Farm (0.512)	0.872	0.37 ± 0.03	15.3	6.78***
Water quality	na	0.222	0.03 ± 0.03	2.3	1.72*
Width	na	0.217	0.23 ± 0.11	7.9	2.34**
Mink					
Urban	Regional (0.429)	0.387	−0.62 ± 0.11	6.4	2.34**
Improved Pasture	Regional (0.812)	0.389	−0.19 ± 0.04	13.1	3.98***
Riparian diversity	na	0.978	1.87 ± 0.31	41.2	9.01***
Scrub	Within-farm (0.611)	0.678	1.21 ± 0.34	12.2	3.87***
Shannon's diversity	Farm (0.362)	0.809	0.84 ± 0.03	17.6	6.54***
Water quality	na	0.212	0.02 ± 0.01	0.8	2.12*
Width	na	0.231	0.21 ± 0.02	1.5	1.76*

Model averaged parameter estimates with unconditional standard errors derived from all model permutations for otter and mink are presented. The independent effect of explanatory variables was determined by hierarchical partitioning (MacNally 2002); *Z*-scores of independent effect are calculated as [observed mean (1000 randomizations)]/SD (1000 randomizations). Asterisks denote significance levels; 0.05 (*), 0.01 (**) and 0.001 (***)

Examination of multivariate model combinations ($n = 63$) for otter revealed a high level of uncertainty, with the top model having an AICω of 0.201, the 95% confidence model set contained 20 models. Multivariate model combinations ($n = 127$) for mink revealed more certainty, with the top model having an AICω of 0.345, the 95% confidence model set contained 23 models. Hierarchical partitioning revealed a low level of variable multicollinearity for both otter and mink occurrence, with joint effects explaining 8.3 and 2.9% of variation for the two species, respectively. Both species were significantly associated with variables without a scale component. Both were associated positively with area of scrub habitat, water quality, riparian diversity and stream width, and negatively with urban land cover. Mink, additionally, were negatively associated with agricultural pasture.

Fig. 2 Relative importance of environmental variables used in the analysis of **a** otter and **b** mink presence. *Grey bars* Akaike weights (AICω); *white bars* regression coefficients; *black bars* independent variation (%), determined through hierarchal partitioning



There was a consistent positive relationship with Shannon's evenness index for otter and Shannon's diversity index for mink.

All variables in both species models significantly explained independent variation using the hierarchical partitioning with *Z*-scores using a 0.95 confidence limit ($Z = 1.65$; Table 3). The standard errors of regression coefficients indicate that the effects of all variables were consistent (Gibson et al. 2004). There were differences in the ranking of variables by regression coefficients, AICω and independent variation differed between models for otter and mink occurrence. However, general trends were consistent, with congruence of all ranks within one rank of that defined by another method. (Fig. 2; Table 3).

Discussion

This is the first study to evaluate the relative importance of spatial scale for the occurrence of otter and mink from within-farm to regional scale. Both species had similar habitat associations but the relative importance of environmental variables was markedly different. Presence of both were significantly associated with immediate local and landscape variables. Occurrence of otter had a weaker association with within-farm scale habitat variables than mink. Conservation efforts should strive to minimise further loss of semi-natural habitats at landscape level, whilst reducing the impacts of urban development, intensive agricultural practices and improving fine scale diversity of riparian areas in the immediate vicinity of watercourses.

The perceived relative lesser importance of within-farm scale variables to the otter, may reflect its larger ranging ability compared to mink (Dunstone and Birks 1985; Roche et al. 2006). Continued conservation of otter relies on extensification of agriculture and recognition of the potential impact of increasing urban development adjacent to and within river corridors. In the present study, otter signs were associated with landscapes of higher Shannon's evenness index value, suggesting the importance of similar sized blocks of different land cover types. This may reflect a threshold in abundance of semi-natural habitat below which habitat patches are too small to be utilised.

Assuring 'stationarity' i.e. the unrestricted distribution of an animal or land cover class, is important when assessing species-habitat associations (Fortin and Dale 2006). Where stationarity does not exist, perceived absence from an optimal area of habitat may be a pseudo-absence created by the isolation of a patch of ideal habitat within a largely unfavourable area. Furthermore, habitat use and activity records using sign surveys may not ensure a complete record of spatial patterns of habitat use (Mason and Macdonald 1986). This study assumes that the detectability of mink and otter was constant at different rivers and that the probability of detection of signs reflects relative activity levels. When levels of detection are variable, due to the dynamic nature of ecosystems, it is important to account for these to prevent bias (Mackenzie 2005). Based on repeat site surveys, with an increase in a single positive site for both species, suggests a high level of confidence in the detection of positive rivers.

Sales-Luís et al. (2007) observed that otters feeding predominantly in a large reservoir also relied heavily on surrounding habitat refugia along tributaries. Therefore, in the present study within-farm scale variables may not be observed, as otter signs at a single point may reflect presence resulting from utilisation of other exploitable areas. Additionally it may be difficult to control for the confounding influence of the solely aquatic habitat on the riparian area. However, the relatively small size of the streams studied means they are highly likely to be significantly influenced by the adjacent riparian. Semi-aquatic species in these small streams are likely to interact more than with the riparian areas of larger rivers.

Mink range over a smaller distance (1–2.5 km; Dunstone and Birks 1985) than otter (40 km; Roche et al. 2006) and as such, their presence or absence reflects immediate habitat characteristics more closely. Mink were associated with river corridors with a higher Shannon's diversity value. Mink are known to select areas of higher small scale habitat diversity in their native range (Burgess and Bider 1980). Rivers frequently constitute farm boundaries and it is likely that an otter's territory may span several farms. In contrast, there may be more than one mink territory within a single farm. Non-spatially explicit models, therefore, may result in inappropriate expectations of how species, such as the otter, respond to conservation schemes based on small spatial scales. Significantly greater riparian bird diversity was recorded at all sites where mink occurred. This may reflect the use of terrestrial prey by mink, as this source can potentially represent a large proportion of their diet (Ward et al. 1986; Bueno 1996). This relationship suggests that the presence of mink could be an indicator of the riparian bird community. Whilst not directly addressed at present, further work may examine whether there is a relationship between mink community and aspects of changing riparian bird community, for example the occurrence of potential prey species such as ground nesting birds.

It was beyond the scope of the current study to quantitatively examine prey availability for both species. In particular, the availability of aquatic prey has been shown to influence significantly the prey choices of mink and otter and their ability to co-exist (Bueno 1996). However, riparian habitat diversity measures and historic water quality may be considered surrogates for prey availability. In agricultural grassland landscapes, impact on water quality include, nutrient enrichment, sedimentation and pathogen contamination (Hubbard et al. 2004). Whilst pathogens may have direct impact on aquatic mammals, indirect effects through prey populations, such as the impact on fish populations due to sedimentation and eutrophication, are likely to have widespread effects.

Many AESs are not targeted at maintaining populations of specific rare species. However, inconclusive results, especially with regard to impact on charismatic species, may undermine uptake and/or public support (Kleijn et al. 2001, 2006; Reid et al. 2007). As current schemes rely on individual farm level implementation, therefore, it may be difficult to apply these measures to large areas consistently (MacFarlane 2000). Whilst broad scale changes are difficult to realise using AESs, they have been demonstrated to increase a diverse landscape matrix (Donald and Evans 2006). Generalist species, such as mink (Ward et al. 1986; Bueno 1996), with the ability to exploit small areas of optimal habitat, are ideally suited to exploiting enhanced small habitat diversity created by AESs. These generalist characteristics are those of pest species and, hence, there is a potential conflict between conservation and farming interests. The conservation of otter may receive a high level of public support but using its presence to assess blanket conservation measures that are restricted to the farm scale, may lead to inaccurate assessment of the benefits of these measures. Conversely, mink may be a better indicator of fine scale diversity achieved from farm scale conservation schemes despite not being the target. It may be inevitable that conservation measures which increase fine scale diversity may benefit both desirable and non-desirable species. Management actions aimed at riparian conditions may more quickly benefit dietary generalist species more than specialised species. However, Bueno (1996) concluded that, in a diverse habitat, the otter's superior aquatic ability and the mink's dietary flexibility promoted co-existence.

Priority species are a means for conservationists to gain public support. However, in some cases their ecology may dictate that they are inappropriate to monitor the success of non targeted conservation prescriptions. Here we have shown that mink, a non-native invasive species, were associated closely with increased fine scale habitat diversity and with higher riparian bird diversity. In contrast, the presence of the otter, a native species of conservation priority, reflects broad scale habitat characteristics. Whittingham (2007) concluded that maximum benefit to biodiversity through AESs may result from targeting few large areas as opposed to many small areas. If this were the case, the otter could be an ideal species to encourage uptake and assess the success of conservation schemes.

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