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SCIENCE DIRECT
Biological Conservation 112 (2003) 363–371
BIOLOGICAL CONSERVATION
www.elsevier.com/locate/biocon

Factors affecting the success of an otter (*Lutra lutra*) reinforcement programme, as identified by post-translocation monitoring

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Received 15 March 2002; received in revised form 25 September 2002; accepted 10 October 2002

Abstract

Monitoring is essential to evaluate the success of translocations, but is frequently neglected. One exception has been the reinforcement of the otter (*Lutra lutra*) population in the Derwent and Esk catchments in North East England, UK, between 1990 and 1993. Here, we use data on otter sprainting activity collected before, during and after translocations to identify relationships with vegetation, food resources and physical river characteristics. Sprainting activity increased significantly with trout density, stream order, and surrounding cover by woodland and semi-natural grassland vegetation, and decreased significantly with stream gradient. The form of these relationships was unimodal, sprainting activity peaking at intermediate levels of environmental variables. A logistic regression model including variables relating to fish density, the physical characteristics of the river and surrounding vegetation cover was able to predict the presence or absence of otter sprainting at different survey sites with an accuracy of 92%. Fish density and the physical characteristics of the river were the most important factors in the model. Models such as this are of practical use for assessing the likely success of future otter translocations, both in North East England and other regions of the UK and Europe.

Keywords: Translocation; Conservation; Sprainting; Fish; GIS; Model

1. Introduction

The transfer by humans of organisms from one place to another (translocation) is becoming increasingly important as a means of reinforcing declining populations of threatened species for conservation purposes (Griffith et al., 1989; Stanley-Price, 1991; Hodder and Bullock, 1997). However, the success of translocations is dependent on factors such as the quality of habitat at the release site, the number of individuals being introduced, the genetic structure of the population and the attitude of the general public to the species concerned (Hodder and Bullock, 1997). Understanding how these factors affect translocation success will maximise the success of future interventions, and also provide a basis for predicting spread of a reinforced population. Evaluation should therefore be a key component of any translocation (Fischer and Lindenmayer, 2000; Armstrong and Ewen, 2001), both at the individual level as the reproductive success of reintroduced individuals, and at the population level in terms of changes in the local density or distribution of the species concerned. There are some examples of extensive monitoring of individuals or populations following translocations (Bright and Morris, 1994; Sjöåsen, 1997; Engelhardt et al., 2000; Pedrono and Sarovy, 2000). However, this is not the case for the majority of translocations and much information is either lacking or not readily available (Hodder and Bullock, 1997; Fischer and Lindenmayer, 2000).

One species that has been the focus of various translocations in the UK and mainland Europe is the otter (*Lutra lutra*) (Jefferies and Wayre, 1983; Jefferies et al., 1986). Otter populations in the UK were relatively large until the mid-eighteenth century. From the late eight-

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PII: S0006-3207(02)00333-6

eenth century to the early twentieth century they were increasingly persecuted for fishery protection and sport. In the late 1950s they suffered a dramatic decline throughout England, Wales and southern Scotland, probably as a result of pollution, persecution, habitat loss, fragmentation and reduced prey availability (Chanin and Jefferies, 1978; Jefferies, 1989; Foster-Turley et al., 1990; Kruuk and Conroy, 1991; Mason and Macdonald, 1993; Kruuk, 1995).

Otter populations are frequently monitored indirectly from their spraints (faeces). Spraints may serve as a mechanism to convey information and regulate the use of resources within a group of animals inhabiting the same territory (Kruuk, 1992). The validity of using measures of sprainting occurrence to derive information on otter population size is the focus of much debate (Kruuk et al., 1986; Conroy and French, 1987; Kruuk and Conroy, 1987; Mason and Macdonald, 1987, 1993; Strachan and Jefferies, 1996). Nevertheless, the use of sprainting as a broad indicator of otter activity patterns and habitat preferences is probably valid (Hutchings and White, 2000).

The historical status and distribution of the otter population of the Derwent and Esk catchments in North East England, UK, up to 1990 has been investigated by Woodroffe (1994). The River Derwent forms a catchment of 2057 km^2 and the River Esk forms a catchment of 363 km^2. Both rivers rise on the North York Moors and drain into the North Sea on the East coast of England. In the 1980s, spraints were rarely found in the Derwent and Esk catchments and evidence for otters was based almost entirely on footprints and infrequent sightings. On this basis, Woodroffe (1994) suggested that otters were rare in both catchments by 1990 and had been declining for some time. In 1990 an otter reinforcement programme was initiated in these catchments. Between 1990 and 1993, 21 otters were released throughout the Derwent catchment, and in 1993, four more otters were released into the Esk catchment (Woodroffe, 1997). This was the first translocation in England to use wild-born rather than captive-bred otters.

In this study, data on the sprainting activity of otters in the catchments of the Rivers Esk and Derwent up to 9 years after the start of the reinforcement programme were used to assess the success of the translocation and identify the key habitat features that were associated with sprainting. The objective was to quantify relationships of sprainting activity of the translocated population with vegetation, food resources and physical landscape characteristics. These relationships would then be of practical use in assessing the requirements of future otter translocations, both in North East England and other regions of the UK and Europe. The success of translocations needs to be monitored over a long time period, not just in the first few years, and the 9-year period over which the data were collected for this study is unique among otter translocations. Continued sprainting activity over this long time period also provides the best evidence for the success of this otter translocation, and thus the validity of the models produced.

2. Methods

2.1. Spraint surveys

Spraint surveys were carried out at up to 351 sites throughout the Derwent catchment over the period 1990–1997 and 46 sites on the Esk over the period 1990–1999 (Fig. 1). Certain sites were surveyed more frequently as part of a separate investigation into seasonality in patterns of sprainting. Of the sites on the Derwent, 90 were surveyed half-yearly, 28 seasonally (quarter-yearly) and 243 annually. All sites on the Esk were surveyed seasonally. Of those sites on the Derwent, seven consisted of a search of a 2-km section of both banks, 69 consisted of a search of a 600-m section of both banks, and 275 consisted of a search of both banks immediately below a bridge. Of those on the Esk, 13 sites consisted of a search of a 600-m section of both banks, and 33 sites consisted of a search of both banks immediately below a bridge. The sites used were dependent on accessibility and selected so that the widest area could be covered throughout the catchment to ascertain if and how the whole catchment was being colonised. This approach followed the recommendation of Kruuk (1995) that the level of the catchment rather than individual rivers or tributaries is the most appropriate for ensuring effective otter conservation. The variation in sampling effort among sites had no effect on the use of data in this study, since the analysis was based solely on presence or absence, rather than any measure of intensity of use.

A spraint site was defined as any place where spraints were deposited, at least 1 m from other spraints (Kruuk, 1995). As spraint sites were found, they were identified with coloured twine markers, and included in the search on subsequent occasions. Spraints were recorded as present or absent at each site, and the location of each spraint survey site was recorded to the nearest 100-m grid cell of the Ordnance Survey (OS) National Grid.

2.2. The river network

The river network was derived from the Ordnance Survey's 50-m gridded digital elevation model (DEM). This DEM was interpolated from contour lines on the OS 1:50 000 map series. Derivation of the river network from the DEM ensured that the network was consistent with the hydrological variables determined from the

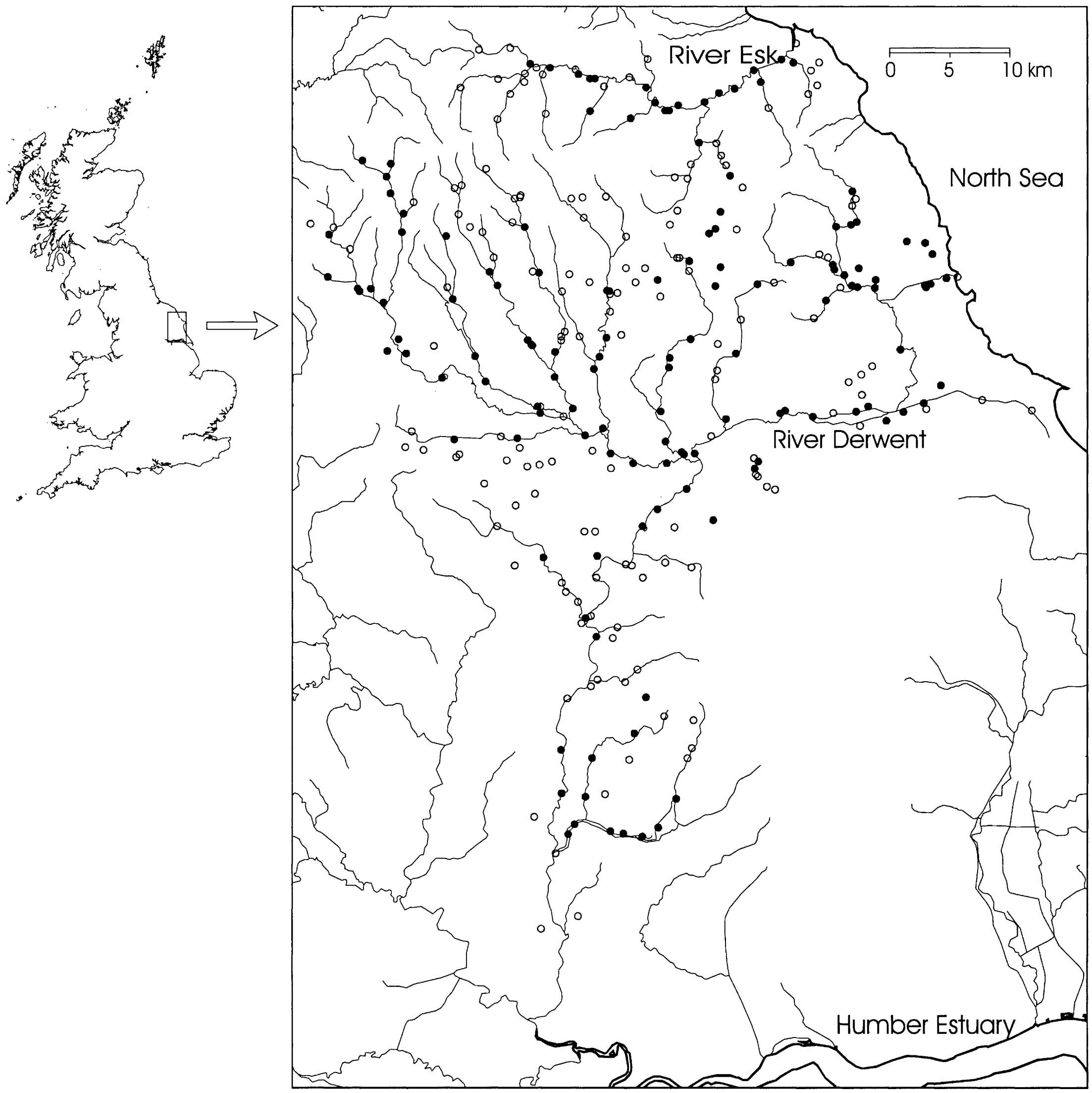

Fig. 1. Map showing the location of the study area within Britain and the location of spraint survey sites in the Derwent and Esk catchments. In the map of the study area, solid circles represent presence of spraints and open circles represent absence of spraints.

DEM. Flow direction was calculated for each of the grid cells represented in the DEM within the GIS Arc/Info. Flow direction is the direction from the cell in question to the lowest of its eight neighbours. From this model of flow direction it was possible to calculate another gridded surface representing flow accumulation. Each cell in this grid contained the number of upslope grid cells that would drain into it. By selecting the cells which exceeded a particular flow accumulation threshold, a representation of the river network was obtained. In this study a threshold value of 300 cells was used as this produced a network which was visually similar to the blue line network on the OS 1:50 000 map series for the study area. The OS co-ordinates for spraint sites were entered into a GIS as a set of points. The system allowed the points on the DEM-derived river network closest to each of the field recorded survey sites to be found. This new set of points was then checked against the OS 1:50 000 map series to make sure the site locations on the derived network were comparable with their positions on the blue line network of the map sheets.

The distance between each survey site and its nearest neighbouring spraint-presence site was also included. The survey sites used may not be independent of one another because of the way the otters move in the river network. By including this variable, any non-independence in the observations can be incorporated explicitly in the analysis, avoiding possible mis-specification of the model.

2.3. River variables

From this gridded (raster) representation of the river network it was possible to determine a number of fluvial geomorphological variables related to stream hydrology. For each spraint survey site, upstream drainage area was calculated using the river network in conjunction with the DEM. Although it was done for all the spraint sites surveyed in the study, the development of a practical predictive model requires the use of as many easily measured variables as possible. Stream order was highly significantly correlated with drainage area ($r=0.99$, $P<0.001$), and because it was measured much more easily, was therefore used as a surrogate measure for drainage area. River gradient was calculated for each grid cell on the river network by finding the maximum and minimum altitudes of neighbouring river grid cells and dividing by the distance between them. The arctangent of this value gives an estimate of river bed gradient.

2.4. Vegetation

The Institute of Terrestrial Ecology Land Cover Map was used to obtain an indication of vegetation type within the study area. This operates at a resolution of 25×25-m grid cells, and each grid cell is assigned to one of 25 different land cover types according to its dominant component land cover derived from satellite imagery (Fuller et al., 1994). Given the 100-m resolution of the spraint survey data and the 50-m resolution of the DEM and the resultant river network, it cannot be expected that the 25-m grid cell land cover map should give detailed information about bankside vegetation. However it would be expected to give information of the occurrence of stands of woodland and other major land cover types in the proximity of spraint survey sites. In order to capture the habitat in the immediate vicinity of the river, a 3×3 cell neighbourhood (75×75 m) was centred around the recorded survey site. This assumes that the spraint survey site and river bank are captured within one cell of this neighbourhood. In addition, a 7×7 cell neighbourhood (175×175 m) was used to encompass the surrounding land cover and vegetation, since this may also influence otter activity.

2.5. Fish density

Data on fish density were obtained from the Environment Agency reports on electrofishing surveys carried out in the study area in January–April 1994, March–May 1995 and October 1995. Records were reported for 56 sites in the River Derwent catchment (Hopkins, 1994, 1996) and 13 sites in the River Esk catchment (Jenkins, 1996). The mean distance between survey sites was 1050 ± 126 m, and the median distance was 699 m. The reports gave detailed quantitative results for trout (*Salmo trutta*) densities at the sites but only subjective qualitative assessments of coarse fish at a number of the sites. However, trout were the most abundant larger fish in most of the sites and their abundance has increased since 1983 (Hopkins, 1996). For these reasons, trout densities only were used in this study. Although otters do not feed exclusively on trout, because of the prominence of trout in these rivers, measures of trout density were assumed to be a reasonable representation of food resources potentially available to otters at the different sites.

Using a similar method to that used for locating spraint survey sites on the river network, the electrofishing sites were also entered as a set of points in the GIS. A vector (line rather than grid) version of the river network allowed the distances, via the network, between each fishing survey site and each spraint survey site to be calculated. A short 'C' program was then written to perform an inverse distance weighted spatial interpolation (Lam, 1983). This allowed an estimate of trout density in the river near each spraint survey site to be made. The program took the densities at the three nearest fishing survey sites to each spraint survey site and calculated a weighted mean of those values. The weight used was $1/d$, where d is the river distance between the two points.

The most important resources that determine the macro-scale density and distribution of fish in a river are water velocity, the level of dissolved oxygen, summer temperatures, the level of nutrients and the degree of pollution (Maitland and Campbell, 1992). Therefore, although the micro-distribution of fish will be affected by small, local variations in the river channel, interpolation along the river network should give a reasonable assessment of fish density at a scale that will be relevant to the distribution of otter activity. Spraint survey sites further than 50 km away from any fish record were excluded from the interpolation, since this is above the scale of otter movements, which have been shown to be up to 40 km (Durbin, 1993). This eliminated spraint survey sites on the Rivers Ouse, Nidd, Swale and Ure that are linked to the Derwent via the river network. Similarly, it resulted in the elimination of spraint survey sites in the River Leven that drains to the North West into the River Tees, but rises close to the headwaters of the River Esk.

2.6. Analysis

Due to the elimination of sites discussed above, the final number of spraint survey sites used in the analysis was 288. These covered a total catchment area of 2297 km^2, 1937 km^2 in the Derwent river system and 360 km^2 in the Esk river system. If spraints had been found at a site in any of the survey years, the site was assigned a presence code of one. If no spraints were found the site was assigned an absence code of zero. There were 137 sites where spraints had been found and 151 where spraints had always been absent.

To investigate the possibility of relationships between habitat variables and the occurrence of sprainting activity, two forms of statistical analysis were performed. Simple cross-tabulations and χ^2 statistics were calculated for the detection of possible relationships between categorical variables, i.e. the presence/absence of different land cover type and presence/absence of sprainting activity. Logistic regression was used to model the occurrence of sprainting activity on the basis of physical river characteristics, trout densities and the categorical land cover type variables.

Logistic regression is an example of an associative-based modelling approach (Rushton et al., 1997; Gough and Rushton, 2000) which attempts to determine relationships between the distribution of species and environmental features without any detailed modelling of demographic processes. It has been used extensively for this type of study (Green et al., 1994; Cardillo et al., 1999; Cowley et al., 2000; van den Berg et al., 2001), and is as effective as alternative techniques such as discriminant analysis and artificial neural networks (Manel et al., 1999).

Table 1
Summary of the significant results of the analysis using cross-tabulation and χ^2 tests

Land cover type	Grid cell neighbourhood	χ^2	Type of association	Significance (P)
Deciduous woodland	3×3	3.85	+	0.049
Meadow/verge/ semi-natural grassland	7×7	6.96	+	0.008
Urban	7×7	4.00	+	0.045
Grass moor	3×3	2.96	–	0.085
Grass moor	7×7	7.12	–	0.008

A significant χ^2 value indicates that there was a significant association between the presence or absence of spraints and that land cover type. A positive association of sprainting with a particular habitat is indicated by a plus sign and a negative association by a minus sign in the table

In order to investigate the functional form of the possible relationships between probability of sprainting activity and the non-categorical variables, logistic regressions were re-run adding an extra independent variable that was the square of the original variable. This allowed the quadratic forms for these relationships to be investigated (Gujarati, 1995). Comparison between different logistic models was made on the basis of the their residual deviance (−2 log-likelihood). Non-independence between spraint sites was considered by checking for signs of overdispersion in the models where the residual deviance of the models would be larger than the numbers of degrees of freedom left after fitting the models (Aitkin et al., 1989; McCullagh and Nelder, 1989).

3. Results

Significant associations between land cover types and the presence or absence of spraints are shown in Table 1. Spraints occurred more often than expected where woodland was found in the immediate vicinity (3×3 cell neighbourhood) of the recorded survey site, and where meadow/verge/semi-natural grassland and urban cover were found in the surrounding land (7×7 cell neighbourhood). Spraints were found less often than expected at sites where grass moorland was found either in the surrounding land or the immediate vicinity, although the latter was only significant at $P < 0.10$. The land cover variables that were significant at $P < 0.05$ were included with those representing stream order, stream gradient and trout density in the logistic regression analysis.

All variables had a significant relationship with the occurrence of sprainting activity (Table 2), and all the individual models showed a significant decrease in their

Table 2
Results of the logistic regression analysis using each of the land cover, trout density, stream order, stream gradient and distance to nearest spraint variables

Variables in model	Sign of coefficient(s)	Residual deviance	Improvement on residual deviance of constant-only model
Deciduous 3×3	+	394.7	3.85**
Urban 7×7	+	394.5	4.03**
Grass moor 7×7	–	391.3	7.22***
Meadow/verge/semi-natural grassland 7×7	+	391.5	7.08***
Stream order	+	391.7	6.83***
Stream order, Stream order^2	+,–	355.8	42.78****
Stream gradient	–	377.7	20.83****
Stream gradient, Stream gradient^2	–, +	377.7	20.85****
Trout density	–	390.8	7.75***
Trout density, Trout density^2	+,–	190.3	208.29****
Distance to nearest spraint	–	368.9	29.70****
Distance to nearest spraint, Distance to nearest spraint^2	–,–	368.8	29.80****

The residual deviance of the constant-only model was 398.6. The significance of the difference between the constant-only model and the models listed is indicated by asterisks (**, $P < 0.05$; ***, $P < 0.01$; ****, $P < 0.001$)

residual deviance values compared with the model with a constant only. For the land cover variables, the signs of the regression coefficients agreed with the results of the simple χ^2 tests obtained from cross-tabulations. Sprainting activity showed strong evidence of possessing unimodal responses to the non-categorical variables, except for stream gradient. Maximum sprainting activity occurred at intermediate stream orders and at intermediate trout densities. There was no significant difference between the residual deviance of models including stream gradient alone and both stream gradient and stream gradient squared. Although the model incorporating distance to nearest spraint site provided a significant improvement over the constant-only model, the inclusion of distance squared did not contribute a significant decrease in residual deviance. Comparison of the residual deviance of each of these models to the number of degrees of freedom left after fitting the model (either 285 or 286) provided evidence of overdispersion in all of the models except that containing both trout density and trout density squared. This simple model predicted 88.5% of the observations correctly. All of the other models were mis-specified as they failed to include other relevant explanatory variables, notably trout density information.

In a full model containing all of the above variables except for the square of stream gradient and the square of distance to nearest spraint (Model 1, Table 3), stream gradient, the trout density variables and the stream order variables were all significant. The meadow/verge/semi-natural grassland land cover type variable was almost significant at $P=0.05$. Each of the variables in turn was removed from the full model and a new model calculated including all variables except the one removed. Comparison of the residual deviance of the full model to the residual deviance of each of these new models indicated that the removal of distance to the nearest spraint and any one of the land cover variables, except meadow/verge/semi natural grassland, caused no significant reduction in predictive power. Excluding all the land cover variables and distance to the nearest spraint resulted in a more parsimonious model (Model 2, Table 3), that was not significantly different to the full model.

Table 3
Results of the full logistic regression model (Model 1) and a more parsimonious model using no land cover variables (Model 2)

Variable	Model 1	Model 2
Constant	−3.696 ****	−3.054 ****
Stream order	0.037 ***	0.042 ****
Stream order^2	-7.2×10^{-5} ***	-8.0×10^{-5} ****
Stream gradient	−0.347 ***	−0.411 ***
Trout density	1.291 ****	1.282 ****
Trout density^2	−0.051 ****	−0.051 ****
Deciduous 3×3	0.393 NS	
Meadow/verge/semi-natural grassland 7×7	1.093 *	
Grass moor 7×7	−0.713 NS	
Urban 7×7	1.029 NS	
Distance to nearest spraint	-1.0×10^{-4} NS	
Residual deviance	143.4	153.0
Improvement on constant-only model	255.20	245.60
% Of observations predicted correctly	92.0	91.3

The figures given for each variable are the estimates of the coefficients in the regression model. The significance of these, assessed using the Wald statistic, are indicated by asterisks (NS, not significant; *$P<0.1$; ** $P<0.05$; *** $P<0.01$; **** $P<0.001$). There is no significant difference between the residual deviance of the two models at $P=0.05$.

4. Discussion

4.1. Sprainting activity, environment and habitat use

Otters have quite broad habitat tolerances, and can persist in a wide variety of freshwater and marine habitats. The habitat surrounding their aquatic habitats is also extremely variable, ranging from forests to moorland, agriculture and even housing and industry (Kruuk, 1995). Based on sprainting behaviour, some researchers have suggested that otters living in freshwater habitats show a preference for woody bankside vegetation (e.g. Jenkins and Burrows, 1980; Mason and Macdonald, 1986). Other researchers, using radio-tracking, have found no such clear habitat preferences (Durbin, 1993). However, the apparent importance of habitat appears to depend at least partly on how it is measured. For example, Macdonald and Mason (1983) showed that habitat preferences were related to the use of root systems of certain trees as den sites, and Kruuk (1995) suggested a preference for specific types of vegetation as resting sites. It was not possible to examine detailed bankside habitat preferences with the relatively broad-scale approach we used. We did find some associations both in the immediate vicinity and in the surroundings at this larger scale, sprainting being associated positively with deciduous woodland and grassland, but showing a negative association with open moorland. However, the results suggest that habitat alone is not a reliable indication of sprainting activity.

Kruuk et al. (1993) found a positive correlation between otter use of streams and fish density, although this was based on only four points. Sjöåsen (1997) also showed that the presence of otters was associated with lakes and rivers with high biomass production. In the present study, we have shown a very significant positive correlation between otter sprainting and trout density. Moreover, the relationship is not a simple linear one, but takes a unimodal form. Thus, otter sprainting activity initially increases with trout density, but then declines at the highest trout densities. There are several possible, non-exclusive reasons behind this unimodal relationship. One may be that rivers with the very highest trout densities are important angling sites, and that human disturbance at these sites was significant in discouraging otters from exploiting the fish populations there. Another reason may be that, if otters are sprainting to regulate their use of resources, this may be necessary at low and moderate trout densities, but not at very high trout densities, where there is no shortage of food resources.

In contrast to our results, Thom et al. (1998) found that the density of trout was lower in stretches of river with otter signs in the Tyne catchment, although they did find positive associations of otter sprainting with higher densities of other fish species, which included minnow. Minnows (*Phoxinus phoxinus*) are noted for their high fat content, which may make them more important than trout in the diet where the species occur together. Salmonids were the most important fish in the diet of otters in the present study. In the Derwent catchment, salmonids accounted for an average of 36% of the otters' diet and bullheads (*Cottus gobio*) for 35% (G. Woodroffe, unpublished data). Bullheads were not found on the Esk and the principal prey items there were salmonids (40%) and eels (*Anguila anguila*) (21%) (G. Woodroffe, unpublished data). However, in both catchments, the otters were taking a diversity of prey species. Because trout are harder to catch than other species, it may be that where trout densities are very high, the densities of other species are lower, and otters prefer to feed on these elsewhere. Unfortunately, our data did not allow us to determine whether this was the case.

Physical aspects of the river in terms of the channel and drainage basin characteristics have so far received relatively little attention compared with vegetation. Kruuk et al. (1993) found a significant association between otter activity and the size of streams, with otter activity, measured as time spent per km stream length, increasing with stream width. When otter activity was corrected for the area of the streams, there was a significant exponential decrease in otter use per hectare of water with increasing stream width, indicating that small, narrow streams are very important for otters. In the present study, the physical variables relating to the characteristics of the rivers themselves were actually better predictors of sprainting activity than the vegetation variables, as has also been found by Durbin (1998). In particular, sprainting activity was significantly associated with the absolute and squared values of stream order and stream gradient. As with trout density, these relationships were therefore unimodal in form, indicating a peak in sprainting activity at intermediate sites but then a decline in sprainting activity at sites with the very highest stream orders and the very lowest gradient. It is likely that both increased human disturbance and declining water quality are significant factors contributing to this decline in sprainting activity in the lowest reaches of the rivers.

A comparison of the results of the present study with those of Kruuk et al. (1993) requires that some relationship exists between stream width and some of the physical characteristics we were able to measure. Relationships between width and stream order are affected by channel bed characteristics, so are not straightforward. However, stream width squared is related to drainage area, both for our specific study area and for rivers in general (Gregory and Walling, 1973). If the data of Kruuk et al. (1993) are analysed using both width squared (corresponding to drainage area) and width raised to the power of four (drainage area squared), the regression relationship of otter activity with these variables is significant ($F = 10.89$, d.f. = 2, 5, $P < 0.05$). The resultant coefficient on width squared is positive and that on width to the power of four is negative. This indicates a significant unimodal function, which is the same form as the models developed in the present study, where stream order was used as a proxy for drainage area. This finding demonstrates that the broad-scale relationships identified from the present study are in fact consistent with fine-scale ones that have been identified from radio-tracking studies.

The present study is the first one that has simultaneously considered the effects of vegetation, food resources and physical river characteristics on otter sprainting activity. Madsen and Prang (2001) showed that a combination of vegetation cover and physical channel characteristics was associated with otter distribution in Denmark, but did not include data relating to food resources. In the present study, we have shown that vegetation, food resources and physical river characteristics are all important individually, but that otter sprainting behaviour depends on the combined effects of these factors, and food resources are of overriding importance. A model using a combination of all these factors could predict otter sprainting behaviour at specific sites with 92% accuracy, and a model based on fish density and the physical river characteristics alone still had 91% accuracy.

4.2. Conservation implications

One of the most important parts of any translocation process is identifying suitable habitats and sites (Bright, 2000). Sjöåsen (1997) found that interactions with conspecifics and locations of food resources were important factors determining movement and establishment patterns in re-introduced otters. Although released otters would establish home ranges adjacent to existing resident animals, they showed a preference for formerly unoccupied areas. This led to the recommendation that if otters are present, reintroductions should take place on the periphery of the existing population to avoid potentially costly conflicts (Sjöåsen, 1997).

The present study has used data from a translocated population to identify sites associated with sprainting activity, and the resultant predictive models have considerable potential for practical application to future translocation exercises, as well as to conservation or population enhancement programmes. Within the North York Moors National Park, the models developed here can be used to predict other areas currently not occupied by otters that may be suitable for future occupation, based primarily on the availability of key food resources. When combined with ecological data on species mobility and dispersal, the models can be extended to dynamic ones to predict future patterns of spread in this area. The success of the translocations in this area in the early 1990s, as indicated by the continued and increasing sprainting activity, has meant that no further translocations are planned in the same areas. However, extending the models to a dynamic form could distinguish between other areas that the otters could colonise naturally, and those that they would be unlikely to reach, and hence where further translocations could be considered.

The models in this study have been developed using data from one region of the UK only. However, the core relationships in the models are consistent with other studies, and this suggests that the models may be applicable to other regions and other countries as well. One of the major advantages of the models is that they are based on data that are either readily available from various sources or relatively easy to collect and do not require extensive fieldwork. This has huge benefits in terms of reduced cost in the initial planning stages of a conservation project. Future validation of the models using data from other areas, both in Britain and overseas, would confirm their usefulness in conservation management for otters, and also highlight the potential applicability of this type of integrated ecological and geographical approach to the management of other species of conservation importance.

Acknowledgements

Gordon Woodroffe is grateful to Laura Winter for valuable assistance in the field survey work. Jim and Rosie Green of the Vincent Wildlife Trust supplied the otters and set up the release programme. We are grateful to the Institute of Terrestrial Ecology for providing the Land Cover data and to the Ordnance Survey for the use of their digital maps. We thank Julia Baker and Charles Hutchings for their contributions to preliminary data handling and analysis. We also thank Steve Rushton, Brian Davis and three anonymous referees for their comments on the manuscript.

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