Spatial distribution, activity, habitat selection of American mink (*Neovison vison*) and polecats (*Mustela putorius*) inhabiting the vicinity of eutrophic lakes in NE Poland

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Abstract. Invasive American mink and native polecats were live-trapped over a period of six years and radio-tracked during one winter-spring season in the lakeside habitats in NE Poland. The number of mink declined whereas number of polecats was stable during 1995–2000, however, except during one winter, mink were always more abundant in the study area than polecats. Significant differences in habitat utilization between radio-collared mink and polecats were observed. Mink moved only along the lake shoreline and showed no seasonal shift in habitat selection. In winter, polecats were most frequently located close to the lake banks, but they also stayed in barns and stables. In spring, they moved further from the lakes. There was considerable interspecies overlap of mink and polecat home ranges in February, and common use of the banks of the 500 m long unfrozen canal was recorded for 4 mink and 5 polecats. The pattern of daily activity of polecat and mink differed: mink were most active at dawn and in early morning whereas polecats at dusk and in beginning of the night. Individuals of both species coexisted in this small area at relatively high densities and to some degree exploited the same habitats, particularly in the vicinity of sites with access to open water.

Key words: Mustelidae, interspecific competition, invasive species, sympatric species

Introduction

In the 20th century the American mink *Neovison vison* (Schreber, 1777) colonized vast areas of Europe (reviewed by Bonesi & Palazon 2007) and inhabited various types of aquatic habitats where it now coexists with several native mustelids (Brzeziński et al. 2008, Sidorovich et al. 2008). Due to its habitat preferences and feeding habits it may be expected that American mink competes for environmental resources mainly with three “semi-aquatic” mustelid species: the Eurasian otter *Lutra lutra* (Linnaeus, 1758), European mink *Mustela lutreola* (Linnaeus, 1761) and polecat *M. putorius* (Linnaeus, 1758). Most studies in which interspecific interactions between invasive American mink and other carnivores have been analyzed have focused on the otter (Erlinge 1972, Chanin 1981, Kyne et al. 1989, Clode & Macdonald 1995, Jedrzejewska et al. 2001, Bonesi & Macdonald 2004a, b, Bonesi et al. 2004, Melero et al. 2008a), and much less attention has been paid to competition with smaller species from the *Mustela* genus or with entire mustelid communities (Lodé 1993, Sidorovich et al. 1996, Maran et al. 1998, Sidorovich 2000, Sidorovich et al. 2001, Harrington & Macdonald 2008). In north-eastern Poland, the American mink population became established at the beginning of the 1980s and numbers increased in the following years (Brzeziński & Marzec 2003, Brzeziński et al. 2010). The expansion of mink took place after the recovery of the otter population (Brzeziński et al. 1996) and thriving populations of both species currently

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inhabit this region of the country. In contrast, European mink was exterminated in north-eastern Poland in the 1920s (Ruprecht et al. 1983). No data exist on polecat population trends. Compared to the American mink, the polecat is a more "terrestrial" mustelid inhabiting a variety of habitats, although it is often found near waterbodies (Blandford 1987). Both species are considered to be opportunistic predators which share similar food resources and which may jointly inhabit vicinities of rivers and streams (Sidorovich et al. 1996, Harrington & Macdonald 2008). Therefore, in many environments in the Temperate Zone, interspecific competition between these two mustelids may be significant and would be expected to increase during periods of limited food resources. The aim of this study was to investigate coexistence of invasive American mink and native polecat in respect to their spatial distribution, daily activity and habitat selection in the vicinity of eutrophic lakes.

Study Area
The study was carried out close to two eutrophic lakes in the Mazurian Lakeland in north-eastern Poland. Łuknajno Lake (53°49'N, 21°38'E) is a shallow lake, up to 3 m in depth, covering an area of 6.8 km². It is circular in shape, with a 10.2 km long shoreline. It is located close to the north-western corner of Śniardwy Lake (53°44'N, 21°45'E), the largest Polish lake (99.8 km²) with a 97.2 km long shoreline and a maximum depth of 23 m. Data were collected by the north-western part of Śniardwy Lake, in an area called Łuknajno Bay. The littoral zone of these lakes is overgrown with broad reedbeds. The banks are low and boggy, with dense willow (Salix sp.) shrubs and belts of alder woods. The lakes are surrounded by a mosaic of pastures, fields, ferrals and pine forest with adjoining broad-leaf stands (including alder woods in wet habitats). The only human settlements within the study area are two small farms located close to the Łuknajno Lake shoreline. Łuknajno Lake is connected to Łuknajno Bay of Śniardwy Lake via a canal, which due to the water runoff from Łuknajno Lake, becomes frozen only at much lower temperatures than the lakes. If the temperature does not drop below -5°C for a prolonged period, this section of water joining the lakes (of about 500 m long) remains open during the winter. The lakes themselves are usually frozen from December until the end of March.

Material and Methods
Mink and polecats were live-trapped in the autumn (November–December), winter (January–February) and spring (March–April), from 1995 to 2000, along a 10 km long stretch of lake shoreline (including the canal): ~4 km along the Łuknajno Lake shoreline and ~6 km along the Łuknajno Bay shoreline of Śniardwy Lake. In each season, wooden-box live-traps baited with fresh fish were set for 4–5 days at 500 m intervals. During a trapping session 18–20 traps were used: 6–7 traps were placed along the Łuknajno Lake shoreline, 10–11 along the Łuknajno Bay shoreline and 2 traps were set at each end of the canal joining the two lakes. Altogether during 15 sessions, traps were set for 1308 trap-nights (the “trapping effort” of all 20 traps used in the study was very similar). Captured mink and polecats were anaesthetized with Narkamon, marked with incisions on the upper part of the ear, weighed and released at the location of their capture. Studies using radio-telemetry were conducted in the winter and spring of 1999. Captured mink and polecats were radio-collared with 18 g Advanced Telemetry Systems transmitters, released and their movements followed using a FT-290RII YAESU receiver with a hand-held aerial. The first radio-telemetry record was made on January 30th and the last on May 1st.
Over this period, 4 mink (2 males and 2 females) and 10 polecats (8 males and 2 females) were trapped, radio-collared and radio-tracked; however, none of them were observed again throughout the entire study period. The location of radio-tracked animals was recorded at least 15 minute intervals (Kowalczyk et al. 2003). For each location activity of animal (active vs. inactive) and habitat type were noted. Altogether, 759 location recordings for mink (63 hours, 15 minutes of radio-tracking), and 734 recordings for polecats (61 hours, 15 minutes of radio-tracking) were included. The largest number of animals was radio-tracked in the first half of February (4 mink and 7 polecats) and the territory overlapping was analyzed only for this short period. Individuals that were radio-collared and radio-tracked outside this period were included only in the study of daily activity and habitat selection. Habitat selection was analyzed separately for the winter (January–March 15th) and spring (March 16th–May 1st). Frequency analysis with χ² test was applied in order to investigate sex ratio, seasonal changes of trapped individuals, habitat preferences as well as daily activity. We used crosstabs procedures in SPSS 13.0 for this purpose (SPSS 2004). Moreover, general linear model (GLM) was applied for trend analysis whereas partial correlation controlled for the year effect was used to check correlation between polecat and mink dynamic (SPSS 2004). We used negative exponentially-weighted smoothing procedure implemented in Statistica 9.0.
Results

Over six years, 74 mink and 26 polecats were trapped. Most individuals were captured only during one trapping session, although 12 mink males, 5 mink females and one polecat male were trapped in more than one session (Fig. 1). The total number of captures of mink and polecats in the study area was 100 and 27, respectively (recaptures of the same individual in one trapping session were excluded).

Mink and polecat males were trapped more frequently than females (Fig. 1). However, in the case of mink there were seasonal differences in the sex ratio of the animals captured. In spring, mink males were captured significantly more often than females, while in the autumn and winter the proportion of trapped males and females was similar ($\chi^2 = 7.61$, df = 2, $p = 0.022$). No seasonal differences in the number of trapped males and females were recorded for polecats ($\chi^2 = 0.53$, df = 2, $p = 0.767$).

The trapping success of both polecats and mink depended on the location of the traps along the 10 km long stretch of lake shoreline in the study area. It was significantly higher for two traps set at the unfrozen canal joining the lakes ($\chi^2 = 11.56$, df = 1, $p < 0.001$ for polecats; $\chi^2 = 36.00$, df = 1, $p < 0.001$ for mink). Of the 27 polecats captured during the study, 8 were trapped in these canal traps. Two traps set at the canal were also visited by 28 out of the 100 captured mink. During two weeks of radio-tracking in the first half of February the polecats and mink utilized shoreline sections of various lengths (Table 1). The home ranges of 4 mink and 7 polecats estimated linearly along the banks of the lakes and the canal varied from 300 m to 2400 m, however, did not depend on number of locations of particular species (Linear regression, $r = -0.13$; $n = 10$; $p = 0.725$). Only two polecat males occupied territories that were totally separated from all other individuals and they stayed far from the canal joining the lakes. All other radio-tracked animals shared common sections of shoreline and all were detected in the vicinity of the unfrozen canal. Within this group, the home ranges of two mink females did not overlap. One of them was also separated from the home range of one of the male mink. The home ranges of three polecat males and two females overlapped to various extents. There was also considerable interspecies overlap of mink and polecat home ranges (Table 1). The banks of the unfrozen canal were frequently traversed by 4 mink and 5 polecats. One mink female and one polecat male were recorded only in the canal section and did not move along the banks of the ice-covered lakes (Table 1). Other individuals occasionally moved further from the canal.

Mink and polecats utilized particular habitats in different proportion in winter ($\chi^2 = 203.94$, df = 5, $p < 0.0001$) as well as in spring ($\chi^2 = 126.43$, df = 5, $p < 0.0001$; Fig. 2). The radio-tracked mink were always located within a narrow strip stretching along the lake banks. They were never recorded further than about 50 m from the

The number of captured mink and polecats varied between years and seasons. However, mink were more abundant in the study area than polecats (Paired-samples T test, $t = 3.71$; df = 15; $p = 0.002$). The highest recorded mink density was 15 individuals per 10 km of shoreline, whereas the highest density of polecats reached 9 individuals per 10 km. Polecats were trapped most frequently in winter (17 individuals) and least frequently in autumn (2 individuals) and the differences were significant ($\chi^2 = 6.97$, df = 2, $p = 0.031$). The number of captured mink denoted 41 in spring, 33 in winter and 26 in autumn, but the differences were not significant ($\chi^2 = 1.70$, df = 2, $p = 0.428$). Density of polecats was stable during 1995–2000 (General Linear Model, effect of year controlled for the seasonal variability, $F = 0.30$; df = 1; $p = 0.593$) whereas density of American mink showed significant decline during 1995–2000 (General Linear Model, effect of year controlled for the seasonal variability, $F = 8.93$; df = 1; $p = 0.011$). The number of trapped polecats was not related to the abundance of mink (Partial correlation controlled for year, $r = 0.05$; $p = 0.848$).

Fig. 1. A – Number of mink and polecats captured and recaptured in the Łuknajno Lake and Śniardwy Lake study area in years 1995–2000; B – Seasonal differences in the proportion of male and female mink and polecats captured in the Łuknajno Lake and Śniardwy Lake study area in years 1995–2000.
In both winter and spring, mink were radio-tracked with similar frequency in two types of lakeside habitat: in alderwoods and in willow shrubs ($\chi^2 = 1.24, df = 1, p = 0.265$; Fig. 2). Polecats spent nearly 70% of the time in the vicinity of the lakes (not further than 50 m from the shoreline), being located in more distant areas for the remaining 30%. In contrast to mink, they preferred different habitats in winter and in spring ($\chi^2 = 182.31, df = 5, p < 0.0001$). In spring their activity in lakeside habitats decreased and they spent about 35% of the time in alderwoods far away from the lakes (one radio-tracked male was recorded in alderwoods as far as 1400 m from the lakes). In this season, polecats avoided human settlements and tree stands other than alderwoods, whereas in winter more than 14% of records came from buildings and about 9% from pine forest (Fig. 2).

The overall daily activity of both species was very similar and denoted 22.1% locations of active animals for polecats and 23.2% for mink ($\chi^2 = 0.27, df = 1, p = 0.606$). However, the pattern of daily activity of mink and polecats was different. Polecats were more active during night as compared to day ($\chi^2 = 12.60, df=1, p=0.0003$) whereas no differences were recorded for mink ($\chi^2 = 0.17, df = 1, p = 0.675$). Mink were most active at dawn and polecats at dusk. Both species were least active during the second half of the night (Fig. 3). Considerable increase of activity of both species was

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**Table 1.** The overlap and extent of the home ranges of mink and polecats radio-tracked during January and February in the Łuknajno Lake and Śniardwy Lake study area. M – mink, P – polecat, m – male, f – female.

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![Fig. 2. Winter and spring habitat selection of radio-collared mink and polecats in the Łuknajno Lake and Śniardwy Lake study area in 1999.](image-url)
recorded during 5:00–8:00 am (25–45% of locations indicated active animals), however, activity of mink was significantly higher as compared to polecat. The second increase of activity for both species was noted after sunset (Fig. 3).

**Fig. 3.** Activity of 4 mink and 10 polecats radio-tracked from 30. 01. to 01. 05. 1999 in the Łuknajno Lake and Śniardwy Lake study area. Mean activity was assessed with negative exponentially-weighted smoothing procedure for each species independently. Arrows indicate differences significant for a given hour computed for 2 x 2 contingency tables with $\chi^2$ test, histograms present number of locations of each species in particular hours.
Discussion

The results of our study confirm the spatio-temporal coexistence of American mink and polecats. This appears to be possible in habitats offering sufficient food and shelter, but where these resources are less abundant, interspecific competition may lead to the decline and exclusion of the weaker competitor. Such a relationship was recorded in the case of American mink and otter (Bonesi & Macdonald 2004a): the increasing otter population caused the decline of the American mink. On the other hand, the heterogenous environment in the present study area favoured the coexistence of competitors and enabled polecats to exploit habitats and resources distant from the lakes, which are not utilized by mink. Bonesi & Macdonald (2004b) drew similar conclusions after observing a habitat shift in mink coexisting in the same area as otters. However, it is difficult to predict how American mink and polecats affect each other (Harrington & Macdonald 2008).

Sidorovich (2000) concluded that American mink may be a strong competitor to native species of mustelids, especially to the European mink and polecat, however, there is no strong evidence that American mink can cause a reduction in polecat numbers. In Białowieża Primeval Forest the densities of polecat and American mink differed according to the size of the river, but they jointly inhabited the majority of the studied water courses (Sidorovich et al. 1996). In general, polecats have been found to prefer small streams, while mink favour small and medium-sized rivers. Lodé (1993) found that the home ranges of polecat and mink males largely overlapped, but the two species utilized different habitats: in autumn and winter polecats exploited woodlands and in spring marshes, whereas mink exploited mainly marshes and did not change habitat seasonally. Common habitats were not visited by polecats and mink at the same time. The temporal habitat partitioning between neighbouring mink and polecats, interpreted as the avoidance of interspecific competition, was recorded also by Harrington & Macdonald (2008).

Habitat preferences and the spacing pattern of American mink and polecats are related to their diets and the availability of prey (Weber 1989a, Jędrzejewski et al. 1993, Lodé 1993, 1994, Jędrzejewska et al. 2001). In general, mink are more successful in exploiting aquatic resources than polecats and thus they are more connected with aquatic habitats, whereas the polecat is a more “terrestrial” animal than mink and its habitat niche is broader (Jędrzejewska & Jędrzejewski 1998).

However, the dietary studies indicate that both species may potentially exploit similar food resources and the niche overlap usually increases in autumn-winter (Jędrzejewska & Jędrzejewski 1998, Sidorovich 2000). The American mink is an opportunistic predator with a very wide food niche breadth, and numerous studies have confirmed its high feeding plasticity (reviewed by Dunstone 1993, Jędrzejewska et al. 2001). A long-term study of mink diet at Lake Łuknajno showed that in this habitat mink mainly exploited two groups of prey: fish and amphibians, which comprised about 80–90% of the total food biomass from autumn until spring (Brzeziński 2008). Polecats, similarly to mink, are opportunistic in their choice of prey (reviewed by Lodé 1997) but some authors believe that they can be considered as specialized anuran foragers (Weber 1989a, b, Jędrzejewski et al. 1993). In environments inhabited by thriving populations of amphibians, polecats and mink feed on frogs all year round (Jędrzejewska & Jędrzejewski 1998), and we assume that the abundance of anurans is very important for the coexistence of mink and polecats. The lakeside habitats in which both these species have been studied are characterized by high densities of frogs: in lakeside alderwoods, the highest mean densities of common and moor frogs exceeded 1000 and 100 adult individuals per ha, respectively whereas their breeding densities in small ponds, marshes and alderwoods were estimated as 37 and 26 individuals per 100 m² of pond area, respectively (Brzeziński, unpublished). Thus, it may be predicted that in optimal hibernating sites in the study area their densities were also high. This would help to explain the distribution and habitat selection of the mink and polecats. In winter, access to open water and muddy banks seem to be very important to mink and polecats because these are the best places for searching for hibernating anurans. Brzeziński et al. (2008) found that in winter, otters and mink are more likely to be present at unfrozen sections of lakes and rivers than along the frozen sections. It is probable that polecats also search for frogs in shallow air-holes or unfrozen stretches of muddy lake banks. Polecats are expert at finding hibernating frogs (Weber 1989a). They penetrate watercourses where anurans hibernate in the banks or at the bottom of waterbodies (Brzeziński et al. 1992).

Habitat shifts in polecat were observed by Weber (1989a) and Lodé (1994), but the patterns of habitat change appear to differ according to the environment and local food resources. The results of the present study also confirm that polecats are flexible in their utilization of different habitats. Movements of polecats recorded by radio-tracking, showed that during winter polecats were searching more intensively for food in
the vicinity of lake/canal banks than in the autumn and spring. In spring, polecats concentrate their hunting activities on spawning congregations and their movements are associated with the dispersion of frogs (Łođe 2000). At the study site, frogs did not spawn in lakes, nor in lakeside alderwoods, but moved to smaller isolated waterbodies in alderwoods distant from the lake, and this is where the polecats searched for breeding frogs. These locations were not visited by polecats in the winter because they were completely frozen and did not offer any food. The pattern of mink movements in the study area suggested that mink, in contrast to polecats, did not forage far from the lakes. This may be explained by the fact that mink, which strongly exploit anurans, also intensively hunt fish. In spring, many fish become an easy target for mink because they spawn in the shallow waters of the lake littoral zone (Brzeziński 2008). Thus, mink are not forced to forage far from lakes or rivers in search of amphibians and their distribution and movements were mostly linear along the banks of waterbodies (see also Gerell 1970, Harrington & Macdonald 2008, Melero et al. 2008b). Mink also did not enter human settlements, even those located close to the lake. In contrast, polecats did venture into buildings; they are known to inhabit human settlements in search of food and shelter, and this behaviour is usually observed during the winter (Blandford 1987, Weber 1989e, Brzeziński et al. 1992). Weber (1989e) suggested that polecats enter human settlements in the winter in order to counter thermoregulatory problems but it seems that the availability of food also seems to be very important. In comparison to mink, polecats do not build up a territorial spacing system and are considered to be nomadic foragers which intensively exploit small areas where resources are locally abundant and then abandon them for several weeks or months before returning (Herrenschmidt 1982, Blandford 1987, Weber 1989a, d, Zabala et al. 2005). Some authors (Weber 1989b, c, Brzeziński et al. 1992) have suggested that polecats are particularly nomadic during harsh winters and this behaviour is forced upon them by the scarcity of food resources (mainly anurans). For example, in Białowieża Primeval Forest polecats mainly inhabited areas close to a forest stream and their home ranges were distributed linearly. However, from time to time in winter some individuals moved away from the stream as far as 1300 m (Brzeziński et al. 1992). In many cases, residential versus nomadic behaviour is difficult to define and polecats are probably able to shift from territorial spacing to nomadism. Resident mink and polecats have a similar spacing pattern, typical for many mustelids (Powell 1979), with little overlapping of the home ranges of one sex and exclusive core areas for each individual. Home ranges of males are larger and can overlap with the home ranges of several females. In general, a similar pattern was observed in the present study; however, in the vicinity of the unfrozen canal the degree of overlap of home ranges, both inter- and intraspecific, was relatively high, and these results are consistent with the observations from the Thames River in UK (Harrington & Macdonald 2008).

The range of mink densities may be very broad, from below one to over 10 individuals per 10 km of shoreline (Gerell 1970, Smal 1991, Sidorovich et al. 1996, Bartoszewicz & Zalewski 2003). In Białowieża Primeval Forest, linear densities of mink and polecats were dependent on the river size and reached up to 7.5 mink per 10 km and 5 polecats per 10 km of the river (Sidorovich et al. 1996). The results of the present study showed that the densities of both species by the two lakes were not stable and from time to time could become relatively high. Similarly the size of mink and polecat home ranges can be highly variable, being influenced by many environmental and population factors (Blandford 1987, Dunstone 1993, Melero et al. 2008b).

The radiotracking of polecats and mink in the present study showed that both species exhibited a pattern of rather low activity: they were active during ca. 1/5 of time. This stays in accordance to other studies in this topic. For instance Dunstone (1993) recorded that mink remain inactive for the majority of the time, while foraging and travelling comprise up to 20% of their time budget. Weber (1989d) noted that polecats can significantly reduce their activity in winter. During this season the reduction of activity to short hunting events can be profitable strategy (e.g. Zalewski 2000). This hypothesis is partially confirmed by the distinct reduction of activity of mink and polecats during second half of the night when the ambient temperatures are the lowest. We recorded that polecats were active most often during night whereas mink showed similar level of activity during day and night. Similarly Harrington & Macdonald (2008) found mink to be more diurnal and polecats more nocturnal, Blandford (1987) found polecats to be predominantly nocturnal whereas Weber (1989d) reported that polecats were more active and diurnal in the summer and less active and more nocturnal in winter. We observed differences in activity pattern of mink and polecat, thus, it cannot be excluded that both species reduce competition by avoiding activity during the same periods.
Our results did not produce any evidence for intensive competition between mink and polecats that could lead to a reduction in their populations. During the six years of the study the densities of both species showed no inverse correlation. The distribution of animals established by radiotracking revealed that individuals of both species could coexist in a small area with overlapping interspecific home ranges, and they may partially exploit the same habitats in winter and spring. On the other hand we observed mechanisms reducing competition: both species utilized lakeside habitat in different proportion and showed different circadian activity. We conclude that invasive mink and native polecat densities may be high in areas offering access to open water, where food resources are abundant and readily available, and also in the vicinity of human settlements located close to lakes and rivers, which may provide shelter and additional foraging grounds for polecats.

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**Literature**


SPSS 2004: SPSS 13.0 for Windows. SPSS, Chicago.


