Folia Zool. – 58(1): 45–56 (2009)

Predation of the alien American mink, *Mustela vison* on native crayfish in middle-sized streams in central and western Bohemia

David FISCHER[1], Petr PAVLUVČÍK[2], František SEDLÁČEK[2, 3] and Martin ŠÁLEK[2, 3]*

[1] *Hornické museum Příbram, Březové Hory 293, 261 02 Příbram, Czech Republic*

[2] *Department of Zoology, Faculty of Science, University of South Bohemia, Branišovská 31, 370 01 České Budějovice, Czech Republic; *e-mail: martin.sali@post.cz*

[3] *Institute of Systems Biology and Ecology, v.v.i., Academy of Sciences of the Czech Republic, Na Sádkách 7, 370 05 České Budějovice, Czech Republic*

Received 18 January 2008; Accepted 3 November 2008

A b s t r a c t . The impact of predation by alien American mink (*Mustela vison*) on endangered stone crayfish (*Austropotamobius torrentium*) was examined in middle-sized streams in central and western Bohemia for the duration of two years. The most frequent food source of the American mink were crustaceans, followed by mammals, amphibians and fish. Crustaceans consisted entirely of one species, the stone crayfish, which was represented in 82% of all collected mink droppings. Analysis of the relative composition of summer and winter diet showed no significant differences between these periods. The identification of predation of the American mink on stone crayfish was based on the collection of prey remains during the period monitored. Predation rates at particular localities were highly variable (0.85–21.5%, average = 7.4%), and decreased significantly in winter periods. The use of crayfish seems to reflect their spatial availability, suggested by the good correspondence between the population density and the number of prey remains. Minks preyed selectively on sexually mature individuals, which increases the seriousness of their predation impact. This study suggests that alien mink could be an important mortality factor for stone crayfish populations on a local scale.

Key words: mink diet, stone crayfish, prey selectivity, density-dependent predation, Czech Republic

Introduction

The American mink *Mustela vison* is a non-native invasive species of a mammalian predator that has established feral populations across all of Europe (B o n e s i et al. 2006). Feral minks were introduced for the purpose of fur farming, but many of them escaped and became naturalized in various types of wetland habitats. In the Czech Republic, the first individuals were recorded in the wild at the beginning of the 1960s, but have recently been reported to occur throughout most of the country (M a z á k 1964, Č e r v e n ý et al. 2003).

The mink is a generalist predator, and its diet consists of a variety of aquatic and terrestrial prey, including small mammals, birds, fishes, amphibians, and crustaceans (e.g. J ę d r z e j e w s k a et al. 2001). Its diet changes significantly depending on potential food sources, seasonal variations of prey availability, different geographical ranges, and local habitat conditions (G e r e l l 1967, D u n s t o n e & B i r k s 1987, A n g e l i c i et al. 2000, S i d o r o v i c h 2000, J ę d r z e j e w s k a et al. 2001). Due to habitat plasticity as well as feeding opportunism, mink may be a limiting factor for prey populations (e.g. W o o d r o f f e et al. 1990, H a l l i w e l l & M a c d o n a l d 1996, C r a i k 1997).

The stone crayfish, *Austropotamobius torrentium*, is a native crustacean species which mainly inhabits upper parts of rivers with gravel or stony bottoms. Present distribution

* Corresponding author

is restricted to 40 remaining localities, where it still survives in relatively high numbers (Š t a m b e r g o v á , pers. comm., F i s c h e r et al. 2004). Habitat degradation, the crayfish plague *Aphanomyces astaci*, and water pollution are considered to be the most important causes in the dramatic decline of the stone crayfish (F i s c h e r et al. 2004, K o z u b í k o v á et al. 2006). Locally, the crayfish has also been an important prey species for a variety of mammalian and bird predators; hence predation could be another factor which might negatively affect crayfish populations. High crayfish population densities have had a large effect on freshwater foodwebs, and the species can become a major prey for local aquatic predators (D e l i b e s & A d r i á n 1987, S m a l 1991, B e j a 1996). Feral mink is a predator species that changes its diet in response to the primary prey, and feeds on this species wherever it is available. In Ireland, mink distribution reflected the abundance of crayfish populations in studied habitats (S m a l 1991).

Due to the rapid spread of the feral mink in most European countries, information describing the possible interactions between this invasive mammalian species and the local biodiversity is still being incremented (B o n e s i et al. 2006). In many regions, minks have had notable impact on mammals (B a r r e t o et al. 1998, E r b et al. 2001, B a n k s et al. 2004), ground nesting water birds (C r a i k 1997, F e r r e r a s & M a c d o n a l d 1999, S i d o r o v i c h et al. 2001), amphibians (A h o l a et al. 2006) and fish populations (H e g g e n e s & B o r g s t r ö m 1988). F e r r e r a s & M a c d o n a l d (1999) reported that mink in the breeding season significantly influenced coot *Fulica atra* and moorhen *Gallinula chloropus* populations. A strong negative impact of mink on the water vole *Arvicola terrestis* is also known from Britain and Belarus (B a r r e t o et al. 1998, M a c d o n a l d et al. 2002). In the Czech Republic, early studies on the predation of feral mink on native populations showed that mink could have an impact on invertebrates as well as vertebrates. An experimental study on artificial nest predation in riverine and fishpond areas has shown that mink caused from 22 to 66 % of mammalian predation events (P a d y š á k o v á et al., in press, P a d y š á k o v á et al., unpubl. data). Heavy predation by mink on waterfowl (Š á l e k et al. 2005), amphibians (P o l e d n í k et al., in litt.), the grass snake *Natrix tessellata* (K a p l e r 1994), and the stone crayfish *Austropotamobius torrentium* (own data) has also been observed in various regions of the Czech Republic.

In this paper, we examine the possible impact of mink predation on prey populations of native crayfish in middle-sized streams in western and central Bohemia. We attempt to describe the composition of the mink diet and evaluate the role of mink predation on stone crayfish populations during summer and winter. In particular, we analyse whether (1) mink predation was affected by the population density of stone crayfish and (2) mink preferably feeds on larger crayfish individuals.

Study Area

The study was conducted in the Brdy highland in central Bohemia, the Czech Republic, on an 80 km^2 area (center at 49°45' N, 13°57' E). The region consists of forested areas (40 %), grasslands (30 %), crop fields (25%), and inhabited areas (5%). The Brdy highland is one of the largest continuous forested areas in the Czech Republic. This range is formed mainly by Cambrian sandstone, conglomerates, and quartzites with altitude between 235 to 630 m a.s.l. The climate is moderate continental with an average annual temperature of about 6.5 °C and a total annual precipitation of 800 mm (C u l e k 1995). The forests are characterized by intensive management. Much of the original forest in the area was composed of beech with an occasional fir, but was replaced by spruce monocultures, most likely, starting before the middle of the 19th century. The vegetation is currently dominated by Norway spruce *Picea abies* which covers approximately 90% of the forested area, most of which are 60–90 years old; occasionally beech *Fagus* sp. and hazel *Corylus* sp. are found in the upper elevations.

The study site was located in the southern part of the Brdy highlands, which is characterized by middle-sized streams. The main rivers flowing through the area are the Bradava, Úslava and Klabava. Watercourses are 1–6 meters wide (usually wider in lower elevations) with depth of 1 meter maximum and with small pools.

River banks are fringed with trees such as alder *Alnus glutinosa*, spruce *Picea abies*, poplar *Populus* sp., willow *Salix* sp. and vegetation such as *Phalaris arundinacea*, *Rubus* sp., *Carex* sp., *Petasites alba,* among many others (H e j l 1987). Fish communities in this part of the study area are composed of brown trout *Salmo trutta*, common sculpin *Cottus gobio*, and in the nearby ponds, the most common species are European perch *Perca fluviatilis,* white bream *Blicca bjoerkna*, and northern pike *Esox lucius* (F i s c h e r , unpubl. data).

The American mink has occurred in the area since the beginning of the 1990´s due to escapes from local fur farms.

D a t a c o l l e c t i o n

The predation of American mink on stone crayfish was monitored at nine sites in five streams (Bradava, Bojovka, Mítovský, Bílý and Padrťský). These streams were chosen because of the sympatric distribution of both monitored species in previous observations. At each site we selected a 300 m long segment of the stream bank in which to investigate mink predation.

The bottom of the monitored streams was mostly covered with gravel, stones and boulders. Width of the streams was 0.9 m in the narrowest points and 7.5 m in the widest parts of the streams, with an average width of 3.5 m. Average depth of monitored areas was 28 cm, with maximum depth less than 90 cm. On average, areas were composed of 53% slow running water, 35% swift running water, and 12% river pools.

C r a y f i s h p o p u l a t i o n

Population density and distribution of the stone crayfish, *A. torrentium,* was monitored from August to September 2005 at all selected localities. During these months, *A. torrentium* is most active and females are not impaired by egg-bearing. Sampling was performed during very low water flow and high water clarity. We searched through all available shelters (hiding places), such as crevices under stones, sunken roots, and burrows in riverbanks.

All captured crayfish were identified and measured with a caliper. Length measurements were defined as total length measured from the tip of the rostrum to the end of the telson. The length of carapace was measured from the tip of the rostrum to the nearest point of the end of the carapace, and the length of claw was measured on the right claw from the joint to the tip of the claw. All measurements were taken the nearest 0.1 mm. The crayfish were weighed individually (wet mass, to the nearest 1/4 g) by a spring-balance. In addition, the crayfish were also sexed and checked for defects like missing claws or other body parts.

Captured crayfish which were bigger than 15 mm were marked by highly visible fluorescent elastomers (VIE). These elastomers were injected into the muscles in the abdominal segments of the crayfish on the ventral side. Recapturing of the crayfish was performed on the following day to minimize the mixing of marked and non-marked crayfish populations outside the selected stream sections. Recapturing was performed only once at each area to minimize negative impacts on the crayfish populations. Marked individuals were released uniformly throughout the whole trapping area.

Crayfish abundance was determined by capture–recapture method using Lincoln's index:

Where N = total number of individuals, M = total number of marked individuals, C = total number of individuals in recapture, R = number of recaptured marked individuals (B e g o n et al. 1990). Population densities were calculated both for the currently flooded watercourse and for the total possible water area between riverbank edges.

In order to determine the distribution of crayfish body lengths in the mink diet, measured body dimensions were used to calculate the following relationships and regressions:

1. relation of total length to the length of carapace ($r = 0.98$; $F (1,46) = 1749$; $p = 0.001$); regression equation $y = -0.008 \cdot x^2 + 2.36 \cdot x - 3.92$ ($R^2 = 0.976$), where y is the total length of the crayfish and x is the length of the carapace in mm
2. relation of total length to the length of claw ($r = 0.95$; $F (1,37) = 332$; $p = 0.001$); regression equation $y = -0.0455 \cdot x^2 + 3.85 \cdot x - 1.609$ ($R^2 = 0.957$), where y is the total length of the crayfish and x is the length of claw in mm
3. relation of mass to the length of claw ($r = 0.93$; $F (1,88) = 547$; $p = 0.001$); regression equation $y = 0.1848\, e^{0.0604x}$ ($R^2 = 0.967$), where y is the mass in g and x is the length of the claw in mm

Differences between male and female ratios of total length to the length of carapace was not significant ($t = 1.27$, $df = 98$, $p = 0.21$). Similarly we found no differences between males and females total length to the length of the claw ($t = 1.29$, $df = 98$, $p = 0.22$) as well as ratio of mass to the length of claw ($t = 1.24$, $df = 98$, $p = 0.18$). For the purposes of the subsequent analysis we jointed both groups together.

Collection of prey remains

We divided the main stream into non-neighbouring 300 m sections. The banks were surveyed up to one to two metres from the streams' edges where there was no vegetation and where sand made it easy to find prey remains. The whole stream basin and stream banks were carefully searched for mink prey remains by the same two trained surveyors, walking either in the river, where the depth allowed, or walking along the shore with one of the surveyors upstream and the other downstream. Crayfish remains consisted of non-utilized prey parts, such as claws, appendages, and discarded carapaces. The number of crayfish preyed on by mink and changes in the rate of mink predation in targeted areas were obtained from the number of crayfish remains. At the start, crayfish remains were collected to eliminate old prey remains. Then the areas were visited three times within seven days to collect fresh remains. When higher numbers of remains were found at the same site, the minimum number of crayfish preyed on was obtained from the number of pairs of claws or crayfish carapaces. Crayfish remains were collected from May to June (summer collections) and from January to March (winter collections).

The impact of mink predation on crayfish was measured as the rate of predation units (RP):

where PC = number of preyed on crayfish, Y = monitored days / 365 days, S_1= area where crayfish remains were collected (m^2) , AC = number of living crayfish, S_2= area where abundance of crayfish was measured (m^2).

The claws of hunted crayfish were measured with a slide gauge, and dimensions were compared with measured dimensions on living crayfish. Using the calculated relationships shown above, dimensions of crayfish remains were used to calculate total lengths and weights of preyed-on animals.

Mink diet

Composition of the mink diet was assessed from faecal analysis (Erlinge 1968, Poledník et al., in litt.). Mink fresh droppings were collected in monitored localities from January 2005 to March 2007. Individual droppings were stored in separate bags, labelled with date and locality. Before analysis, droppings were soaked for several hours in detergent and then washed through a sieve (0.5 mm mesh). Fish species were identified according to the keys of Libois & Hallet-Libois (1988), Knollseisen (1996) and by comparison of hard remains (jaw bones, pharyngeal teeth, vertebrae, and scales) with a reference collection. Other vertebrates were determined from skeletal remains, teeth, hair, and feathers. The importance of different types of prey was specified by their relative numeric contribution to the diet. Excrements were collected in the same areas and at the same time as the crayfish remains. Composition of predator diet was expressed as the relative frequency of particular prey categories (e.g. percentage of droppings containing remains of a particular prey).

A rough approximation of the number of crayfish individuals ingested daily by mink could not be calculated directly from droppings. Therefore, the theoretical number of ingested stone crayfish (IC) was calculated from the daily energetic requirements of mink (DER), average calorific content of crayfish (CC), average crayfish weight (CW), and crayfish digestibility (CD):

$$IC = \frac{DER}{CC * CW * CD}$$

Daily energetic requirements for mink of average weight vary from 1000 to 1500 $kJ \cdot day^{-1}$ for females and males, respectively (Dunstone 1993). Digestibility of crayfish is 0.5 and average calorific content of crayfish is 4.09 $kJ \cdot g^{-1}$ (Beja 1996). Average weight of preyed on crayfish was calculated by the regression equations given above.

Statistics

The Windows-based software Statistica 7.1 (Stat Soft. Inc. 2005) was used for analyses. Differences between frequencies in the occurrence of crayfish in mink diet during summer and winter were evaluated by the Chi-square test. The dependence of mink predation rate on crayfish population density was tested by linear regression. The dependence of the mink predation rate on the average depth of the river basin and the dependence of the mink predation rate on the proportion of faster-flowing sections of the monitored areas were tested in the same way. The dependences of total length on the length of carapace and of total length on the length of claw and the dependence of the mass on the length of claw were modeled by polynomial regression. Comparisons of the differences between summer and winter periods and between first and second year were performed with a matched t-test. Matched t-test was also used for the evaluation of the differences between the average body length of crayfish in populations and the average body length of hunted crayfish in different areas. The differences between size categories of crayfish were tested by Chi-square test. Comparisons of differences between male and female ratios of total length to the length of carapace and ratios of total length to the length of the claw and ratios of mass to the length of the claw were performed with an independent t-test. Statistica software was also used for counting means and for plotting scatter plot graphs.

Results

Population density of stone crayfish

In total, we trapped 878 crayfish individuals. The body weight of trapped crayfish ranged from 1.5 to 33.25 g, with mean weight of 3.9 g. Stone crayfish abundance varied among particular localities, with densities ranging from 4.21 to 7.17 individuals per m^2 (average = 5.42 ind. per m^2). The highest population density was recorded in Bojovka Těnovice with 7.17 ind. per m^2, followed by Bojovka Číčov and Borovno with 6.8 and 6.0 ind. per m^2, respectively (Table 1).

Mink diet

On the whole, 87 mink droppings were collected in the summer and winter periods from 2005–2007. Crustaceans were the most frequent food source for minks, followed by mammals, amphibians, and fish. These four food categories together formed about 92% of their whole diet; birds, insects, and plants were of secondary importance. Crustaceans consisted entirely of one species, the stone crayfish *Austropotamobius torrentium*, which was represented in 82% of all collected mink droppings. Based on collected material, we estimate stone crayfish represented 55 to 60 % of the mink total prey biomass. Among fish, the most common prey were the stream species bullhead *Cottus gobio* and brown trout *Salmo trutta*, represented in 41% and 35% of samples respectively. Other fish prey were species characteristic for reservoirs or ponds (*Perca fluviatilis, Blicca bjoerkna, Esox lucius*). Analysis of the relative composition of summer and winter diets showed no significant differences between these periods ($t = 0.986$; $df = 6$; $P = 0.362$). Similarly, we found no seasonal differences in the frequency of stone crayfish in the mink diet ($\chi^2 = 0.915$; $df = 1$; $P = 0.339$).

Table 1. Population density of stone crayfish and the proportion of prey remains in particular study areas in intermediate-sized streams in western and central Bohemia.

Study area	Prey remains per m^2 per year			Crayfish density (ind. per m^2)
	summer	winter	average	
Padrťský creek I.	0.28	0.28	0.28	4.46
Padrťský creek II.	0.32	0.10	0.21	4.43
Padrťský creek III.	0.23	0.08	0.16	4.21
Bílý creek	0.05	0.02	0.01	5.72
Borovno	0.35	0.06	0.36	6.00
Hořehledy	0.39	0.14	0.48	4.97
Bojovka-Těnovice	1.15	0.33	0.44	7.17
Bojovka-Číčov	0.00	0.00	0.00	6.80
Mítovský creek	0.08	0.01	0.04	4.96

Predation on crayfish

The determination of predation of the American mink on stone crayfish was based on the collection of prey remains during the monitoring period. In total, 364 prey remains were found. The numbers of prey remains found differ significantly between seasons ($t = 3.08$; $df = 7$; $p = 0.018$). In the winter collections, prey remains comprised only 114 items, while in the summer, we collected 250 prey remain items.

In 2005, we found 2.53 (± 0.17) ind. per m^2 per week, while the density increased to 4.65 (± 0.31) ind. per m^2 per week in 2006. However, the comparisons of all recorded prey remains between the years revealed no significant trend ($t = 1.844$, $df = 5$, $P = 0.124$). Predation rate was expressed as the number of prey remains for a selected bank distance and time period relative to population density of crayfish (%). Predation rates at particular localities were highly variable (Table 1). The lowest predation was recorded in the Bílý creek (0.85%), whereas in the Bojovka-Těnovice the predation rate was 25 times higher (21.5%). Mean predation rate was 7.4%. To study the effect of crayfish population density on the predation rate of the American mink, the results of crayfish trapping were compared with the recorded number of individuals preyed on during the monitored period. There was a strong correlation between the density of principal prey and subsequent number of prey remains ($r = 0.864$; $F = 17.715$; $P = 0.006$, see Fig. 1). Minks significantly preferred localities with a high population density of stone crayfish.

The number of crayfish remains along streams was also focused on, but no significant differences were found in the predation rate between the swift and slow water sections ($t = 1.569$, $F = 0.596$, $P = 0.465$) or between predation rate and the depth of the river basin ($t = 0.787$, $F = 0.004$, $P = 0.951$). Prey remains of stone crayfish were found in all the parts of the selected stream transects.

Based on daily energetic requirements (1000–1500 kJ·day^{-1} for females and males), average calorific content of crayfish (4.09 kJ·g^{-1}), and digestibility of crayfish individuals

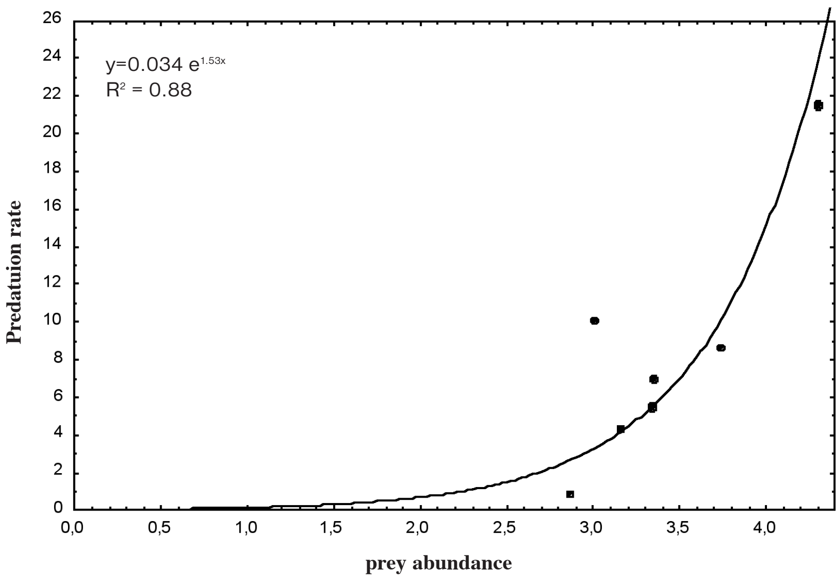

Fig. 1. Relationship between predation rate (prey remains per m^2 per year)/(ind. per m^2) and prey abundance (ind. per m^2) in study areas.

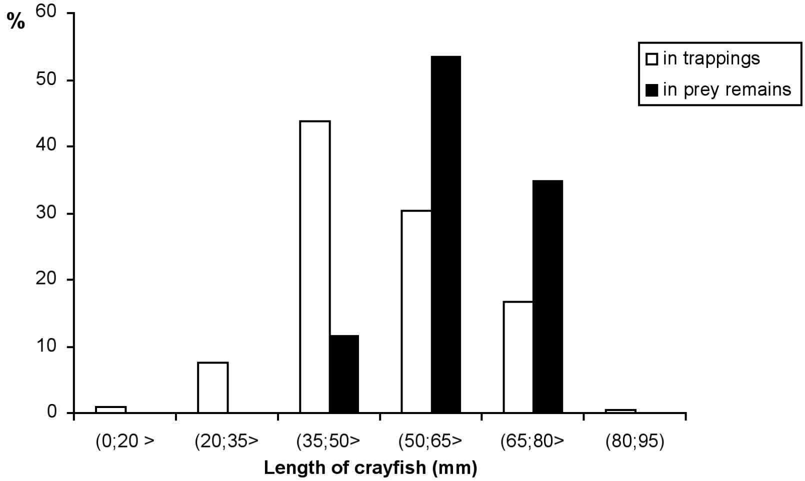

Fig. 2. Distribution of length categories of crayfish prey in crayfish trapping and mink prey remains (n = 86 in prey remains, n = 878 in trappings).

(50 %), a rough approximation was performed of the amount of crayfish preyed on by one mink per one day. The average weight of preyed on crayfish (7.49 g), was used for this calculation, and thus was estimated the average calorific content per one crayfish individual as 30.63 kJ. Furthermore, it was estimated that the proportion of crayfish biomass in the mink diet was 55 %. Our estimate of the number of preyed on crayfish per day was 37 for male and 54 for female (13 505 and 19 710 crayfish per year).

The length of crayfish in prey remains varied from 36.3 to 79.6 mm, with an average length of 61.3 (± 1.1) mm. The distribution of the crayfish prey length in prey remains was bimodal, with peaks between 50–65 mm (n=79) and 65–80 mm (n=53). Crayfish which were bigger than 45 mm, representing sexual mature individuals, formed 94% of all prey remains. In contrast, crayfish obtained by trapping ranged from 13 to 86 mm in length, with an average length for the trapped crayfish of 50.6 (± 1.2) mm. A comparison of length of crayfish obtained by trapping and by observing mink prey remains shows that minks prefer larger individuals than would be expected from trapping samples ($\chi^2 = 51.98$, df = 5, P = 0.001, Fig. 2) only. Similarly, this trend was also found for individual localities (t = 4.27, df = 5, P = 0.0037).

Discussion

This paper reports on interactions between an alien mammalian predator and its principal prey, the stone crayfish, in middle-sized streams in the western and central part of Bohemia (Czech Republic). Our data, like most others from across Europe which have investigated food ecology, show the feral mink as an opportunistic predator, exploiting a variety of food types consisting of vertebrate (mammals, amphibians, fish) and also invertebrate (crayfish and insects) prey (e.g. Erlinge 1972, Smal 1991, Jędrzejewska et al. 2001, Poledník et al., in litt.). In our study the most common prey items were crustaceans, composed entirely of the stone crayfish *Austropotamobius torrentium*, which were recorded in 82 % of mink droppings. Based on the methods used, we were not able to directly estimate the absolute number of prey individuals, but we estimated indirectly that stone crayfish formed 55–60 % of the total prey biomass. Similarly S m a l (1991) also reported high predation on crayfish, accounting for an average 66 % of mink diet. Mink diets closely reflect changes in food availability, seasonal prey variability, and local habitat diversity (G e r e l l 1967, D u n s t o n e & B i r k s 1987, A n g e l i c i et al. 2000, S i d o r o v i c h 2000, J ę d r z e j e w s k a et al. 2001). We propose that the habitat where the minks in this study lived notably effected the composition of their diet. The watercourses within our study area include oligotrophic stream habitats with low species diversity for potential feeding sources. Stone crayfish is by far the most abundant native prey species in these selected streams throughout the year, and its population numbers are the result of its characteristic life cycle (C r o l l & W a t t s 2004). High population density of stone crayfish may also have influenced foraging strategies of the feral mink, such as individual feeding specialization. For example, a study from northeastern Belarus documented, that three of ten radio-tracked minks were strict food specialists (S i d o r o v i c h et al. 2001).

Feral American minks have become one of the greatest predation threats for both invertebrate and vertebrate biodiversity, and are linked with marked population declines or local extinctions of various prey species (B a r r e t o et al. 1998, N o r d s t r ö m et al. 2002, N o r d s t r ö m & K o r p i m ä k i 2003, A h o l a et al. 2006, B o n e s i et al. 2006). Theoretical models based on the number of harvested crayfish in study area suggested that for the number of individuals preying, the quantity should exceed 37 preyed crayfish per day (more than 13 000 individuals per year). High number of daily-predated crayfish is the effect of low digestibility and the average weight of prey crayfish in contrast to other important prey items such as fish or mammals. Predation rates in our study varied from 0.85 to 21.49% of stone crayfish population per year. Previous study from the target area documented a decline in crayfish numbers of 53% between years 2000–2004 due to mink predation (F i s c h e r 2005). These results indicate that for a longer time period mink could be the limiting factor for crayfish population in middle-sized streams in the Brdy highland.

We also observed mink predation rate is strongly linked with the population density of its principal prey. This data agrees with the results of S m a l (1991) who found a positive correlation between crayfish and mink densities. Mink could preferentially occur in high density patches where their principal prey is found (density-dependent predation, A r n o l d & F r i t z e l l 1987). Density-dependent predation could be also linked with area-restricted predation (N a m s 1997), or with a numerical response of a predator to high density patches (H o l t 1977). However, our data were unable to reveal these types of dependence.

Seasonal variability in predation rate on crayfish could have been related to crayfish activity and environmental conditions, which may have influenced the availability of prey. The decrease of crayfish prey remains and the frequency of observed droppings in winter (though this trend was not significant) was a distinctive feature of the observed mink population. Similarly, seasonal variations of crayfish predation have been previously reported for mink (G e r e l l 1967, S m a l 1991) and also for other aquatic predators such as otters (e.g. B e j a 1996, C o r r e i a 2001, C l a v e r o et al. 2006). Crayfish activity is dependent on water temperature, being maximal in the summer months, when crayfish are more mobile (T r o s c h e l & D e h u s 1993, T r o s c h e l et al. 1995). During the winter months, stone crayfish are less active, spend more time in burrows and thus may decrease their predation risk. Moreover, in severe weather conditions, some parts of middle-sized streams are frozen, which would also decrease prey availability. Another factor enhancing predation could be the stone crayfish aggregation during summer in pools which do not dry out. Summer drying in middle-sized streams in our study area is a highly frequent event involving the reductions in flow and even the complete drying out of the streams, but usually resulting only in a heterogeneous mosaic of residual water. Therefore, water pools could attract various species of predators because of aggregation of potential prey. Otters preying on crayfish and fish in Iberian streams significantly concentrated their feeding activity in pools (Magalhães et al. 2002). On the other hand, we found no correlation between predation rate and speed of the water current.

Comparing body length of stone crayfish obtained by trappings and in prey remains demonstrates minks selectively feed on crayfish with an average length of around 61 mm, which represent sexually mature individuals. In contrast, average sizes of trapped individuals were significantly smaller than preyed on crayfish. These results are in accord with those of Beja (1996), which showed otters selectively preyed on bigger crayfish individuals than were recorded in the population. However, data interpretation could be limited by an over evaluation of the length of prey remains. Minks might also feed on smaller individuals, which could be eaten completely. In addition, crayfish trapping for evaluation of population density affects results because of the difficulty of trapping individuals smaller than 15 mm. Crayfish below this size were also not possible to mark with visible fluorescent elastomers, hence this category was not included in the evaluation of population densities.

In conclusion, this study indicates mink predation could be an important mortality factor for stone crayfish populations on a local scale. Predation may depend not only on population density of crayfish but also on availability of other prey. Patterns of mink predation on crayfish seem to reflect their spatial availability, suggested by good correspondence between population density and number of prey remains. Minks preyed selectively on sexually mature individuals, which increase importance of its predation impact. To obtain detailed information about the interactions between these two species, a long-term study focused on crayfish population response is needed.

Acknowledgements

We are grateful to Viola Pavlová, Petra Nová for their assistance with fieldwork, Marie Pacovská for helping with determination prey remains. We also thank Oldřich Nedvěd, Pavel Blahák, Jan Zima and two anonymous reviewers for their comments to manuscript and David Hardekopf and Richard Klee for correcting the English manuscript. This study was supported by the grant MSMT6007665801 of the Czech Ministry of Education and by the research aim of the Institute of Systems Biology and Ecology AV0Z60870520.

LITERATURE

Ahola M., Norsdström M., Banks P.B., Laanetu N. & Korpimäki E. 2006: Alien mink predation induces prolonged declines in archipelago amphibians. *Proc. R. Soc. B 273: 1261–1265.*

Angelici F.M., Luiselli L. & Rigiero L. 2000: First note of dietary habits of American mink *Mustela vison* in Italy. *Mammalia 64: 253–257.*

Arnold T.W. & Fritzell E.K. 1987: Foods habits of prairie mink during the waterfowl breeding season. *Can. J. Zool. 65: 2322–2324.*

Banks P.B., Norrdahl K., Nordström M. & Korpimäki E. 2004: Dynamic impacts of feral mink predation on vole metapopulations in the outer archipelago of the Baltic Sea. *Oikos 105: 79–88.*

Barreto G.R., Rushton S.P., Strachan R. & Macdonald D.W. 1998: The role of habitat and mink predation in determining the status and distribution of water voles in England. *Animal Conserv. 78: 129–137.*

Begon M., Harper J.L. & Townsend C.R. 1990: Ecology: individuals, populations and communities (second edition). *Blackwell Scientific Publications*.
Beja P.R. 1996: An analysis of otter *Lutra lutra* predation on introduced American crayfish *Procambarus clarkii* in Iberian streams. *J. Appl. Ecol. 33: 1156–1170*.
Bonesi L., Harrington L.A., Maran T., Sidorovich V.E. & Macdonald D.W. 2006: Demography of three populations of American mink *Mustela vison* in Europe. *Mammal Rev. 36: 98–106*.
Clavero M., Prenda J. & Delibes M. 2006: Seasonal use of coastal resources by otters: Comparing sandy and rocky stretches. *Estuarine, Coastal and Shelf Science 66: 387–394*.
Correia A.M. 2001: Seasonal and interspecific evaluation of predation by mammals and birds on the introduced red swamp crayfish *Procambarus clarkii* (Crustacea, Cambaridae) in a freshwater marsh (Portugal). *J. Zool. 255: 533–541*.
Craik C. 1997: Long-term effect of North American mink *Mustela vison* on seabirds in western Scotland. *Bird Study 44: 303–309*.
Croll S.L. & Watts S.A. 2004: The effect of temperature on feed consumption and nutrient absorption in *Procambarus clarkii* and *Procambarus zonangulus*. *J. World Aquaculture Soc. 35: 478–488*.
Culek M. 1995: Biogeografické členění České republiky [Biogeography of the Czech Republic]. *Enigma, Praha (in Czech)*.
Červený J., Kamler J., Kholová H., Koubek P. & Martínková N. 2003: Encyklopedie myslivosti [Encyclopedia of game management]. *Ottovo nakladatelství – Cesty, Praha (in Czech)*.
Delibes M. & Adrián M.I. 1987: Effects of crayfish introduction on otter *Lutra lutra* food in the Donãna National Park, SW Spain. *Biol. Conserv. 42: 153–159*.
Dunstone N. 1993: The mink. *Poyser Natural Society, London*.
Dunstone N. & Birks J.D.S. 1987: The feeding ecology of mink (*Mustela vison*) in coastal habitat. *J. Zool. 212: 69–83*.
Erb J., Boyce M.S. & Stenseth N.Ch. 2001: Spatial variation in mink and muskrat interactions in Canada. *Oikos 93: 365–375*.
Erlinge S. 1968: Food studies on captive otters (*Lutra lutra* L.). *Oikos 19: 259–270*.
Erlinge S. 1972: Interspecific relations between otter *Lutra lutra* and mink *Mustella vison* in Sweden. *Oikos 23: 327–335*.
Ferreras P. & Macdonald D.W. 1999: The impact of American mink *Mustela vison* on waterbirds in the upper Thales. *J. Appl. Ecol. 36: 701–708*.
Fischer D., Bádr V., Vlach P. & Fischerová J. 2004: Nové poznatky o rozšíření raka kamenáče v Čechách [New data on crayfish distribution in Bohemia]. *Živa 2: 79–81* (*in Czech*).
Gerell R. 1967: Food selection in relation to habitat in mink (*Mustela vison*, Schreber) in Sweden. *Oikos 18: 233–246*.
Halliwell E. & Macdonald D.W. 1996: American mink *Mustela vison* in the Upper Thames catchment: relationship with selected prey species and den availability. *Biol. Conserv. 76: 51–56*.
Heggenes J. & Borgström R. 1988: Effect of mink, *Mustela vison* Schreber, predation on cohorts of juvenile Atlantic salmon, *Salmo salar* L., and brown trout, *S. trutta* L., in three small streams. *J. Fish Biol. 6: 885–894*.
Hejl I. 1987: Brdy [Brdy Mountains]. *Středočeské nakladatelství, Praha (in Czech)*.
Holt R.D. 1977: Predation, apparent competition, and the structure of prey communities. *Theor. Popul. Biol. 12: 197–229*.
Jędrzejewska B., Sidorovich V.E., Pikulik M.M. & Jędrzejewsky W. 2001: Feeding habits of the otter and American mink in Bialowieza Primeval Forest (Poland) compared to other Eurasian population. *Ecography 24: 165–180*.
Kapler O. 1994: Setkání s norkem americkým [Meeting the American mink]. *Živa 4: 186 (in Czech)*.
Knollseisen M. 1996: Fischbestimmungsatlas, als Grundlage fur nahrungsökologische Untersuchungen. *Reports on Wildlife Research and Game Management, Boku, Wien*.
Kozubíková E., Petrusek A., Ďuriš Z., Kozák P., Geiger S., Hoffmann R. & Oidtmann B. 2006: The crayfish plague in the Czech Republic – a review of recent suspect cases and a pilot detection study. *Bulletin Français de la Pêche et de la Pisciculture 380–381: 1313–1324*.
Libois R.M. & Hallet-Libois C. 1988: Éléments pour l´identification des restes craniens des poisons dulcaquicoles de Belgique et du nord de la France. *Fisches d´ostéologie animale pour l´archéologie, Série A, No. 4. Centre de Recherches Archéologiques du CNRS, APDCA, Juan-les-Pins*.
Macdonald D.W., Sidorovich V.E., Anisomova E.I., Sidorovich N.V. & Johnson P.J. 2002: The impact of American mink *Mustela vison* and European mink *Mustela lutreola* on water voles *Arvicola terrestris* in Belarus. *Ecography 25: 295–302*.

Magalhães M.F., Beja P., Canas C. & Collares-Pereira M.J. 2002: Functional heterogeneity of dry-season refugia across a Mediterranean catchment: the role of habitat and predation. *Freshw. Biol. 47: 1919–1934*.

Mazák V. 1964: Einige Bemerkungen über die Gattung *Lutreola* Wagner, 1841 in der Tschechoslowakei. *Lynx, n.s. 3: 17–29*.

Nams V. O. 1997: Density depended predation by skunks using olfactory search images. *Oecologia 110: 440–448*.

Nordström M. & Korpimäki E. 2003: Effects of island isolation and feral mink removal on bird communities on small islands in the Baltic Sea. *J. Anim. Ecol. 73: 424–433*.

Nordström M., Hogmander J., Nummelin J., Laine J., Laanetu N. & Korpimäki E. 2002: Variable response of waterfowl breeding populations to long-term removal of introduced American mink. *Ecography 25: 385–394*.

Padyšáková E., Šálek M., Poledník L., Sedláček F. & Albrecht T. 2009: Does removal of American mink affect the success of simulated nests in linear habitats? *Wildlife Research (in press)*.

Sidorovich V.E. 2000: Seasonal variation in feeding habits of riparian mustelids in river valleys of NE Belarus. *Acta Theriol. 45: 233–242*.

Sidorovich V.E., Macdonald D.W., Pikulik M.M. & Kruuk H. 2001: Individual feeding specialization in the European mink, *Mustela lutreola* and the American mink, *M. vison* in north-eastern Belarus. *Folia Zool. 50: 27–42*.

Šálek M., Poledník L., Beran V. & Sedláček F. 2005: The home ranges, movements and activity pattern of the American mink in the Czech Republic. In: *Abstracts of the IX. International Mammalogical Congress, Sapporo, Japan*.

Smal C. M. 1991: The American mink *Mustela vison* in Ireland. *Mamm. Rev. 18: 201*.

Stat Soft, Inc, 2005: Statistica 7.1. *www.statsoft.com*

Troschel H.J. & Dehus P. 1993: Distribution of crayfish species in the Federal Republic of Germany, with special reference to *Austropotamobius pallipes*. *Freshw. Crayfish 9: 390–398*.

Troschel H.J., Schulz U. & Berg R. 1995: Seasonal activity of stone crayfish *Austropotamobius torrentium*. *Freshw. Crayfish 10: 196–199*.

Woodroffe G.L., Lawton J.H. & Davidson W.L. 1990: The impact of feral mink *Mustela vison* on water voles *Arvicola terrestris* in the North Yorkshire Moors National Park. *Biol. Conserv. 51: 49–62*.