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11

Diets of semi-aquatic carnivores in northern Belarus, with implications for population changes

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Introduction

In this chapter we present data on the diet of the guild of semi-aquatic carnivores, the European mink (*Mustela lutreola*), the American mink (*M. vison*), the polecat (*M. putorius*) and the otter (*Lutra lutra*). These species share habitats in rivers, streams and lakes in northern Belarus. The data are used to test predictions from the hypothesis that the decline of European mink is caused by changes in prey availability, or by competition for food with other carnivores within the guild.

There are a number of carnivore species in Europe that may be termed 'semi-aquatic', species that live close to water, and which capture at least part of their food by swimming and diving. These include the otter, which feeds mostly on fish and some amphibians (for summaries, see Mason & Macdonald, 1986; Kruuk, 1995), the European mink with a diet of amphibians, small mammals, fish and crayfish (Sidorovich, 1992*a*), the American mink, which has been introduced in many areas since the 1930s and which feeds on small mammals, fish, amphibians and crayfish (for review, see Dunstone, 1993), and the polecat with a diet of mostly small mammals and amphibians (Sidorovich, 1992*a*). There have been no studies of this whole complement of semi-aquatic predators in any one area, however. Such an approach is necessary in order to assess possible competition for food, to draw comparisons between the effects of prey species on different predators, and to study the effects of these species on each other.

The European mink has disappeared from large parts of its former range in Europe (Sidorovich 1992*b*; Chapter 17). It is present now only in small areas of France and Spain, and in areas east of Estonia, in north-eastern parts of Belarus and in restricted parts of Russia. Other semi-aquatic mammals have either held their own (polecat), or decreased far less dramatically (otter: Foster-Turley *et al.*, 1990), or have spread and substantially increased in numbers (American mink: Chapter 19).

A number of hypotheses have been put forward to explain the decline of *M.*

lutreola; here we test the idea that a change in food availability is the cause. In north-eastern Belarus there is an opportunity to investigate this possibility, in an area where the European mink is still present but declining (Sidorovich, 1992*b*), and where we can compare its feeding ecology with that of taxonomically close and ecologically similar species in the same area. We think that the possibility of changes in available prey biomass as a cause of population changes in such predators should be taken seriously. There are strong suggestions, at least in some areas, that prey populations may be limiting numbers of semi-aquatic predators such as the otter (Kruuk *et al.*, 1993; Kruuk, 1995).

Our hypothesis states that the decline in numbers of the European mink is caused at least partly by changes in food availability, because of either (i) declining prey populations or (ii) increased competition for food with other predators. Some predictions from (i), which we test here, are that:

P1 The European mink is a more highly specialized predator than the American mink, otter or polecat.
P2 The European mink is more dependent on prey that has declined and is declining that the other predators are.

Some predictions from (ii) are:

P3 There is a large overlap in diet with other predators that have increased in numbers.
P4 Such overlap occurs especially over prey species that are scarce.

In this chapter we will be concerned only with diet, and not with foraging behaviour; thus, we will not address the possibility of direct, aggressive competition over food between species.

Study areas

The observations were made in various water bodies in an area of about 20 km by 40 km, at the head of the River Lovat in Belarus (Vitebsk region, Gorodok district; 56 °N 32 °E). The area is wooded, with little agriculture and sparse human habitation; the dominant vegetation consists of alder (*Alnus glutinosa* and *A. incana*), birch (*Betula pubescens* and *B. pendula*), spruce (*Picea abies*), aspen (*Populus tremula*) and oak (*Quercus robur*). Preliminary data suggest that there is no significant pollution (V. Sidorovich, unpublished observations).

In this area the European mink was common in all aquatic habitats, but it has sharply declined in the few years leading up to 1995. The American mink is

now common, after its arrival in the study area in 1988 (Sidorovich, 1992*b*). Polecats are relatively common everywhere, but they are not confined to riparian strips, as are the other three species studied. The otter is common in all waters. Many of the water bodies are inhabited (and have been modified) by beaver (*Castor fiber*). Other common large predators include the wolf (*Canis lupus*), bear (*Ursus arctos*) and lynx (*Lynx lynx*).

The major aquatic habitats consisted of two glacial lakes, Lake Zavesno and Lake Zadrach, about 20 km apart, and various feeding streams and outflows. The river Lovat flows into Lake Zavesno, then on to Lake Zadrach, and later through a wide flood plain to Lake Mezha (outside our study area). As habitat categories we distinguished (i) fast-flowing streams and rivers, (ii) slow-flowing rivers (including drainage canals), and (iii) lakes.

1 Fast-flowing rivers and small streams. The flow rate is between 0.3 and 1.0 m/s, there is no flood plain, and the banks are mostly wooded. These include the River Lovat above Lake Zadrach, and below Lake Zadrach to the Ljahovsky drainage systems; the Servajka, Uzhovsky, Bibinsky, Borkovsky, Rudnjansky, Trubachovsky, Mahalovsky and Skljanka streams. These streams are shallow, may dry up in summer and they may be up to 8 m wide. The smaller ones may contain fish during only part of the year. The species diversity of fish is low (there are no salmonids), Crayfish (*Astacus astacus*) may be moderately abundant or absent; there are few water voles (*Arvicola terrestris*) and birds, but many common frogs (*Rana temporaria*).
2 Slow-flowing rivers and drainage canals. The rivers are up to 25 m wide and up to 2.5 m deep, with a flow rate less than 0.3 m/s. The flood plain along the margins tends to be covered in swamp dominated by bullrush (*Typha latifolia* and *T. angustifolia*) and reeds (*Phragmites communis*). Large-scale flooding occurs in spring. There is a considerable diversity of fish species (but this is low in the artificial drainage canals). Crayfish abundance is variable; water voles, birds and common frogs are common on the flood plains. In winter access by the animals to the rivers and drainage canals themselves may be limited because of ice.
3 Lakes Zavesno and Zadrach are about 40 ha and 100 ha in area, respectively, and up to about 5 m deep. They are surrounded by forest and also some agriculture. Both lakes have marginal reed beds and swamps. There are high densities and diversity of fish species. Crayfish fluctuate between very abundant and absent; water voles, birds and common frogs are very common. Often the animals have no access to water in winter, because the lakes freeze over.

Methods

We collected faeces at various dates between April 1988 and May 1995, mostly from dens or holts. Faeces were collected only if we had a positive identification of the species; this was made from the appearance of the faeces for otter (Mason & Macdonald, 1986). Scats of the two mink species and polecat were usually collected near dens, and the occupant was identified where possible from tracks (Sidorovich, 1994) or, more often, after capture with a box-trap at the entrance, before releasing the animal again.

In the laboratory, faeces were dissected dry, or washed with detergent. The contents were identified microscopically, using published keys of mammalian hair (Day, 1966; Teerink, 1970; Debrot *et al.*, 1982), fish scales and other bones (Galkin, 1953; Pucek, 1981) or pharyngeal teeth (Zhukov, 1965, 1988), amphibian bones (Bohme, 1977) and by comparisons with our own reference collection. It was decided to concentrate on aquatic and semi-aquatic prey, therefore most mammalian and bird remains in the faeces were identified to Class only. Hair of the carnivores themselves was ignored.

For statistical treatment results were expressed as the percentage of faeces containing a given prey category, and for a general overview prey occurrence as a percentage of all occurrences was calculated. For calculations of statistical significance the data were analysed using SAS (1991), using Kruskal–Wallis χ^2 approximation. Levels of significance are shown.

Results

A total of 4312 faeces were collected and analysed, 1930 from American mink, 1474 from European mink, 641 from otter and 267 from polecat. The prey categories identified are listed in the Appendix.

The results from all areas and seasons are summarized in Table 11.1. as the percentage of faeces containing a given prey category. Proportions of faeces containing each prey category were significantly different between predators, for all prey categories except 'other'. In American mink scats small mammals, amphibians and fish dominated and occurred about equally often; in European mink scats amphibians were by far the most important, with fish also present in large numbers; for otters fish dominated all other kinds of prey, closely followed by amphibians; polecat scats were usually full of small mammal remains, again followed in importance by amphibians. The prey category that was strikingly important for all four predators was amphibians.

In general, these same trends and differences were also present when the four predators were compared for different habitats: fast-flowing streams, slow-flowing rivers and lakes (Table 11.2). However, amphibians were less important for both mink species when feeding in lakes compared with rivers ($p < 0.05$), whereas crayfish were important to them especially in lakes ($p < 0.05$ and < 0.01). Most other differences in prey between habitats were not significant. When comparing the prey of the four predators within each habitat type, it was noticeable that differences were especially large in slow-flowing rivers.

Table 11.1. *Percentages of faeces of American and European mink, otter and polecat, containing various prey categories*

Species	No. of faeces	Small mammals	Amphibians	Fish	Crustaceans	Bird/ Reptiles	Other
American mink	1930	32.0	26.0	32.4	6.7	8.2	6.5
European mink	1474	14.5	56.5	26.6	10.9	3.5	7.6
Otter	641	0.3	45.1	61.2	14.5	1.7	1.2
Polecat	267	64.4	30.0	1.9	0.7	9.0	4.5
Significance:		***	***	***	**	*	n.s.

All habitats and seasons combined. The statistical significance is shown for differences between predator species for each prey category (Kruskal–Wallis χ^2 approximation, d.f. = 3). n.s., not-significant; *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

We obtained few samples during the autumn. Although there was considerable variation in diet between the seasons, little of that was statistically significant (Table 11.3). It was striking that, in spring, European mink faeces contained more amphibians than did the scats of any of the other predators ($p < 0.05$). American mink scats showed many more small mammal remains in winter ($p < 0.05$).

Amongst small mammal prey, the species identified most often for both American and European mink was the water vole (*Arvicola terrestris*). Polecats took many bank voles (*Clethrionomys glareolus*), and to a lesser extent so did American mink (see Appendix). Amongst amphibian prey, the common frog (*Rana temporaria*) was by far the most important for all four carnivores. *Rana arvalis* could not be distinguished from *R. temporaria* in the faeces, but was uncommon in the study area, where *R. temporaria* was abundant. Very few toads (*Bufo bufo*) were taken, despite their great abundance in the area. Fish

Table 11.2. *Prey remains in faeces from different habitats in north-east Belarus*

Species	No. of faeces	Prey categories: Small mammals	Amphibians	Fish	Crustaceans	Bird/Reptiles	Other
A. Fast-flowing streams							
American mink	1200	29.2	34.2	30.3	4.9	9.6	6.2
European mink	992	16.2	64.2	21.9	8.0	3.5	9.8
Otter	143	0.0	53.8	76.9	2.1	0.0	1.4
Polecat	53	64.2	34.0	3.8	0.0	5.7	3.8
Significance:		*	*	n.s.	n.s.	*	n.s.
B. Slow-flowing rivers							
American mink	466	35.5	51.2	14.1	1.9	6.2	6.0
European mink	337	16.0	68.9	14.3	10.3	3.1	11.5
Otter	399	0.4	36.1	57.1	26.7	1.2	0.2
Polecat	156	75.7	20.6	0.6	0.0	5.2	3.2
Significance:		***	*	***	**	n.s.	n.s.
C. Lakes							
American mink	264	36.3	12.8	29.5	14.5	5.4	11.5
European mink	145	19.9	42.4	29.1	24.5	6.6	2.8
Otter	99	0.0	30.3	52.5	38.4	1.0	4.0
Polecat	58	55.2	31.0	3.4	3.4	19.0	6.9
Significance:		n.s.	*	n.s.	n.s.	n.s.	n.s.

Table shows the number of faeces examined and the percentage of faeces containing prey remains.

prey was very varied for the three more aquatic predators; in otter spraints pike (*Esox lucius*), roach (*Rutilus rutilus*) and perch (*Perca fluviatilis*) predominated, and although these species were also important to the two minks, in their scats the fish diversity appeared to be greater than for otters.

To compare the overall diet diversity in the four carnivores, we calculated

Table 11.3. *The effects of seasonality: percentage of faeces containing prey categories*

	Spring	Summer	Autumn	Winter
A. American mink				
No. sampling periods	8	9	1	2
No. faeces	454	1210	48	218
Small mammal	23.8	25.8	35.4	83.0
Amphibians	53.7	17.1	50.0	11.9
Fish	20.5	41.9	27.1	6.0
Crustaceans	5.1	7.9	0.0	5.0
Birds/Reptiles	3.7	11.2	2.1	2.3
Others	5.7	7.4	4.2	3.7
B. European mink				
No. sampling periods	7	9	1	5
No. faeces	369	849	30	226
Small mammal	15.7	11.2	20.0	24.3
Amphibians	70.7	45.2	73.3	73.5
Fish	14.4	35.2	10.0	16.4
Crustaceans	9.2	12.5	0.0	8.8
Birds/Reptiles	4.9	3.5	3.3	1.3
Others	6.8	8.7	20.0	3.1
C. Otter				
No. sampling periods	4	1	1	1
No. faeces	357	99	143	42
Small mammal	0.6	0.0	0.0	0.0
Amphibians	46.2	30.3	53.8	40.5
Fish	55.2	52.5	76.9	78.6
Crustaceans	13.2	38.4	2.1	11.9
Birds/Reptiles	2.8	1.0	0.0	0.0
Others	0.6	4.0	1.4	0.0
D. Polecat				
No. sampling periods	3	2	1	3
No. faeces	61	89	53	64
Small mammal	34.4	61.8	64.2	96.9
Amphibians	60.7	28.1	34.0	0.0
Fish	1.6	2.2	3.8	0.0
Crustaceans	0.0	2.2	0.0	0.0
Birds/Reptiles	3.3	16.9	5.7	6.3
Others	9.8	4.5	3.8	0.0

Table 11.4. *Overlap of food niche (Pianka index), based on six prey categories*

	European mink	Otter	Polecat
American mink	0.83	0.79	0.78
European mink		0.86	0.58
Otter			0.27

Levin's index of niche breadth (Levin, 1968; Ciampalini & Lovari, 1985) for the six food categories. Thus, the index may vary between 1 and 6; it was 4.31 for American mink, 3.33 for European mink, 2.57 for otter, and 2.37 for polecat. This shows that the American mink had the most varied diet, and the polecat was the most specialized; both minks are considerably less specialized than either otter or polecat.

In order to evaluate the overlap in diet between the species we used Pianka's index (Pianka, 1973; Ciampalini & Lovari, 1985). Comparisons between the four carnivores are shown in Table 11.4. At the broad level of our prey categories there was a large overlap of prey selection by European mink with both American mink and otter. The lowest coincidence of prey species occurred between polecat and otter, and between polecat and European mink.

Discussion

The observations reported here are based on faecal analyses, and we do not have the necessary information to convert these into estimates of diet (as e.g. Lockie, 1959; Carss & Parkinson, 1996). Thus, in our comparisons between species we will assume that such conversion factors are substantially the same for all of them. It has been demonstrated for otters that when estimating diet from faecal analyses, even from very large samples, the actual percentage occurrence in the diet may be substantially different from that in the spraints (Carss & Parkinson, 1996).

Frequently taken prey and large items tend to be underestimated, rare prey and small items overestimated. Nevertheless, in these studies with captive animals the rank-order of importance of similar-sized prey was the same in diet and spraints. Clearly, we have to keep these reservations in mind when drawing conclusions from our analyses.

The observations in the Belarus study area suggest that the two mink species both occupy a food niche that is very wide, with a diet covering a spectrum of small mammals, amphibians, fish and various other prey. They are much more general predators than either otter or polecat, therefore. Our first prediction (P1) that European mink are more specialized than the others in this complement of semi-aquatic carnivores, is not borne out.

These trends appeared to hold, with small modifications, throughout the seasons and in the different habitats that we considered.

A second, important, prediction (P2) from our starting hypothesis was that European mink are more dependent on prey categories that are declining than the other predators are. Our data suggest that the most important single prey species for European mink is the common frog, occurring in almost half of the European mink's scats. We have no information on population trends for this species, but in the study area it was very abundant indeed, with numbers being relatively stable, and it has been so for a least the previous 10 years (densities of up to 12 frogs/10 m^2 of stream and riverbank: M. Pikulik, unpublished observations).

The common frog was also the single most important prey species in the diet of other predators that appear to be thriving, and frogs are extremely abundant in north-east Belarus. Thus, although there have been suggestions that many amphibians have declined everywhere (Pechmann *et al.*, 1991; Wake 1991), this was not likely to be the reason why this one predator declined and is still declining in our study areas.

The single prey species that is next in importance for the European mink, though far less important than frogs, is the crayfish, which is abundant in many places in our study area. There have been large fluctuations in crayfish populations in Eastern Europe, and the species has disappeared from many areas in Europe due to 'crayfish plague' (Maran & Henttonen, 1995). However, in our study area it is common, especially in lakes (our unpublished observations). It also appears to be at least as important to otters as it is to European mink, if not more so (see Appendix), and the evidence is that otter numbers are being maintained.

Thus, there is no evidence to link the observed decline of European mink in Belarus (Sidorovich, 1992*b*) to changes in biomass of its available main prey species, and our second prediction is not supported.

European mink are slightly more specialized than American mink, but between the two species there is a very large overlap in dietary interest, as there is also between European mink and otters. In the case of the otter, we are concerned with a species that has been present in the same areas as the European mink for a long time in evolutionary terms. The American mink, however, is a recent arrival (see Chapter 17). The coincidence of dietary interest between the two minks confirms our third prediction (P3), based on competition for food between the established European mink and the newly arrived American species.

Thus, the possibility of competition for food between these two in our study sites should be considered. The prey species that figured especially strongly in the zone of overlap were rodents and frogs. Our preliminary and unpublished observations suggest that both these categories were abundant. We were not able to quantify this, but competition between the two mink species for this resource did appear to be unlikely.

In many areas the decline in European mink predated the arrival of the American mink by many decades (see Chapter 17). On present evidence, this decline cannot be explained by competition for resources with the other semi-aquatic predators. Nor can we suggest some species-specific response to a declining resource as a cause, a response by only the European mink and different from that by the otter and polecat in the past, and different from those two as well as from the American mink more recently. Generally, the European mink has a very catholic diet compared with the otter and polecat, though perhaps slightly less so than the American mink.

In conclusion, our data do not provide support for the hypothesis that changes in availability of prey, or competition for prey, are a main cause for either the gradual long term or the accelerated recent decline of the European mink.

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Appendix

Percentages of the total number of occurrences of different prey, in faeces of European mink, American mink, otter and polecat. All habitats, all seasons combined. One occurrence is the observation of one prey (species, or category) in a scat.

American mink: $n = 2160$ occurrences (in 1930 faeces).
European mink: $n = 1763$ occurrences (in 1474 faeces).
Otter: $n = 795$ occurrences (in 641 faeces).
Polecat: $n = 295$ occurrences (in 267 faeces).

	American mink	European mink	Otter	Polecat
A. Mammals				
Total	28. 4	11. 9	0. 0	58. 7
Arvicola terrestris	2. 2	1. 8	0. 3	3. 1
Clethrionomys glareolus	2. 1	0. 7	0. 0	5. 8
Microtus agrestis	0. 4	0. 3	0. 0	2. 7
M. arvalis	0. 3	0. 1	0. 0	2. 4
M. oeconomus	0. 4	0. 1	0. 0	0. 0
Apodemus sylvaticus	0. 5	0. 0	0. 0	0. 0
Ondatra zibethica	0. 0	0. 0	0. 0	1. 0
Unidentified rodent	12. 3	4. 8	0. 0	38. 3
Neomys fodiens	0. 5	0. 3	0. 0	0. 0
Sorex spp.	3. 7	1. 4	0. 0	1. 7
Talpa europaea	0. 6	0. 1	0. 0	0. 0
Unidentified small mammal	5. 4	2. 3	0. 0	3. 7
B. Birds				
Total	5. 8	2. 7	1. 3	8. 1
Unidentified	5. 8	2. 7	1. 3	8. 1
C. Reptiles				
Total	1. 4	0. 3	0. 0	0. 0
Lacerta vivipara	0. 9	0. 1	0. 0	0. 0
Natrix natrix	0. 5	0. 2	0. 0	0. 0
D. Amphibians				
Total	22. 7	47. 4	35. 6	27. 2
Rana temporaria/arvalis	20. 5	46. 7	35. 3	24. 1
Rana esculenta complex	1. 7	0. 5	0. 3	0. 0
Bufo bufo	0. 5	0. 2	0. 0	3. 1
E. Fishes				
Total	31. 1	22. 8	49. 9	2. 0
Esox lucius	3. 0	1. 0	12. 0	1. 0
Abramis spp.	0. 4	0. 1	2. 3	0. 0
Alburnoides bipunctatus	1. 2	1. 1	0. 4	0. 0
Alburnus alburnus	2. 3	1. 1	2. 0	0. 0
Blicca bjoerkna	0. 4	0. 4	1. 1	0. 0
Leuciscus cephalus	1. 0	0. 5	0. 0	0. 0
L. idus	0. 4	0. 2	0. 6	0. 0
L. leuciscus	0. 8	0. 7	0. 0	0. 0
Rutilus rutilus	7. 4	4. 7	12. 4	0. 0
Scardinius erythrophthalmus	0. 5	0. 3	0. 8	0. 0
Unidentified cyprinid	0. 7	0. 1	0. 4	0. 0
Cobitis taenia	1. 8	2. 8	1. 1	0. 0
Misgurnus fossilis	0. 2	0. 3	1. 1	0. 0
Nemacheilus barbatulus	0. 2	0. 6	0. 0	0. 0
Lota lota	1. 1	0. 9	0. 0	0. 0
Gasterosteus aculeatus	1. 5	3. 5	1. 5	0. 0
Perca fluviatilis	5. 8	3. 4	9. 3	0. 0
Gymnocephalus cernus	1. 1	0. 6	2. 2	0. 0
Stizostedion lucioperca	0. 0	0. 0	1. 4	0. 0
Unidentified fish	0. 2	0. 5	0. 3	1. 0
F. Crustaceans				
Total	5. 9	9. 1	11. 9	0. 7
Astacus astacus	5. 9	9. 1	11. 9	0. 7
G. Insects				
Total	5. 0	5. 2	1. 0	3. 4
Dytiscus spp.	2. 4	4. 2	1. 0	1. 4
Unidentified insect	2. 6	1. 0	0. 0	2. 0
H. Molluscs				
Total	0. 3	1. 4	0. 0	0. 0
Unidentified mollusc	0.3	1.4	0.0	0.0
I. Vegetable matter				
Total	0.6	0.0	0.0	0.0
Bilberry	0.6	0.0	0.0	0.0

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