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Evaluation of sign surveys as a way to estimate the relative abundance of American mink (*Mustela vison*)

Laura Bonesi* and David W. Macdonald

Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, U.K.

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Abstract

American mink *Mustela vison* are an invasive species in many parts of the world (e.g. Europe, Iceland and South America) and in many of these areas they are a threat to the native wildlife. It is therefore important to establish a reliable and efficient method to estimate their relative abundance in order to manage their populations. In this study, the use of surveys of signs (scats and footprints) as a way to estimate the relative abundance of American mink was evaluated. Populations of mink in three areas of England were studied to evaluate the impact of three factors (surveyor, marking places and month) on the probability of deposition and detection of signs. Among these factors only month had a significant effect. In the second part of the study, sign surveys were compared with live trapping and it was found that the proportion of sections with mink signs was only loosely correlated to the abundance of mink as estimated from live trapping. In conclusion, this study suggests that, provided that surveyors are trained, that there is a sufficient number of marking places in each section, and that the surveys are carried out in comparable seasons, sign surveys are an appropriate way to monitor the relative abundance of mink. Sign surveys are better than trapping when it is necessary to monitor mink populations over large areas because they are less time consuming, require less manpower and are cheaper.

Key words: relative abundance, sign surveys, scats, footprints, trapping, *Mustela vison*

INTRODUCTION

Monitoring the abundance and distribution of animals is essential for understanding their population ecology and for devising management and conservation actions (Macdonald, Mace & Rushton, 1998). However, monitoring animal populations may be difficult, especially when cryptic species are involved. In this case, when direct observation is not possible, indirect methods of monitoring must be used, such as searching for footprints and faecal pellets, or recording road kills (e.g. Reid, Hansen & Ward, 1966; Bull, Holthausen & Bright, 1992; Philcox, Grogan & Macdonald, 1999).

Indirect methods of monitoring populations can be used to record three facets of the status of a species: its distribution, its relative abundance and its absolute abundance. Absolute abundance measures the number of animals present in a population, while relative abundance measures the number of animals present during a sampling occasion in relation to other samples that might be separated in space or time (Wilson & Delahay, 2001). In general, recording distribution, while not easy, is not nearly as difficult as assessing abundance, particularly absolute abundance.

In this paper, the validity of using signs, namely scats and footprints, to quantify the relative abundance of American mink is discussed. This species is nocturnal and elusive and for these reasons its populations have mostly been monitored indirectly (e.g. Mason & Macdonald, 1983; Sidorovich, Jedrezejewska & Jedrezejewski, 1996; Loukmas & Halbrook, 2001).

Whether or not signs can be used to estimate abundance has long been debated for the Eurasian otter *Lutra lutra*, a mustelid that uses the same habitats as mink. Evidence so far is consistent with the hypothesis that otter surveys produce an estimate of the relative abundance of otters at low densities (Ruiz-Olmo, Saavedra & Jimenez, 2001), but not at high densities (Kruuk *et al*., 1986; Conroy & French, 1987), and that surveys are a reliable indicator of otter distribution.

Unlike the otter, no study exists that relates mink distribution and abundance to signs. In the Eurosiberian region, mink is an invasive species brought over from North America, now widespread in the United Kingdom and rapidly colonizing other countries in Europe and elsewhere (e.g. Kauhala, 1996; Ruiz-Olmo *et al*., 1997). Because mink are a threat to native wildlife (e.g. Lawton

*All correspondence to: L. Bonesi.
E-mail: laura.bonesi@zoo.ox.ac.uk

& Woodroffe, 1991; Barreto *et al*., 1998; Ferreras & Macdonald, 1999; Macdonald, Sidorovich *et al*., 2002), it is of paramount importance to establish a reliable and efficient method to monitor their populations. In North America, trapping for the fur trade already provided a means of estimating the relative abundance of mink (e.g. Erb, Boyce & Stenseth, 2001). However, for the sole purpose of determining the relative abundance of mink on a regional basis, live-trapping is not cost-effective. Surveying for signs, being cheaper and less time consuming, would be preferable, if it could be validated.

To use signs as an index of relative abundance, one must understand both what determines the probability of signs being detected by the surveyor and what determines the probability of signs being deposited by the animal. It is important to stress that there are statistical and systematic errors in this process. Statistical errors arise from random factors such as the selection of sampling units. Systematic errors result in failing to detect animals included in a sample, and they exhibit either a consistent positive or a negative influence on the results (Thompson, White & Gowan, 1998). The aim must be to avoid systematic errors and to reduce statistical ones. While the latter are reduced by increasing the sampling effort, the former are more elusive.

The first objective of this study was to quantify sources of systematic error in estimating the relative abundance of mink from sign surveys. In particular, how three different factors, namely marking places, surveyor and month, affect the probability of deposition and detection of mink signs, were considered. The second objective of this study was to compare sign surveys with live trapping of mink, another method commonly used to estimate its abundance.

METHODS

Study areas

The study took place at 3 sites in England: (1) the River Teign (Ordnance Survey grid reference: SX804883 to SX712893); (2) the River Exe (OS grid reference: SS949139 to SS921229), (3) and in an area of central England of 50 × 50 km comprising different rivers (OS square SPse). The study area on the River Teign comprised 12 km of main river plus 3 km of tributaries, whereas on the River Exe it comprised 15 km of main river. The study area in central England was made up of 44 discontinuous sites each 500 m long spaced at a distance of 6.2 km (SD = 2.2) along rivers. The River Teign is an oligotrophic river with river banks lined by extensive broadleaf woodlands and conifer plantations (Chanin, 1976). The width of this river ranges between 5 and 15 m and its depth is 2 m at most. The River Exe is richer in nutrients, being surrounded mostly by agricultural areas, and it has a gentler gradient compared to the River Teign. The width of this river ranges between 5 and 20 m and it is up to 3 m deep. In both rivers the most abundant fish species were salmon *Salmo salar* and trout *S. trutta* (A. Bailey, pers. comm.). The rivers in the area in central England are rich in nutrients being surrounded by agricultural areas. Their width was on average 3.5 m (SD = 3.7, range 1–30 m, $n = 44$). The average rainfall of these areas in 1999 was 61 mm/month and the average temperature was 11 °C (range 3–24).

Survey strategy

The study areas of the rivers Teign and Exe were divided into 500 m contiguous sections, the study area in central England consisted of non-continuous 500 m sections. This length of section was adopted so that this study would be comparable to most of the other mink and otter surveys conducted in Europe where the standard section length is of 500 or 600 m (e.g. Strachan & Jefferies, 1996). The left and the right banks were both surveyed up to 5 m from the river's edge. The River Teign was surveyed 11 times, in December 1998, in January, February, March, April, May, June, August and October 1999, and in January and March 2000. The River Exe was surveyed once, in November 1998. The rivers in central England were surveyed 5 times, in March, July, October and January 1999, and in March 2000. It took on average 89 min (SD = 35, range 30–210, $n = 30$) to survey a 500 m section while collecting habitat data, and 49 min (SD = 10, range 35–75; $n = 30$) to survey a section only for signs. Apart form the surveys carried out in January and February 1999 on the River Teign, all other surveys were at least 20 days apart. All surveys were carried out at least 3 days after the last major rainfall event. This seemed to be sufficient to ensure that mink had enough time to deposit signs along the bank. This assumption was supported because we observed no difference in the proportion of positive sections between the survey of March 1999 (10 positive sections out of 20) which was preceded by heavy rain, and that of March 2000 when the weather was dry (11 positive sections out of 20). Trapping estimated that 3 mink were present on the river in both periods.

A team of trained surveyors conducted the surveys by walking along the bank and searching for the signs. All signs were removed so that they were not counted more than once. The training consisted in surveying alongside an experienced surveyor for a minimum of 5 sections with signs, and then being assisted in sign identification for at least 3 days. On the rivers Teign and Exe records were made of the places where signs were likely to be found, such as trees, fallen trees, boulders, side-bars, bridges, weirs, tributaries, and side channels. These are collectively referred to as 'marking places'. Information about habitat, marking places, and signs was recorded for each 500 m section. Habitat information was recorded following a modification of the standard procedure of the River Habitat Survey (Raven *et al.*, 1997).

Identification and quantification of field signs

Otters *Lutra lutra* were the only species present in the study areas whose signs could be confused with those of

Table 1. Habitat and marking places of mink *Mustela vision* measured within each 500 m section on the rivers Teign and Exe

Variable	Definition and importance to the mink	Measurement/categories
Trees	Density of mature trees within 5 m of the bank; potential denning sites	1. None 2. Isolated/scattered 3. Regularly spaced 4. Occasional clumps 5. Semi-continuous 6. Continuous
Cover	Vegetation cover on the bank defined on the base of the composition of the vegetation where five types are distinguished: bryophytes, short herbs, tall herbs, scrub, and trees	1. Bare earth/rock, etc. 2. Uniform: predominantly one type of vegetation but no scrub or trees 3. Simple: two or three vegetation types 4. Complex: four or more vegetation types
Tree roots	Tree roots on the bank; potential marking and denning sites	Number of tree roots
Boulders	Boulders at or near the bank; potential marking sites	1. Very few (0–3) 2. Few (4–10) 3. Medium (11–20) 4. Many (21 +)
Side-bars	Side bars along the bank; potential sites for finding footprints	1. Few (0–3) 2. Medium (4–6) 3. Many (7 +)
Pools	A distinct feature of deeper water where back currents are usually present; potential hunting ground	Number of pools

mink, as polecats *Mustela putorius* and martens *Martes martes* were absent (Birks & Kitchener, 1999). Usually mink faeces are easy to recognize and to distinguish from those of otter. Mink scats are usually more compact than those of the otter, often appear cork-screwed, and are *c*. 6–8 cm long and *c*. 0.9 cm in diameter. They often contain fur or feathers and have an unpleasant smell when fresh, while those of otters have a sweet-musky smell (Dunstone, 1993).

Otter and mink footprints have a different shape and size (see Dunstone, 1993). Mink footprints have a more stellate appearance, and are less rounded than those of otters. Mink footprints show 5 toes around a central pad, although sometimes only 4 register and claw marks are occasionally visible at the end of the paw.

Study design and statistical analysis

An investigation of how surveyor, marking places, and month affected the probability of deposition and detection of signs of mink was carried out. It was assumed that marking places and month affected mainly the deposition of signs by mink, while surveyor affected the detection of signs of mink. The impact of each factor was examined in turn while keeping all other factors fixed, unless previous analyses or reasonable assumptions justified otherwise. In this way variability was minimized when assessing the influence of each factor.

We measured the abundance of signs as the number of sections containing signs per survey rather than as the number of signs per section or per survey. As expected, these 2 measures were correlated in our study (Pearson correlation coefficient $(r_p) = 0.868$, $P = 0.001$, $n = 11$). The number of sections containing signs per survey was used because it is a more coarse but more robust measure, being less sensitive to the possibility of not finding all the signs.

Surveyor. To compare the ability of different surveyors to find signs, only data collected on the same river during the same month by 2 different surveyors was used. For this analysis data from the River Teign and the River Exe were used. Usually 1 surveyor surveyed the right bank while the other covered the left bank. The study involved a total of 7 surveyors combined into 4 pairs. All surveyors received the same training and were of comparable experience. The number of positive and negative sections found by each surveyor was compared within each pair using chi-square tests and a Bonferroni adjustment was used to take into account multiple tests. This analysis assumed that, on average, a similar number of sections on both banks had signs. For this to be true there must be little difference in habitat and marking places between the left and the right bank to neutralize the recognized effect of habitat on its use by mink (Yamaguchi, 2000). Differences in habitat and marking places between the left and the right bank were tested using a *t*-test to compare the density of different features that are known to be potentially important in determining habitat use and sign deposition by mink (Mason & Macdonald, 1983). A Bonferroni adjustment was used to take into account that 6 *t*-tests were carried out for the River Teign and 5 for the River Exe. A list of the habitat features and marking places selected is given in Table 1.

Marking places. The influence of marking places on the probability of finding signs was studied. For this analysis data from the River Teign and the River Exe were used. ‘Marking place’ was defined as specific land marks where mink actively or passively leave their signs. Four kinds of marking places were considered, 3 suitable for finding droppings (tree-roots, boulders and bridges) and 1 suitable for finding footprints (soft verges). On the River Exe, the number of marking places within each 500 m section was counted. On the River Teign, each section was classified as having relatively few, average or many of each kind of marking place. Correlation was used to relate the abundance of marking places to the number of signs. To minimize possible sources of variability, only surveys that recorded simultaneously both signs and marking places were considered. These surveys occurred in October 1999 on the Teign and in November 1998 on the Exe.

Month. The proportion of positive sections occupied by mink were calculated for each month. For this analysis data from the River Teign and from the study area in central England were used. the counts of positive and negative sections in the two study areas using chi-square tests were compared. Because 5 chi-square tests were performed, a Bonferroni adjustment that lowered the probability at which a result would be accepted as significant to 0.01 was used.

Trapping

To evaluate estimates of relative mink abundance obtained with sign surveys, they were compared with those obtained by live trapping. Eight trapping sessions were carried out on the River Teign between December 1998 and March 2000. During each trapping session, 40 traps were located at intervals of *c*. 200 m along the river, baited with sprats *Sprattus sprattus* and left in place for *c*. 1 week (mean number of trapping nights per month = 209, SD = 53, $n = 8$). Traps were checked every day in the morning and mink were anaesthetized and handled using standard procedures (e.g. Bonesi, Dunstone & O' Connell, 2000) and marked using microchips. Trapping was suspended between April and June 1999 during the gestation–weaning period, because it has been shown that on the River Teign that trapping at this time of the year is unsuccessful (Birks, 1981), especially where mink densities are low (Chanin, 1976).

RESULTS

The effect of the surveyor

No difference was found between the left and the right bank in terms of habitat and marking places (Table 2), thereby supporting the assumption that mink were likely to use both banks.

No significant differences were found when comparing the ability of our seven different surveyors to find mink signs (Fig. 1) (chi-square tests: A,B, $\chi^2 = 1.90$, d.f. = 1, $P = 0.17$; C,D, $\chi^2 = 0.08$, d.f. = 1, $P = 0.78$; E,D, $\chi^2 = 0.59$, d.f. = 1, $P = 0.44$; F,G, $\chi^2 = 0.00$, d.f. = 1, $P = 1.00$).

Table 2. Average quantity of each habitat and marking places of American mink *Mustela vison* on the left and on the right bank on the River Teign and River Exe. The measurement units of each variable are reported in Table 1. The significance of the *t*-tests of the differences between the means of the left and right bank, is reported in column four and seven. NC means not calculated (because no data collected). The Bonferroni adjustment lowered the level to which a test was accepted as significant to 0.008 for the River Teign and to 0.010 for the River Exe

	Teign			Exe		
Variable	Left bank	Right bank	*P*	Left bank	Right bank	*P*
Trees	4.54	4.86	0.02	3.36	3.60	0.35
Cover	2.96	3.08	0.45	1.54	1.88	0.36
Tree roots	2.17	2.04	0.55	48.80	34.50	0.10
Boulders	1.67	2.00	0.10	2.70	2.10	0.07
Side-bars	1.00	0.95	0.32	1.78	1.90	0.57
Pools	0.88	1.00	0.72	NC	NC	

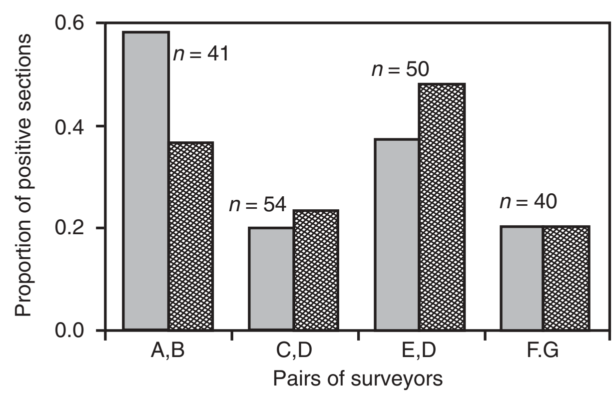

Fig. 1. Proportion of 500 m sections found positive by different pairs of surveyors searching for signs of mink *Mustela vison* during repeated surveys along the rivers Teign and Exe. A Bonferroni adjustment lowered the level to which a test was accepted as significant to 0.013 and there was no significant difference in the ability of different surveyors to detect signs of mink. Sample sizes, expressed as the total number of sections surveyed, are shown at the top of the histograms.

The effect of marking places

We examined whether there was a higher probability of finding mink signs in sections with a higher number of marking places. No relationship was found between the abundance of marking places and the number of scats (Teign: trees, Spearman rank correlation coefficient $(r_s) = 0.03$, $P = 0.82$, $n = 48$; boulders, $r_s = 0.03$, $P = 0.86$, $n = 48$; bridges, $r_s = -0.19$, $P = 0.19$, $n = 48$). On the contrary, the number of groups of footprints and the number of soft verges were significantly correlated (Teign: $r_s = 0.25$, $P = 0.04$, $n = 48$; Exe: $r_p = 0.23$, $P = 0.04$, $n = 60$). In general, footprints were a more common sign than scats. On the River Teign the ratio of the number of groups of footprints to scats was 1:0.7, on the River Exe this ratio was 1:0.5.

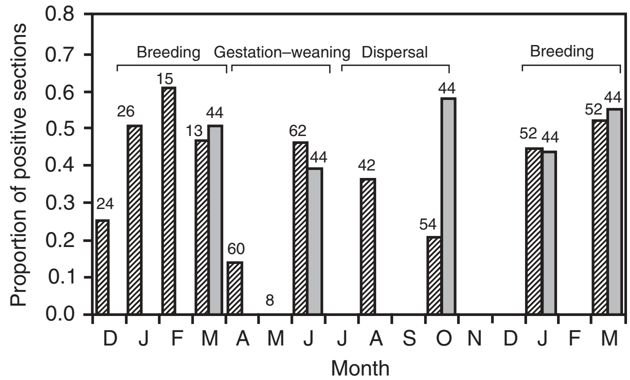

Fig. 2. Proportion of sections with signs of mink *Mustela vison* in different months. Numbers above the histogram bars indicate the number of sections surveyed. Different timings of the reproductive season of mink are also shown.

Table 3. Number of mink *Mustela vison* trapped during each of the eight trapping sessions. Numbers in parentheses show the number of recaptures. Trap days indicates the effort per each session expressed as one trap out for 1 day

Trapping session	Trap days	No. of mink trapped	Sex of mink trapped
Dec 1998	202	0 (0)	
Jan 1999	152	0 (0)	
Feb 1999	268	2 (0)	♂♀
Mar 1999	161	1 (0)	♂
Aug 1999	138	4 (1)	♂♀♀♀(♀)
Oct 1999	257	1 (1)	♀(♂)
Jan 2000	235	1 (1)	♀(♂)
Mar 2000	262	3 (0)	♂♂♀
Total trapped		12 (3)	

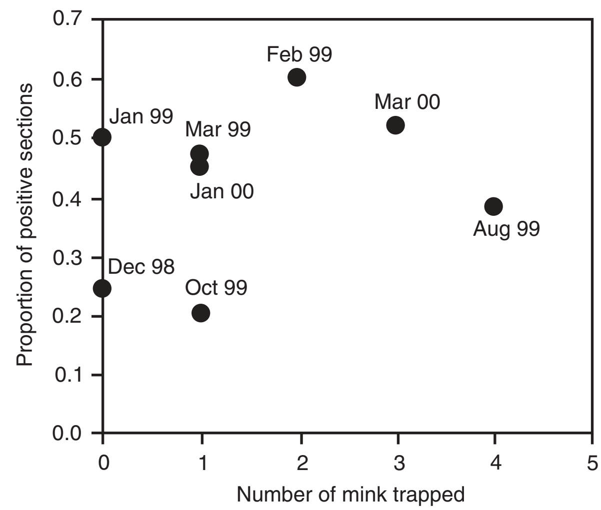

Fig. 3. Relationship between the number of mink *Mustela vison* trapped and the proportion of sections with mink signs. Each point represents a different trapping/survey session.

The effect of month

The proportion of sections with signs of mink varied considerably during the year with minima during in April, December and October on the River Teign, and peaks during the 'breeding' season in January, February and March in both areas, and in June (Fig. 2). The proportion of positive sections on the River Teign and on the rivers in central England in different months was not significantly different (chi-square tests: March 1999 – $\chi^2 = 0.06$, d.f. = 1, $P = 0.81$; June 1999 – $\chi^2 = 0.45$, d.f. = 1, $P = 0.50$; January 2000 – $\chi^2 = 0.01$, d.f. = 1, $P = 0.92$; March 2000 – $\chi^2 = 0.07$, d.f. = 1, $P = 0.80$), with the exception of October 1999 ($\chi^2 = 13.86$, d.f. = 1, $P < 0.001$). It is possible that the higher proportion of positive sections in central England in October was owing to the higher density of mink in this area compared to the River Teign, with juveniles still dispersing in central England while all dispersal activity may have stopped on the Teign. The large fluctuations in the proportion of positive sections in Fig. 2 illustrate that month is a crucial factor affecting the deposition of signs (coefficient of variation: Teign 52%; central England 16%). For example, knowing that a given river has 20% of positive sections gives very little information unless the month is also specified, because such a figure could arise either from a high density population in a gestation period or from a low density population in a breeding period.

Correlation between trapping and signs

A total of 12 different mink was trapped on the River Teign, comprising five males and seven females (Table 3). The rate of recapture of these mink was low, possibly indicating a high turnover of the population (for a discussion on the causes of population turnover on the Teign see Birks, 1981). Trapping estimated a higher number of mink in the study area during August than at other times (Table 3). The density of mink on the river was estimated from trapping to be between two and four adult mink (0.17–0.33 mink/km), a very low density indeed when compared to that of other studies where mink reached densities of 2 mink/km (Dunstone & Birks, 1985). In December 1998 and January 1999, no mink were trapped because often the first period of trapping is not successful in spite of mink being present in the area (cf. Yamaguchi, 2000).

The proportion of sections with signs of mink was compared with the number of mink trapped on the River Teign (Fig. 3). These two measures were gathered simultaneously as mink were trapped while signs were collected. The number of mink trapped was only weakly positively related to the proportion of sections with mink ($r_s = 0.27$, $n = 8$, $P = 0.12$ one tail). Both in 1999 and in 2000 between January and March, during the breeding season, a disproportionately higher number of positive sections was found irrespective of the number of mink being trapped (Fig. 3).

DISCUSSION

Effect of different factors on the probability of deposition and detection of signs

Among the three factors that we considered, only month seemed to have a substantial effect on the probability of mink depositing signs. The other two factors, *surveyor* (affecting the probability of the observer detecting signs of mink), and *marking places*, had little or no effect.

There was no tendency to find more scats with increasing number of tree-roots, boulders and bridges, but there was a significant tendency to find more footprints with increasing number of soft verges. This is probably because the deposition of scats depends not only on the movement path and presence of a suitable marking place, as in the case of footprints, but also on whether the animal decides to defecate at that particular point. In this way, the deposition of scats may be less dependent on marking places and more dependent on the animal's intentional behaviour than is footprint deposition.

Mink scats are likely to last in exposed conditions for about 1 month (estimated for otters in Kruuk *et al*., 1986; Mason & Macdonald, 1986) while footprints probably have a shorter life depending on external factors such as rain, flooding and trampling. These considerations suggest that the surveys are likely to depict the distribution of mink during a period roughly corresponding to the previous month. Removing all the signs at each survey ensured that the same distribution was not recorded twice.

The positive message from this study was that, provided the surveyors are trained and there is a sufficient number of marking places in each section, the proportion of sections with signs probably depends mainly on the abundance and behaviour of mink. It is therefore important to understand how behaviour and activity affect the deposition of signs by mink in order to use signs as an estimate of mink relative abundance. It is fortunate that mink have a well-defined yearly cycle, with set breeding, gestation, weaning, and dispersal seasons, because this helps in the interpretation of how behaviour can affect sign deposition.

A high proportion of sections with signs was found during the breeding season, between January and March. At this time of year, mink are very active and male mink who are only temporarily present in the population (known as 'transient males') also start to appear (Gerell, 1971; Ireland, 1990; Yamaguchi & Macdonald, in press); both these factors are likely to increase the abundance of signs. High proportions of sections with signs were found also in June when the mother was still associated with her kits, this being one of the times of year with the highest density of mink. Although many signs are found, females and kits are difficult to trap in this period (Chanin, 1976; Ireland, 1990; Yamaguchi, 2000). The lowest proportion of sections with mink signs was recorded between April and May. These months correspond to the gestation, parturition and weaning period and coincide with particularly low levels of male and female activity (Dunstone & Birks, 1985; Ireland, 1990). In spite of the effect of behaviour on the deposition of signs by mink, we suggest that surveys for signs have the potential to be used to estimate the relative abundance of mink because the proportion of sections with signs of mink is highest at times of the year when the density of mink is highest (breeding season and June); it is lowest at times of the year when the density of mink is lowest (gestation season and December); and it is intermediate at times of the year when densities are intermediate (dispersal season).

Given that the yearly cycle of mink within the same biogeographic region is probably synchronous (Dunstone, 1993), sign surveys have the potential to be used to compare the relative abundance of mink in distant areas, provided the surveys are carried out during comparable seasons and the spatial distribution of surveyed sites is similar. In particular, the absolute density of mink should not be compared between spatially continuous and discontinuous surveys. Signs in both these kinds of surveys fluctuate in a similar way (Fig. 2), but they estimate mink densities in different ways. A continuous survey contains several mink home ranges and attempts to estimate the density of mink in a given stretch of river. In discontinuous surveys, such as those commonly used in Europe (e.g. Strachan & Jefferies, 1996), the length of the sections surveyed is much smaller than the home range of a single mink and therefore can only detect the presence or absence of individual mink at each site, but not their densities. The overall proportion of sites in an area covered by discontinuous surveys is probably proportional to the abundance of mink in the area (Gaston *et al*., 2000), but this cannot be compared directly with estimates of absolute abundance derived from continuous surveys.

Indices of abundance developed for the otter and other species cannot estimate their relative abundance above a threshold population density because they tend to became asymptotic (Gibbs, 2000; Ruiz-Olmo, Saavedra *et al*., 2001). Although mink populations in our study were at a low density on the River Teign and Exe, saturation is less likely to be problematic for mink because they deposit signs much less frequently than do otters. During our study, many more sections were found with otter signs (Teign: yearly average = 55%, SD = 25, $n = 11$ months) than with mink signs (Teign: yearly average = 36%, SD = 19, $n = 11$ months), even though there were more mink than otters in the study area.

Comparing sign surveys and trapping for estimating abundance

Our study shows that the proportion of sections with mink signs was only loosely related to the number of mink trapped. Ideally, one would like to compare these estimates of relative mink abundance with the absolute abundance of mink to quantify the error, but unfortunately there is currently no easy way to estimate absolute mink abundance. Trapping is not an unbiased estimate of mink abundance, because one cannot be sure to have trapped all mink present and because the number of mink trapped depends on seasonal behaviour and levels of mink activity (Ireland, 1990; Yamaguchi & Macdonald, in press), in a similar way as surveys for signs do. Moreover, the rate of recapture in low-density populations of mink, such as the one studied here, is so low as to make studies of capture–mark–recapture not applicable. For low-density populations, signs might sometimes be a better way of detecting the presence and relative abundance of mink than trapping. For example, during the breeding season a consistently high proportion of sections with signs was found, but in some months of this season no mink were trapped. Thus, mink signs were a better indicator that mink were present in the area than trapping, and the probability of detection of signs seemed to be high (about 0.5) even if mink were at low densities. At higher mink densities the situation might be different, and trapping might be more effective at estimating the relative or even the absolute number of mink.

Whether to use trapping or surveying for signs as a way to estimate relative mink abundance depends on several other considerations. Time and costs are usually the biggest constraints on ecological studies. The time necessary and the costs of surveying a river stretch of 10 km for 1 month was calculated, assuming that surveyors are paid £7 per h and excluding the cost of transport, which we assumed to be the same in both cases. It was estimated that trapping would take 80 h and cost about £650 including bait and anaesthetics, but excluding the cost of traps which is about £900, while surveying would require only 15 h and £110. There is a 6:1 ratio in the expenses and 5:1 ratio in the time between the two methods, making surveying a much cheaper and quicker method to estimate mink relative abundance. Both trapping and surveying allow the collection of ancillary data and samples; however, if trapping-mark-recapture is carried out for long enough the absolute abundance of mink can also be estimated, especially if it is coupled with radio-tracking. Trapping and surveying are both influenced by mink activity levels at different times of the year. Captures increase disproportionately during the breeding season and at times when kits and juveniles are around (Gerell, 1971; Chanin, 1976; Birks, 1989; Ireland, 1990; Smal, 1991). Factors affecting trapping success such as weather, the trapper's ability and habitat have never been explicitly tested for mink, but in our experience trapping is more susceptible to individual ability than surveying.

Because of time and costs constraints, it often happens that local studies are based on trapping (e.g. Birks, 1981; Chanin, 1983; Ireland, 1990; Yamaguchi & Macdonald, in press), while regional studies are necessarily based on surveying (Barreto *et al*., 1998; e.g. Mason & Macdonald, 1983; Ruiz-Olmo, Palazon *et al.*, 1997; but see Smal, 1991). Ultimately, the decision on whether to carry out a trapping or a survey study depends on the density of mink, on whether an estimate of absolute mink abundance is needed, and on which ancillary data one wishes to collect. If absolute abundance is needed, only trapping can be used at present.

Recommendations on the use of signs to estimate the relative abundance of mink

(1) External factors are not expected to introduce major biases in the results of mink sign surveys provided that: (a) surveys are not carried out during heavy flooded conditions; (b) surveyors are trained and of comparable motivation and experience; (c) there are at least a few suitable features within each sample unit for the animal to leave its signs.
(2) The proportion of sections with signs has the potential to be used to compare the relative abundance of mink between different areas, provided the surveys are carried out during comparable seasons and that the spatial distribution of surveyed sites is similar (continuous *vs* discontinuous surveys).
(3) At low mink densities, sign surveys might be a better way to estimate the relative abundance of mink than trapping.
(4) Sign surveys cannot be used to compare the relative abundance of otters and mink because otters tend to leave more signs than mink.

Research needs to develop further an index of relative mink abundance based on signs

(1) Studies on the relationship between mink relative abundance as estimated from trapping, and the proportion of positive sections at a range of mink densities need to be carried out.
(2) Other factors that might potentially affect the deposition and detection of signs, for example diet and weather, should be investigated.
(3) The rate at which signs decay and are replenished should be assessed (e.g. Lehmkuhl, Hansen & Sloan, 1994).
(4) The use of track-board survey of the kind used for martens (e.g. Bull *et al*., 1992; Foresman & Pearson, 1998) should be evaluated as a way of estimating the relative abundance of mink.

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