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SHORT COMMUNICATION

Distinguishing tracks of mink *Mustela vison* and polecat *M. putorius*

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Abstract Targeted trapping and monitoring methods for mink rely on the correct identification of mink tracks on tracking plates. Previously, there has been no reliable method by which mink tracks can be distinguished from polecat tracks. We present a simple discriminant function based on three measurements that can be used to distinguish the tracks of mink and polecats on clay-based tracking plates with classification success greater than 90%. The method could potentially be used in other circumstances.

Keywords Footprint · Mustelid · Raft trapping system · Tracking plate · Non-target · Discriminant function analysis

Introduction

American mink *Mustela vison* in the UK and mainland Europe are an introduced, 'pest' species (Macdonald and Harrington 2003). Recently, an innovative trapping method has been developed for mink that utilises tracking plates on rafts to target trapping efforts (Reynolds et al. 2004). These tracking rafts also provide a useful monitoring tool (Harrington et al. 2007). Tracks of mink are easily distinguished from those of stoat *M. erminea* and otter *Lutra lutra* on the basis of size (Strachan 1995), but the distinction between mink and polecat *M. putorius* (two similarly-sized mustelids) remains problematic. Sidorovich (1999) described qualitative differences between the tracks of these species, but these are difficult to apply reliably in the field.

Polecats are associated with riparian areas in mainland Europe (Rondinini et al. 2006) and have been recorded on tracking rafts set to monitor and trap mink in the UK (Harrington, unpublished data); thus, there is potential for confusion. The protected status of the polecat (schedule 6, Wildlife and Countryside Act 1981) means that intentional trapping of polecats is prohibited in the UK; therefore, it is important to prevent misidentification if possible. Furthermore, positive identification of polecat, as opposed to mink, tracks would reduce time and effort when initiating a mink control programme. We present a quantitative approach for distinguishing between the tracks of mink and polecat collected from tracking plates.

Materials and methods

Track collection

Tracks were collected from wild individuals trapped in the Upper Thames valley, Oxfordshire, UK, in 2005 (study site and trapping methods in Harrington et al. 2007) by releasing animals from traps at the entrance to a wooden tunnel (0.2×0.2×2.4 m) beneath which was placed a layer of moist clay (see Reynolds et al. 2004). The tunnel and extended tracking plate were thus designed to simulate a tracking raft but were extended to allow the collection of multiple tracks from each individual. To avoid collecting tracks from running animals, we placed a temporary obstruction at the far end of the tunnel to encourage animals to walk, as we assume they would when voluntar-

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ily visiting a tracking raft. All individual mink and polecats were adult.

Individual footprints were photographed using a digital camera (set on macro with the flash off), alongside a ruler for calibration. Overlaid tracks and tracks with fewer than three clear toe prints or with poorly defined pad margins were excluded from analysis (<10% of cases).

Track measurement

Impressions of both fore and hind feet of mink and polecats have five-toe pads and three main inter-digital pads, the latter usually merged in tracks as a single pad (Sidorovich 1999; Strachan 1995). Claw marks are only occasionally present, and the fifth (outermost) toe pad is commonly absent. We included both fore and hind foot tracks, as well as left and right foot tracks, and did not distinguish between these in the analyses because our goal was to produce a robust method to distinguish the tracks of the two species, usable by practitioners in the field, without necessitating identification of these traits.

We measured 15 linear variables involving five general track measurements and ten detailed measurements of individual track components and the spacings between them (Fig. 1). We also calculated eight measurement ratios ($W1/L2$, $W1/L3$, $W1/d5$, $d1/d4$, $(d1/W1)\times 10$, $[\text{mean}(d1,d2)/W1]\times 10$, $d6/d4$, $d4/W1$) because we expected any inter-specific differences to be apparent in the shape, rather than the size, of the track and recorded the presence and shape of claw marks. Tracks were measured within ArcMap (ArcGIS 9; www.esri.com) to a precision of 0.1 mm.

Analyses

Our analytical method broadly follows that described by Zielinski and Truex (1995).

Repeatability To test the repeatability of track measurements, an additional five 'repeat' measures of six track variables (that varied in their relative magnitude) were taken non-sequentially from a subset of five of the mink tracks. The variation among individuals was compared with the variation within individuals (repeated measures) using nested analysis of variance (ANOVA). Measurement error was calculated as the percentage of overall variance attributable to within-individual (repeat) measurements (Bailey and Byrnes 1990).

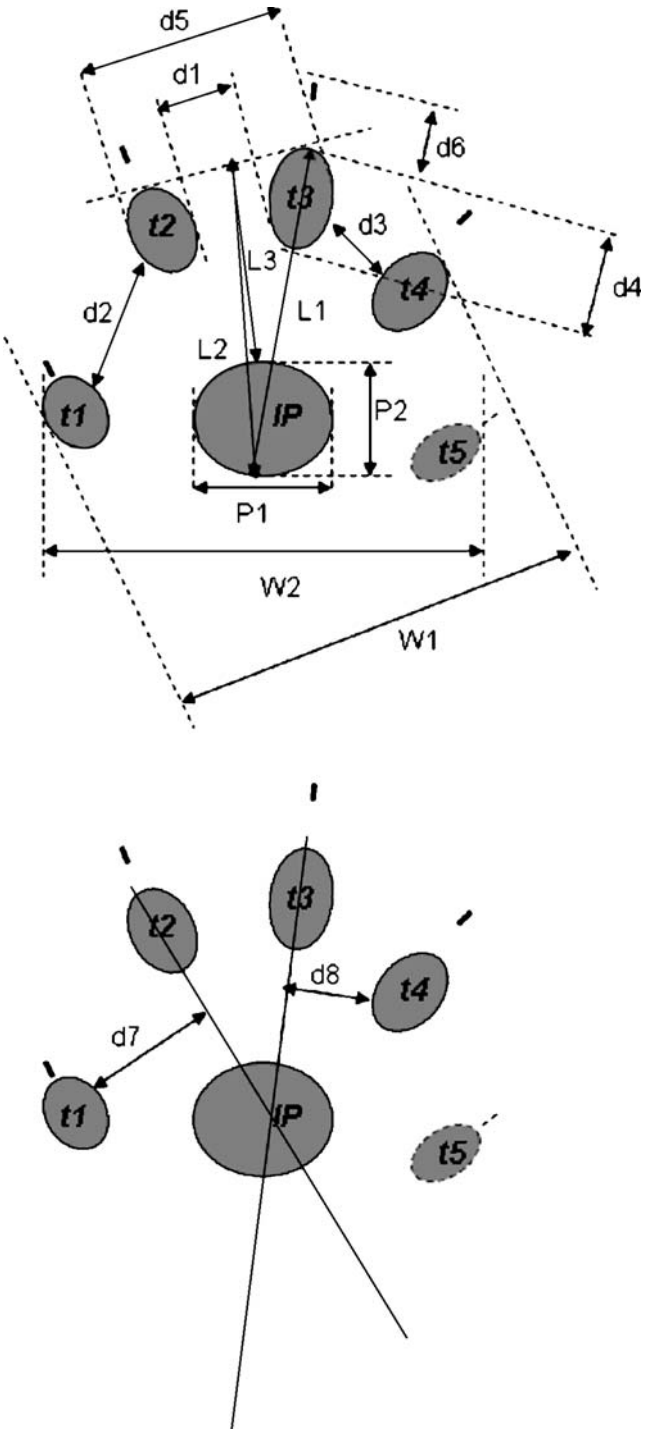

Fig. 1 Schematic showing track measurements: *W1* Greatest distance between t1 and t4, *W2* greatest distance between t1 and t5, *L1* greatest distance between the top of t3 and the bottom of the interdigital pad, *L2* greatest distance between the top of t2–t3 and the bottom of the interdigital pad, *L3 L2* measured to the top of the interdigital pad, *d1* smallest distance between t2 and t3, *d2* smallest distance between t1 and t2, *d3* smallest distance between t3 and t4 (the measurement *d*2 does not need to be distinguished from *d*3 because the mean of the two measures is used as a variable), *P1* greatest width of the interdigital pad, *P2* greatest length of the interdigital pad, *d4* greatest length of the toe pad of t3, *d5* greatest distance between t2 and t3, *d6* straight line distance from top of toe pad of t3 to the tip of the claw mark, *d7* smallest distance between a line bisecting t2 and t1, *d8* smallest distance between a line bisecting t3 and t4 (as for *d*2 and *d*3, *d*7 and *d*8 do not need to be distinguished from one another)

Gross morphology To examine the overall size of tracks among species-sex groups, we calculated 95% confidence intervals and ranges for the width (*W*1 and *W*2) and length (*L*1, *L*2 and *L*3) of all tracks and tested for statistical differences among groups using ANOVA (with species-sex included as a single factor), and Tukey's test for pairwise differences. We separated the sexes in this initial analysis of overall size differences to take account of the sexual dimorphism found in both mink and polecats.

Univariate analyses and variable reduction To allow the use of right and left foot tracks without distinguishing between them, we used the mean of pairs of non-symmetrical measurements in analyses (i.e. mean of *d*2 and *d*3, of *d*1, *d*2 and *d*3, and of *d*7 and *d*8); including linear measurements and ratios between them, this gave a total of 22 variables for analysis. To reduce the number of variables used in a multivariate analysis and to identify those that were most precise, reliable, easily measured and allowed the greatest inter-specific discrimination, we calculated standard deviations, coefficients of variation (CV), number missing and the inter-specific effect size of all variables. We also used correlation matrices to eliminate highly correlated variables, in which case, we retained the variable with the best combination of large effect size and low CV. For all selected candidate variables, we used a *t* test to test for inter-specific differences (α adjusted for multiple tests using the Bonferroni correction).

In all analyses, we treated track, rather than individual, as the experimental unit because nested ANOVA including species, individual and track demonstrated that track (rather than individual) accounted for most variation not attributable to species (average 30.10%; cf. Zielinski and Truex 1995).

Multivariate analyses We used linear discriminant function analysis to develop an algorithm capable of distinguishing tracks of adult mink and polecat. Variables initially used in discriminant function analysis were selected on the basis of univariate results. To develop the simplest discriminant function possible, we excluded variables one at a time and eliminated those that resulted in the least reduction in classification success until we obtained a model with an acceptable number of variables and a classification success greater than 95%.

We examined covariance matrices to test for homogeneity and searched for outliers using Mahalanobis distance (Tabachnick and Fidell 1989). We used Mahalanobis distance to test the significance of discriminant functions, and we assessed the classification success of each discriminant function independently using a separate test dataset. None of the tracks in the test dataset were used in the process of developing the discriminant function.

Results and discussion

We obtained 56 tracks from 12 mink (five males, six females, one unknown) and 63 tracks from nine polecats (three males, six females; mean male mink weight= 1,460 g, mean female mink=840 g; mean male polecat= 1,510 g; mean female polecat=1,030 g). A subset of five mink (one male, four females) and three polecats (one male, two females) were selected at random and extracted to form a separate test dataset to assess the classification success of discriminant functions, leaving 35 tracks from seven mink (four males, two females, one unknown) and 47 tracks from six polecats (two males, four females) that were used for preliminary univariate analyses and in developing the discriminant function.

Repeatability For all track measures tested, among-individual variation was greater than within-individual variation (all $F_{4,20}>82$, $p\leq0.0001$). Measurement error varied between 1.11 and 5.79%.

Gross morphology Male mink tracks were statistically significantly wider (*W*1 and *W*2) than those of polecats of both sexes and those of female mink ($p<0.01$, Tukey's test, individual error rate; for *W*1, there was also a statistically significant difference between the sexes in polecats). There was no overlap among 95% confidence intervals for male mink and polecats. However, ranges did overlap, and therefore, width could not be used as a distinguishing feature between species.

In both species, tracks of males were significantly longer (*L*1, *L*2 and *L*3) than those of females ($p<0.01$, Tukey's test, individual error rate) but were similar for same sex individuals between species.

Claw marks were apparent in 74% of mink tracks and 98% of polecat tracks. Sidorovich (1999) suggested that polecat claw marks are crooked rather than straight, as in mink tracks. We did find 'crooked' claw marks more often in polecat tracks than in mink tracks (37 vs 3%). However, the high proportion of polecat tracks with apparently straight claw marks (63%) meant that this was not a reliable distinguishing feature.

Univariate analyses and variable reduction We selected six variables (*W*1, *W*1/*L*3, *d*1, *d*4, *W*1/*d*5 and mean *d*7, *d*8) for development of the discriminant function. All of these variables differed statistically between species (*t* test, $p<0.008$, Bonferroni corrected for six tests). One variable (*d*6) also differed statistically between species (*t* test: $t_{46}=-7.58$, $p<0.001$) but was excluded from multivariate analyses because the measurement was missing in 59% of mink tracks and was highly variable in polecat tracks (CV= 40.5%). Where long claws are visible, tracks can fairly

Table 1 Classification success of four discriminant functions using the original development dataset (from seven mink and six polecats) and an independent test dataset (from five mink and three polecats)

Variables	D^2	F, df, p	Proportion correctly classified	
			Original dataset	Test dataset
*W*1 *W*1/*L*3 *d*1 *d*4 *W*1/*d*5 mean *d*7,*d*8	11.45	28.67, 6,64, <0.0001	0.986	1.000 (n=32)
*W*1 *W*1/*L*3 *d*1 *W*1/*d*5 mean *d*7,*d*8	11.28	34.42, 5,65, <0.0001	0.972	1.000 (n=32)
*W*1 *W*1/*L*3 *d*1 mean *d*7,*d*8	11.16	43.23, 4,66, <0.0001	0.958	0.969 (n=32)
*W*1 *d*1 mean *d*7,*d*8	9.97	4.12, 3,69, 0.0095	0.973	0.939 (n=33)

All tracks were collected from clay-based tracking plates, Upper Thames Valley, Oxford, 2005.
D^2 Mahalanobis distance

reliably be designated as polecats if the distance from the top of the toe pad to the top of the claw mark is greater than 6 mm. However, for values of less than 6 mm, tracks may belong to either mink or polecat and multivariate analyses are necessary. Similarly, large values of *d*1 may be used as an approximate 'rule of thumb' (>4 mm=mink, but <4 mm may be either species).

Multivariate analyses: discriminant analysis A model based on all six selected variables correctly classified 98.6% of tracks and 100% of the test dataset tracks (Table 1). The simplest model, however, included three variables (*W*1, *d*1 and mean *d*7,*d*8) and achieved a classification success of 97.3% (93.9% on the test dataset; Fig. 2).

There was no substantial deviation from homogeneity in the covariance matrix and no outliers (based on Mahalanobis distance).

Classification guidelines We present the following classification algorithm to distinguish between mink and polecat tracks on tracking rafts:

$$\text{If } 1.70 - 0.75(W1) + 2.43(d1) + 1.85(\text{mean}\, d7, d8)$$

$$> 0, \text{ classify the track as mink, if}$$

$$< 0 \text{ classify the track as polecat.}$$

Clear, high-definition tracks are essential for precise measurement of component variables. This is easily achieved using tracking plates but requires maintenance of tracking plates and very smooth clay. On tracking plates used to detect the presence of mink, set in areas where it is known or suspected that polecats are present, we recommend that the clay is renewed and smoothed frequently to increase classification success.

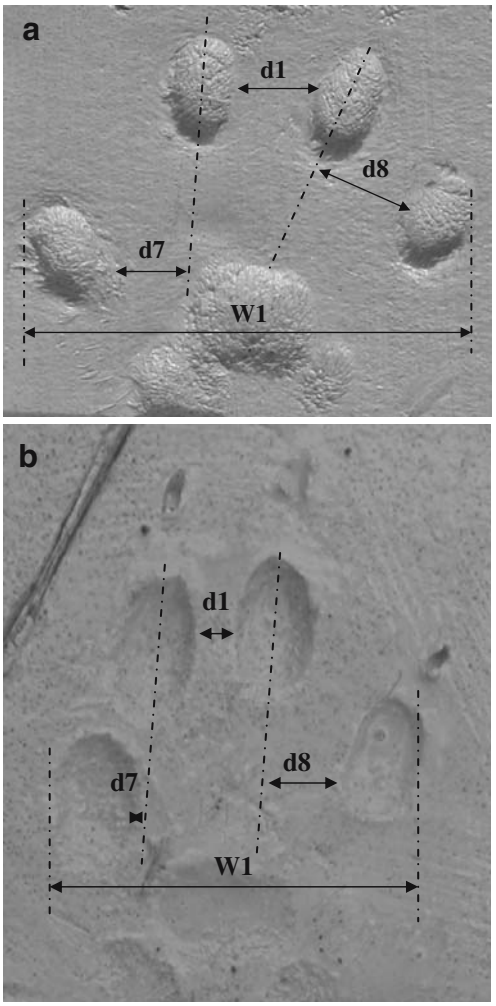

Fig. 2 Typical mink (**a**) and polecat (**b**) tracks showing the three basic measurements (*d*1, *W*1 and the mean of *d*7 and *d*8) required to distinguish between them. Note the wider spacing of the toe pads in the mink track compared with the polecat track and specifically the difference in *d*1 between the two species. Note also the positions of the two outer toe pads, in both tracks, relative to the rest of the track and to the inner toe pads, resulting in the overall appearance of a much wider track (relative to track length) in mink than in polecat

Measurements can be taken directly in the field using calipers. Alternatively, photographs of tracks can be taken (including a ruler for calibration) and measurements taken later, using calipers to measure tracks from prints or softwares such as ArcGIS or Photoshop (www.adobe.com) for digital measurements.

This algorithm has been developed using tracks on clay-based tracking plates. We do not know how well it will perform on tracks found on natural substrates or with running animals. It has also been developed for use on tracks of adult animals and cannot be used to identify tracks of juveniles, although this will only be a potential problem in summer. Further work is required to develop a classification algorithm that includes both juveniles and adults.

The ability to identify polecat tracks suggests that the potential exists to develop a terrestrial version of the tracking plates as a survey method and monitoring tool. Existing survey methods for polecats are limited and/or extremely labour intensive (e.g. Birks 1997). We do not know whether a track-based method would prove to be either reliable or efficient for polecats, but tracking tunnels are a standard method used to detect stoat presence (King and Edgar 1977). This possibility warrants further attention.

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References

Bailey RG, Byrnes J (1990) A new, old method for assessing measurement error on both univariate and multivariate morphometric studies. Syst Zool 39:124–130

Birks JDS (1997) A volunteer-based system for sampling variations in the abundance of polecats (*Mustela putorius*). J Zool 243:857–863

Harrington LA, Harrington AL, Macdonald DW (2007) Estimating the relative abundance of American mink *Mustela vison* on lowland rivers: evaluation and comparison of two techniques. Eur J Wildl Res (in press), DOI 10.1007/s10344-007-0114-2

King CM, Edgar RL (1977) Techniques for trapping and tracking stoats (*Mustela erminea*): a review, and a new system. NZ J Zool 4:193–212

Macdonald DW, Harrington LA (2003) The American mink: the triumph and tragedy of adaptation out of context. NZ J Zool 30:421–441

Reynolds JC, Short MJ, Leigh RJ (2004) Development of population control strategies for mink *Mustela vison*, using floating rafts as monitors and trap sites. Biol Conserv 120:533–543

Rondinini C, Ercoli V, Boitani L (2006) Habitat use and preference by polecats (*Mustela putorius* L.) in a Mediterranean agricultural landscape. J Zool 269:213–219

Sidorovich VE (1999) How to identify mustelid tracks. Small Carniv Conserv 20:22–27

Strachan R (1995) Mammal detective. Whittet, London, p 128

Tabachnick BG, Fidell LS (1989) Using multivariate statistics, 2nd edn. Harper Collins, New York

Zielinski WJ, Truex RL (1995) Distinguishing tracks of marten and fisher at track-plate stations. J Wildl Manage 59:571–579