

Demography of three populations of American mink *Mustela vison* in Europe

L. BONESI*†, L. A. HARRINGTON*, T. MARAN‡, V. E. SIDOROVICH§
and D. W. MACDONALD*

*Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Tubney House, Tubney, Abingdon, OXON OX13 5QL, UK, †Department of Biology, University of Trieste, Via Weiss 2, 34127 Trieste, Italy, ‡Foundation 'Lutreola', Paldiski Road 145, 13522 Tallinn, Estonia, §Vertebrate Predation Research Group, Institute of Zoology, National Academy of Sciences of Belarus, 27 Akademicheskaya St., BY-220072 Minsk, Belarus

ABSTRACT

1. Demographic data on an invasive species of management concern, the American mink, are presented. Data were obtained on three feral mink populations in Europe distinguished by differences in the time elapsed since population establishment.
2. Demographic data are presented in the form of life tables, age–sex distributions and sex ratios. Mink lived a maximum of 6 years, and mortality of 1-year-olds and adults differed substantially between populations.
3. The data support the hypothesis that mink populations subject to culling have a higher proportion of young (less than 1 year old) to adults compared with non-culled populations.

Keywords: age structure, culling, life tables, mortality, sex ratio

INTRODUCTION

Demographic data on mammals are difficult to gather, but their availability is often a prerequisite for conservation, management and modelling. Here, we present demographic data for the American mink, a species native to the Nearctic region, but introduced to many countries around the world for commercial fur production. We derived demographic parameters using data obtained from culling operations carried out on three island populations of feral mink. Previous demographic studies on mink have been based predominantly on capture-mark-recapture data where only two age classes can be distinguished, juveniles and adults (e.g. Gerell, 1971; Smal, 1991). More detailed studies of mink mortality have been conducted in captivity (e.g. Schneider & Hunter, 1993), but it is not possible to extrapolate these results to wild or feral populations because they are subject to different selective pressures. The use of culling data for demographic studies offers the advantage of allowing precise age assessment and thus calculation of age-specific demographic parameters.

METHODS

Study areas and history of mink populations

We obtained mink carcasses from culling operations on three islands: (i) Hiiumaa (Estonia); (ii) South Harris (UK); and (iii) North Uist (UK) (Fig. 1). Hiiumaa island (c. 1000 km²) is part of the western Estonian archipelago in the Baltic Sea, about 22 km from the Estonian mainland. Having been introduced to fur farms on the island, the first confirmed report of

Correspondence: L. Bonesi. E-mail: lbonesi@units.it



Fig. 1. Map locations of the study areas and detailed map of the Hebrides showing South Harris and North Uist.

feral American mink on this island was in 1983, although escapees are believed to have established in the wild much earlier than this (Maran, 1991). Captive breeding on the island ceased in 1996 and the last captive animal was killed in 1998. The Isles of South Harris (*c.* 300 km²) and North Uist (*c.* 600 km²) are both part of the Outer Hebrides, off the west coast of Scotland (Fig. 1). South Harris is connected by land to the larger islands of North Harris and Lewis. Mink were introduced to Lewis for fur farming where they have been present as a feral population since at least the 1960s, although they did not reach South Harris until the 1980s (Vincent Wildlife Trust Survey data, cited in Swan, 1999). The last fur farm on Harris and Lewis closed in 1961 (Dunstone, 1993). There has never been a fur farm on North Uist; therefore, mink are thought to have reached the island using the islets of The Sound of Harris, a strait of *c.* 15 km that separates the Isle of North Uist from South Harris, as 'stepping stones'. Although there have been sporadic sightings of mink on North Uist since the mid-1970s, mink were only confirmed on the island in the summer of 1999 (Harrington *et al.*, 1999). From North Uist, mink have continued to spread down the Western Isles to Benbecula and South Uist and are currently the focus of an EU-LIFE-funded cull (Moore, Roy & Helyar, 2003).

Culling campaigns

Details of the culling campaigns conducted in the three studied areas are reported in Table 1. Our sample from Hiiumaa included all 41 of the mink captured between December 1998 and April 1999. Following the removal of 50 mink, the island was believed to be mink-free (Macdonald *et al.*, 2002); thus, our sample represents 82% of the entire population. From South Harris, we obtained a sample of 156 mink captured between October 1992 and May 1995 during intensive culling along the south coast in an attempt to reduce dispersal across the Sound of Harris. Our sample represents about 50% of the total captures. Hudson & Cox (1989) estimated 15 000–18 000 mink on Harris and Lewis (assuming a sex ratio of 1:1), while the later estimates of Moore *et al.* (2003) were between 50% and 70% lower than those of

Table 1. Details of culling campaigns

	Hiiumaa*	South Harris	North Uist
Reason for culling	Eradication	Local control	Eradication/distribution assessment
Culling started	December 1998	~1970	October 1999
Culling ended	December 1999	Ongoing	Ongoing
Estimated no. mink	50	7500–9000 females†	180–325 females‡
No. mink culled	50	~750 mink/year†	42 in first 7 months
Trap nights	~3850 trap nights	Variable	5958 trap nights over 7 months

One 'trap night' is one trap out for one night.

*Macdonald *et al.* (2002).

†Hudson & Cox (1989): these data are for the Isles of Harris and Lewis as a whole.

‡Moore *et al.* (2000).

Hudson and Cox. From North Uist, our sample included 39 of the 42 individuals captured throughout the entire island during intensive culling between October 1999 and April 2000. On Hiiumaa mink were captured using leghold traps, while on South Harris and North Uist cage traps were used, and in both cases mink were humanely killed following capture.

Age assessment

Mink were aged by Matson's Laboratory (PO Box 308, Milltown, MT 59851, USA) using counts of incremental cementum annuli of the upper left canine. Cementum annuli in mink are quite distinct and the pattern regular, so the method is accepted for ageing this species (Matson, 1981). The reliability of estimated age was assessed for each tooth during analysis by comparison with a standardized species-specific model. Reliability was rated as *high*, *medium* or *low*, corresponding to estimated accuracies of ± 0 , 1 and 2 years, respectively.

For the purpose of the analysis, we assumed that all mink were born on 1st May (Dunstone, 1993). We define a *juvenile* mink as one between 3 months and 6 months of age, a *subadult* as between 7 months and 1 year, and an *adult* as 1 year or older. The youngest individual caught in our study was almost 3 months old; therefore, the data do not include *kits* (defined as individuals less than 3 months of age and usually still with their mothers, cf. Yamaguchi & Macdonald, 2003).

Mink reproduce seasonally and their populations can be defined as 'birth pulse populations' (Caughley, 1977), so we expect age distributions of mink measured at different times of the year to differ, but to be the same when measured at the same time over consecutive years. For this reason, mink populations are only comparable when considering culling (or live-trapping) data over the same period. To take these limitations into account, we divided the year into two parts: before and after breeding. *Pre-breeding* populations included all mink culled between November and May (inclusive), i.e. *after* dispersal (August–October) and *before* kits leave the den (mid-end of June) (Dunstone, 1993). *Post-breeding* populations included all mink culled between June and October (inclusive). Thus, pre-breeding populations include only subadults and adults (if present kits would have been below ground in dens and thus not trapped); post-breeding populations may include all age classes except subadults and would be expected to include a large proportion of dispersing juveniles.

Due to the lack of post-breeding data from Hiiumaa, to be able to compare age and sex structures of the three populations, we limited this particular analysis to the pre-breeding populations only.

Life tables

We used static life tables (Lowe, 1969; Caughley, 1977) where the data describe the age distribution of a population at a given point in time. We used Caughley's (1977) method 3 to calculate survival and mortality rates as this method does not require knowledge of the rate of increase and does not assume a stable age structure. Although this method does require individuals to be marked at birth, this assumption was fulfilled by the fact that they shared a common birthdate (cf. McDonald & Harris, 2002). We excluded North Uist from the life table analyses because the sample size was too small.

As all mink on Hiiumaa were culled between December and April, for this population we were able to calculate only the pre-breeding life table. Thus, for comparative purposes, for South Harris we calculated two life tables: one for the year-round data (which allowed us to assess juvenile mortality rates) and one for the pre-breeding data only (for comparison with the Hiiumaa life table).

We calculated the mean annual adult mortality rate for each population by dividing the sum of the mortality values (d_x) for all adult age classes by the sum of the corresponding l_x values, where l_x is the proportion of individuals in the population surviving at the start of the age interval (Caughley, 1977).

RESULTS AND DISCUSSION

Culling results

On both Hiiumaa and North Uist the bulk of the culling occurred during the pre-breeding season, while on South Harris mink were culled throughout the year. As expected, the post-breeding sample from South Harris comprised predominantly juveniles with few 1- and 2-year-olds (Fig. 2). The very youngest animals of this sample were almost 3 months old and captured at the end of July. On North Uist, there was limited culling during the summer; most mink were captured during the intensive culling session beginning in November and were therefore predominantly subadults (Fig. 2). As has been recorded elsewhere in the UK (e.g. Yamaguchi & Macdonald, 2003), despite relatively constant culling *effort* through the year on South Harris, culling *success* varied seasonally: most mink were culled during juvenile

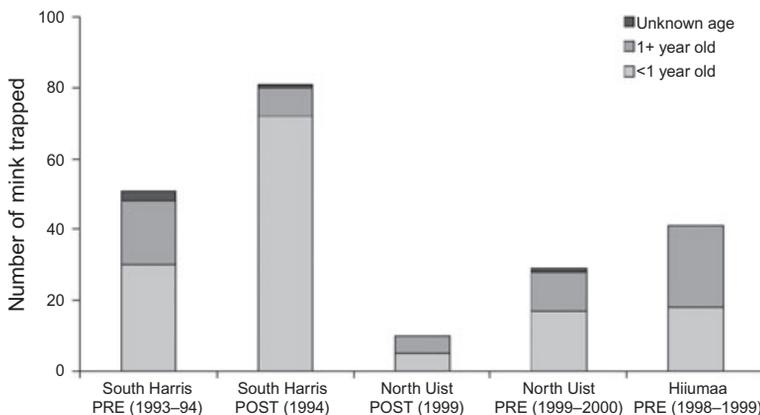


Fig. 2. Number of mink culled at different times of the year in all three populations. The pre-breeding season (PRE) ranges from November to May, the post-breeding season (POST) from June to October. Numbers in parentheses indicate the years in which mink were culled.

dispersal (August–October) with a second minor peak during the mating season (January–March; Fig. 3).

Age structures and sex ratios

Reliability of the age assessment from cementum annuli was high (± 0 years) for 85%, 99% and 62% of the sample for Hiiumaa, South Harris and North Uist, respectively. Reliability in all other cases was rated medium (± 1 year). The oldest individual caught was a 6-year-old female captured on North Uist in August (reliability of this age assessment was medium); all other mink caught on North Uist were 2-year-old or younger. The oldest individuals on South Harris and Hiiumaa were 4- or 5-year-old, respectively (Table 2).

Limiting the comparative analysis to pre-breeding populations reduced our sample sizes to 41, 48 and 28 for Hiiumaa, South Harris and Uist, respectively. The pre-breeding age structure differed statistically between populations ($\chi^2 = 13.53$, d.f. = 6, $P = 0.04$, 3-, 4- and 5-year age classes combined; Fig. 4), being slightly biased towards adult individuals (>1 year old) on Hiiumaa and towards younger ones (<1 year old) on North Uist, while being almost even on South Harris (Table 2). The island of Hiiumaa hosted a relatively stable, non-culled mink population (Macdonald *et al.*, 2002) and exhibited an adult-biased age structure that can only develop if the population is not affected by regular culling (Whitman, 2003). In

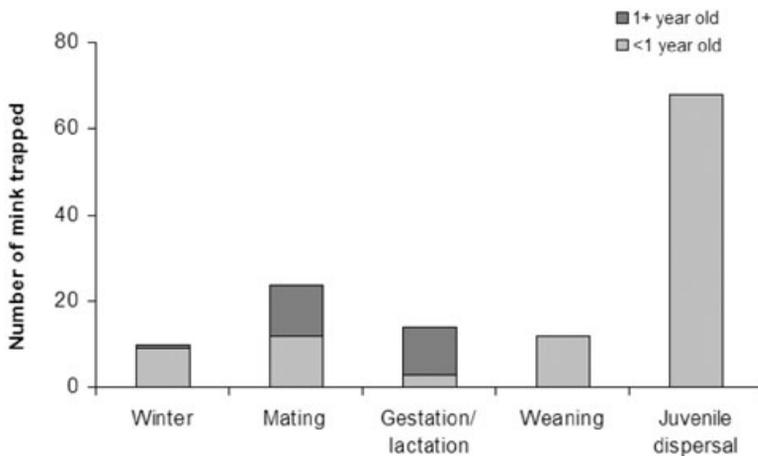


Fig. 3. Number and age of mink culled at different stages of the mink's yearly cycle on South Harris. Winter: November to December; mating: January to March; gestation/lactation: April to June; weaning: July; juvenile dispersal: August to October.

Table 2. Comparison of the pre-breeding populations in the three islands

	Hiiumaa	South Harris	North Uist
% Young (<1 year)	44%	52%	57%
Maximum age (years)	5	4	2
Mean age (years)	1.54	1.15	0.78
Sex ratio (males : females)	0.8	1.0	1.5
Culled frequently?	No	Yes	No
Age of mink populations (years)	~20	~30	~5
Sample size	41	48	28

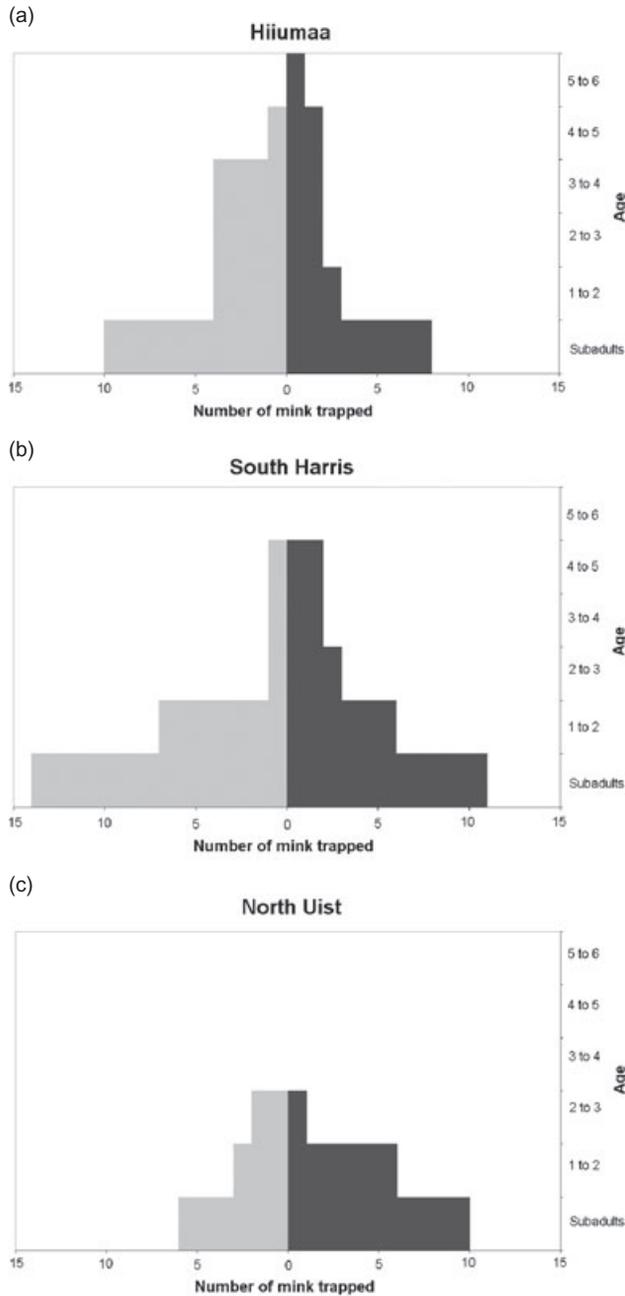


Fig. 4. Age–sex structures of male (black) and female (grey) mink calculated on the pre-breeding populations.

contrast, the island of South Harris hosted a relatively stable population where mink were culled annually, but where losses were rapidly replenished by newborns (Moore, Robertson & Aegerter, 2000). If culling occurs frequently, such as on South Harris, we expect a larger proportion of younger animals in the population compared with non-culled populations

(Dunstone, 1993; Sidorovich, 1997; Whitman, 2003). This is effectively what we observed when comparing South Harris with Hiiumaa (Table 2).

Pre-breeding sex ratios did not differ statistically from 1:1 in any of the three populations (South Harris $\chi^2 = 0.00$, d.f. = 1, NS; North Uist $\chi^2 = 1.29$, d.f. = 1, NS; Hiiumaa $\chi^2 = 0.61$, d.f. = 1, NS) (Table 2). The sex ratio on North Uist calculated on the whole sample was, however, biased towards males with 2 males : 1 female ($\chi^2 = 4.33$, d.f. = 1, $P = 0.04$, $n = 39$).

Life tables

The pre-breeding life tables for South Harris and Hiiumaa, respectively are shown in Table 3a and b. Subadult mortality in the pre-breeding season was high in both populations. Mortality of 1-year-old mink, however, while very high on South Harris, was low on Hiiumaa, where having passed the first year of life the chances of getting to be at least 3 years old were relatively high. Mean adult mortality of the pre-breeding populations was 0.57 and 0.30 for South Harris and Hiiumaa, respectively. The higher mortality rates of 1-year-old mink on South Harris compared with Hiiumaa may be partly explained by culling but may also be due to more intense intraspecific competition due to the higher population density on South Harris. On Harris and Lewis mink were estimated to be present in their thousands in an area of *c.* 2000 km² (Hudson & Cox, 1989; Swan, 1999), while on Hiiumaa only 50 mink were present in an area of *c.* 1000 km², hence densities on Harris and Lewis were likely to be at least two orders of magnitude greater than those on Hiiumaa.

Calculation of the life table for the South Harris population based on year-round data is shown in Table 3c. Of the 97 mink under 1 year, 72 were juveniles and 25 were subadults. When calculated separately for juveniles and subadults, mortality rate was respectively, 0.65 and 0.16, indicating that juvenile mortality was high as expected and as reported previously by other authors (e.g. Dunstone, 1993), but that having survived the juvenile stage, the chances of surviving as a subadult were fairly high. Juvenile and subadult mortality rates refer to the chance of dying over the 3 months of being a juvenile and the 6 months of being a subadult, respectively, and are thus greater than that for an adult in real terms. However, the fact that very few adults were captured in the post-breeding season (June–October, $n = 8$) compared to the pre-breeding season (November–May, $n = 23$) suggests that juvenile mortal-

Table 3. Static life history table of the mink population on the islands of South Harris and Hiiumaa

<i>x</i>	(a) South Harris – pre-breeding				(b) Hiiumaa – pre-breeding				(c) South Harris – all year			
	<i>n_x</i>	<i>d_x</i>	<i>l_x</i>	<i>q_x</i>	<i>n_x</i>	<i>d_x</i>	<i>l_x</i>	<i>q_x</i>	<i>n_x</i>	<i>d_x</i>	<i>l_x</i>	<i>q_x</i>
Juveniles	–	–	–	–	–	–	–	–	72	0.65	1.00	0.65
Subadults	25	0.48	1.00	0.48	18	0.61	1.00	0.61	25	0.06	0.35	0.16
1	13	0.36	0.52	0.69	7	0.06	0.39	0.14	21	0.24	0.29	0.81
2	4	0.04	0.16	0.25	6	0.00	0.33	0.00	4	0.01	0.06	0.25
3	3	0.00	0.12	0.00	6	0.17	0.33	0.50	3	0.00	0.04	0.00
4	3	0.12	0.12	1.00	3	0.11	0.17	0.67	3	0.04	0.04	1.00
5	0	0.00	0.00		1	0.06	0.06	1.00	0	0.00	0.00	
6					0	0.00	0.00					

The first two life tables (a and b) include mink culled during the pre-breeding season only, the last one (c) includes mink culled all year round between November 1993 and October 1994. Where *x* = age class; *n_x* = number of mink in each age class; *d_x* = proportion dying within age interval; *l_x* = proportion surviving at start of age interval; *q_x* = mortality rate

ity might have been overestimated in this population. It is possible that juveniles were entering traps more readily than adults, a phenomenon known to occur in mink (Ireland, 1990), thereby effectively reducing the probability of trapping adults in the post-breeding season by occupying all the available traps.

Mink on North Uist: demography of a colonizing population

Mink were confirmed to be present on the island of North Uist in 1999 only a few months before our sample was collected, thus the population was considered to be still in the colonizing stages. The North Uist population differed from both the South Harris and Hiiumaa populations in that it was characterized by young and predominantly male individuals (Table 2). It is possible that these young individuals were 'dispersers' from South Harris and the reason why they were predominantly males may be due to the fact that, in mustelids, males are expected to disperse longer distances (Biggins *et al.*, 1985) and male mink swim further (Bjornsson & Hersteinsson, 1991) than females. The capture in early August 1999 of three females that showed signs of lactating also suggests that mink on North Uist might have been already breeding.

ACKNOWLEDGEMENTS

Mink from South Harris were trapped by the Lewis and Harris Mink Control Unit, from North Uist by the Uist Mink Group, where our work was funded by Scottish Natural Heritage (SNH), and from Hiiumaa by Vadim Sidorovich and Tiit Maran, where our work was funded by a grant to David Macdonald by the Darwin Initiative. We thank Alison Rothwell for information on the South Harris control operations, and Sandra Baker, Nicola Rooney and Mike Thom for help with the post-mortems. We also thank Danielle Clode, Robbie McDonald, Ian Newton and Georgina Mace kindly made comments on earlier drafts.

REFERENCES

- Biggins, D.E., Schroeder, M.H., Forrest, S.C. & Richardson, L. (1985) Movements and habitat relationships of radio-tagged black-footed ferrets. In: *Black-Footed Ferret Workshop Proceedings* (Ed. by S.H. Anderson & D.B. Inkley), pp. 11.1–11.7. Wyoming Game and Fish Department, Cheyenne, Laramie, Wyoming.
- Bjornsson, T. & Hersteinsson, P. (1991) Mink in southern Breidfjordur Bay. *Wildlife Management News (Iceland)*, **7**, 3–12.
- Caughley, G. (1977) *Analysis of Vertebrate Populations*. Wiley, London.
- Dunstone, N. (1993) *The Mink*. Poyser, London.
- Gerell, R. (1971) Population studies on mink *Mustela vison* in southern Sweden. *Oikos*, **8**, 83–109.
- Harrington, L.A., Grogan, A.L., Bonesi, L. & Macdonald, D.W. (1999) *Survey of American Mink, Mustela Vison, on North Uist*. Unpublished report to Scottish Natural Heritage, Wildlife Conservation Research Unit, Oxford.
- Hudson, P.J. & Cox, R. (1989) *Mink Problems in the Outer Hebrides: A Pilot Study*. *The Game Conservancy Annual Review of 1988*. pp. 133–135.
- Ireland, M.C. (1990) The behaviour and ecology of the American mink *Mustela vison* Schreber in a coastal habitat. PhD Thesis. University of Durham, Durham, UK.
- Lowe, V.P.W. (1969) Population dynamic of the red deer (*Cervus elaphus* L.) on Rhum. *Journal of Animal Ecology*, **38**, 425–457.
- Macdonald, R.A. & Harris, S. (2002) Population biology of stoats *Mustela erminea* and weasels *Mustela nivalis* on game estates in Great Britain. *Journal of Applied Ecology*, **39**, 793–805.
- Macdonald, D.W., Sidorovich, V.E., Maran, T. & Kruuk, H. (2002) *The Darwin Initiative – European Mink Mustela lutreola: Analyses for Conservation*. Wildlife Conservation Research Unit, Oxford.
- Maran, T. (1991) Distribution of the European mink, *Mustela lutreola*, in Estonia: an historical review. *Folia Theriologica Estonica*, **1**, 1–17.
- Matson, G.M. (1981) *Workbook for Cementum Analysis*. Milltown, MT.
- Moore, N., Robertson, P.A. & Aegerter, J.N. (2000) *Feasibility Study into the Options for Management of Mink in the Western Isles*. CSL, MAFF, London.

- Moore, N.P., Roy, S.S. & Helyar, A. (2003) Mink (*Mustela vison*) eradication to protect ground-nesting birds in the Western Isles, Scotland, United Kingdom. *New Zealand Journal of Zoology*, **30**, 443–452.
- Schneider, R.R. & Hunter, D.B. (1993) A survey of the causes of mortality in adult mink, with emphasis on the lactation period. *Canadian Veterinary Journal*, **34**, 103–108.
- Sidorovich, N.V. (1997) Plasticity and decline of reproduction in the American minks. In: *Mustelids in Belarus* (Ed. by N.V. Sidorovich), pp. 170–172 Zolotoy Uley publisher, Minsk.
- Smal, C.M. (1991) Population studies on feral American mink *Mustela vison* in Ireland. *Journal of Zoology*, **224**, 233–249.
- Swan, C.A. (1999) *An Appraisal of the Mink Situation on Harris and Lewis in the Outer Hebrides and the Possibilities of an Eradication Scheme*. The Game Conservancy Trust, Fordingbridge.
- Whitman, J.S. (2003) Age structure differences in American mink, *Mustela vison*, populations under varying harvest regimes. *Canadian Field Naturalist*, **117**, 35–38.
- Yamaguchi, N. & Macdonald, D.W. (2003) The burden of co-occupancy: intraspecific resource competition and spacing patterns in American mink, *Mustela vison*. *Journal of Mammalogy*, **84**, 1341–1355.

Submitted 2 March 2005; returned for revision 31 August 2005; revision accepted 1 April 2006
Editor: RM