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American mink, *Mustela vison* diet and predation on waterfowl in the Słońsk Reserve, western Poland

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Abstract. The abundance, diet, and prey relationships of American mink *Mustela vison* were studied in the Słońsk Reserve (W Poland) on two plots: shore and reservoir. Estimated mink number within the Reserve was 69 in autumn–winter 1998/1999 and 50 during spring 1999. The diet of American mink consisted mainly of mammals, birds and fish. In autumn–winter, birds formed 4–16%, whereas mammals constituted up to 56% and fish up to 62% of the biomass consumed, depending on the plot. In spring and summer, however, birds formed 45–60% of the biomass consumed in the reservoir and 35–46% of the biomass taken by mink on the shore. The European coot *Fulica atra* was the most frequently consumed prey. In spring, mink removed 7.8% (N=278 killed birds) of coots nesting in the Reserve, 1.8% (N=9) of breeding grebes *Podiceps* spp. and 11.2% of ducks (N=93 taken birds). On straw platforms only 13.6% of greylag geese *Anser anser* broods were successful. From 35 to 77% of the nests on straw platforms were destroyed by mink. In wooden boxes 46.4% of mallard *Anas platyrhynchos* and 33.3% of shelduck *Tadorna tadorna* nests were successful. American mink destroyed 22–40% of the nests in boxes. However, the arrival of American mink to the Słońsk Reserve has not resulted in a noteworthy decrease in waterfowl populations.

Key words: American mink, diet, predation on birds, waterfowl nesting success, predator impact

Introduction

American mink were brought from North America to European fur farms in the late 1920s. However, many of them escaped and thousands of animals were released into the wild. The first individuals were recorded in the wild between the 1930s to 1960s in various European countries (Lever 1985), and by the end of the 1990s, it was a common and widespread semi-aquatic predator inhabiting coasts, flowing waters, banks of lakes, ponds and other reservoirs (Bravo & Bueno 1992, Dunstone 1993, Bevanger & Henriksen 1995). Mink are generalist predators: rodents, shrews, birds, amphibians, fish and crustaceans constitute the bulk of their diet in Europe (Jędrzejewska et al. 2001). The diet composition of mink varies depending upon habitat type. Mammals, fish and amphibians are most important food resources on rivers, whereas birds and fish predominate in the diet of mink living near lakes and ponds (Jędrzejewska et al. 2001). Due to their both terrestrial and aquatic hunting as well as generalist feeding habits, mink are capable of driving prey species into decline. Indeed, in various regions heavy predation by mink on rodents (Barreto et al. 1998), birds (Ferreras & Macdonald 1999) or fish (Heggenes & Borgström 1988) has been observed. In Great Britain, the numbers of American mink are negatively correlated with numbers of water voles *Arvicola terrestris*

(H a l l i w e l l & M a c d o n a l d 1996). After 20 years of mink occurrence in the Masurian Lakeland, on north-eastern Poland, a decline in muskrat *Ondatra zibethicus*, coot *Fulica atra* and some duck species was observed, although a study on the mink diet in that area suggested that the proportion of birds in the mink diet was very low (B r z e z i ń s k i 1998). Therefore, the impact of mink in the early phase of its expansion is not well known.

In Poland, the first American mink were observed in 1962 in Central and Eastern Poland (R u p r e c h t et al. 1983). However, in the western part of the country mink did not appear until the end of the 1980s, and in Słońsk Reserve, the mink has been present less than 10 years. The Reserve is one of the most important protected areas for birds in Europe (W e s o ł o w s k i & W i n i e c k i 1988, G r i m m e t t & J o n e s 1989). Large concentrations of different bird species occur there year-round. Major water level fluctuations are characteristic of this area and can reach 4 m annually. Owing to such drastic changes, artificial nesting structures have been installed over many years for the protection of nests against inundation by water. Wooden boxes and platforms made of straw are put high on willow trees. These nests are used by greylag geese *Anser anser*, mallards *Anas platyrhynchos* and shelducks *Tadorna tadorna*.

The main aim of our study was (1) to describe the diet composition of American mink during the initial phase of its colonisation, and (2) to assess the impact of mink predation on bird populations in the Słońsk Reserve.

Study Area

The Słońsk Reserve covers 46.6 km^2 and is located in western Poland (52°34' N, 14°43' E) where the Warta River flows into the Odra River. The lower Warta River valley is surrounded by dikes creating an artificial reservoir which acts as a catchment for floodwater. Normally, from autumn to spring 50–100% of the reserve is flooded, with only small islands and hummocks above the water. The area forms a mosaic of flooded meadows, old riverbeds and irrigation channels (M a j e w s k i 1983). Willow *Salix* spp. thickets are the dominant vegetation with older willow trees much more rare. The Słońsk Reserve has been protected as a Ramsar Site since 1984 because it is particularly important as a nesting site for waterfowl, grebes, terns, gulls, shorebirds, and coots (2,000–14,000 breeding pairs, B a r t o s z e w i c z et al. 2000). During the moulting season up to 25,000 ducks concentrate here (P a n e k & M a j e w s k i 1990) and during autumn and spring migrations up to 250,000 birds stay in the reserve (M a j e w s k i 1983, B a r t o s z e w i c z et al. 2000). The reservoir is also the wintering place for several tens of thousands of birds.

The reserve is sporadically inhabited by ten species of carnivores: weasel *Mustela nivalis*, stoat *M. erminea*, American mink, polecat *M. putorius*, pine marten *Martes martes*, stone marten *M. foina*, otter *Lutra lutra*, badger *Meles meles*, racoon dog *Nyctereutes procyonoides* and fox *Vulpes vulpes* (B a r t o s z e w i c z 1997, B a r t o s z e w i c z unpublished data). Additionally, the racoon *Procyon lotor* appeared in the reserve in 2000. High water levels for most of the year and its dynamic fluctuations limit access by predatory mammals to the reserve.

Two plots were selected and scat samples were collected and the density of American mink determined (Fig. 1). The shore plot (two parts with total area of 5.7 km^2) was located in the Partially Protected Reserve and included 11.4 km of shoreline and a 0.5 km wide belt of flood waters adjacent to the shore. There were many trees (mainly willows and poplars *Populus* spp.) growing on the dam. The reservoir plot (12.5 km^2) was located in the central

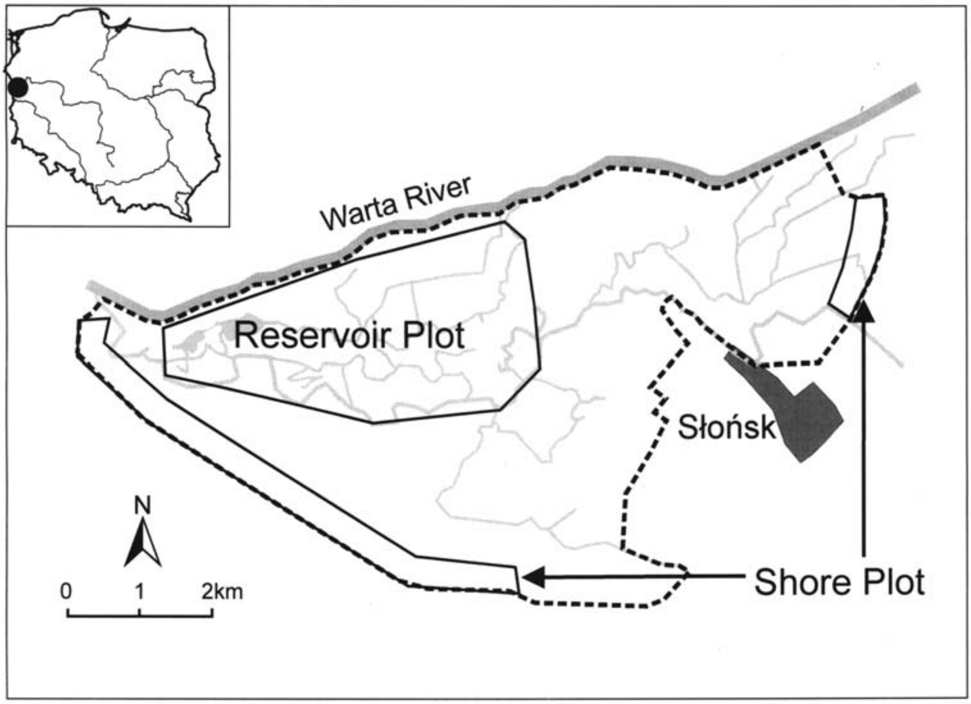

Fig. 1. Map showing location of the Słońsk Reserve and study plots.

part of the Strict Reserve. It remains under water throughout most of the year. Artificial nesting structures for birds have been installed in this location. There are 300 permanent wooden boxes and, in addition, 100 straw platforms are erected each spring.

Material and Methods

Estimating the number of American mink

An index of mink abundance from 1996 to 1999 was obtained using the annual numbers of individuals found killed on the 9 km of road adjoining the reserve. The road was searched 2–5 days per week and dead mink were collected. The density of mink on the shore plot was estimated using the maximum numbers of trapped and radiotracked animals. Live trapping of mink was conducted each month from October 1998 to May 1999. Wooden box traps were set at ground level near the water at c. 200 m intervals. Trapping was conducted on the shore plot and traps were operated from 7 to 14 days, with a total of 1835 trap-nights (35–186 trap-nights per month). Fish were used as bait, and traps were checked once a day during the morning. Captured mink were anaesthetised with Bioketan (Ketaminum hydrochloricum), sexed, weighed, individually marked with ear notches, and the animal was radiocollared. Three seasons were distinguished: autumn–winter (16 September – 15 March), spring (16 March – 15 June), and summer (16 June – 15 September). Autumn and winter seasons were combined, because during the migration and wintering periods bird species and numbers are similar (Bartoszewicz et al. 2000). In summer, the trapping success for mink was very low and during this season, it was impossible to estimate the number of mink. Mink density was estimated using two methods. First, for each season the mean number of mink in the shore plot was calculated by averaging the maximum number of mink caught during that season and the number of animals alive at the end of the season (calculated from daily survival rates of radiotracked individuals; Trent & Rongstad 1974). Twenty-six mink were collared: 14 were radio-tracked in autumn–winter and 12 in spring (two were radio-tracked in both seasons). Collared animals were tracked from 2 to 143 days each (on average 30 days) and located 1–2 times per day. If their position did not change within a period of 5–7 days, the area was searched. The search resulted in finding either a dead animal or a collar. The number of days of survival of all radiotracked animals was used to calculate their daily survival rate (Trent & Rongstad 1974). The confidence interval (95% CI) for the daily survival rate was calculated using a binomial distribution (Krebs 1989). The second method used to estimate mink numbers used was the mark-recapture models available in the JOLLY program (Pollock et al. 1990, J. E. Hines program). Model AX was selected with time specific survival and capture-probability and with between-period resightings. Resighting data was included in the model if we radio-tracked mink between periods of trapping and death of mink data.

It was impossible to catch animals in the flooded area of the reservoir plot. Mink on the reservoir do not have many natural shelters and they were assumed to spend days inside wooden boxes for ducks and straw platforms for geese. These boxes and platforms were therefore checked by boat on six occasions. The maximum number of mink observed in every season was used as an index for mink density in the flooded area. None of the radiotracked mink from the shore plot travelled between shore and reservoir plots.

Determining the diet composition and number of prey removed

In total, 1013 scats collected from January 1998 to July 1999 were analysed. Most of the samples were taken from the resting sites of radiotracked individuals or from duck nest boxes where mink had rested. Prior to the analysis, each scat was dried in an oven at 40 °C and stored at room temperature. Analysis of scats followed a standard procedure (Lockie 1959, Goszczyński 1974). Prey was identified on the basis of bony remains and microscopic characteristics of hair and feathers according to identification keys (Böhme 1977, Pucek 1984, Teerink 1991). The biomass of consumed prey was obtained by applying coefficients of digestibility after Fairley et al. (1987) and Jędrzejewska & Jędrzejewski (1998). The food niche breadth were calculated after Levins (1968) for 6 main food groups: 1) muskrats, 2) other mammals, 3) birds, 4) amphibians, 5) fish, 6) invertebrates and plant material.

The impact of mink on birds in two seasons (autumn–winter and spring) was estimated from the average density of mink, their diet composition, and food requirements (Jędrzejewska & Jędrzejewski 1998). The number of a given prey group eaten per day per mink (N_{pd}) was calculated as:

$$N_{pd} = (DFC \text{ x } Bp) / BMp,$$

where DFC is average daily food consumption (150 g; Danilov & Tumanov 1976); Bp is the fraction of given prey biomass in mink diet; and BMp is the mean body mass of given prey. The following body masses were used: muskrat 1100 g (P u c e k 1984), coot 650 g, duck 600 g, grebes 400 g. Mean body mass of Anatidae was calculated as a weighted mean of body masses of duck species found as prey remains near mink resting sites. The number of prey eaten by mink per season (N_{ps}) was calculated as:

$$N_{ps} = N_{pd} \times D_m \times Nday,$$

with D_m being the mean seasonal density of mink, and Nday equal to the number of days per season (autumn–winter – 191 days, spring – 81 days).

To assess the selection by mink of particular groups of birds in Słońsk Reserve, an Ivlev's electivity index D (modified by J a c o b s 1974) was calculated:

$$D = (r - p) / (r + p - 2rp),$$

where r is the proportion of number of each species among mink prey, and p is the proportion of number of bird group in the reserve. Ivlev's D index ranges from –1 (total avoidance of prey group), to 0 (selection proportional to occurrence), to 1 (maximum positive selection).

Additionally, the remains of birds preyed upon by mink in the Słońsk Reserve were collected during searches of mink caches and shelters, straw platforms, and wooden boxes.

Estimating the density of breeding birds and their nesting success

The number of breeding birds has been estimated in the Słońsk Reserve in 1998 and 1999. The size of the breeding population was assessed using methods tested on other wetlands, but with stable water levels (B o r o w i e c et al. 1981, R a n o s z e k 1983, B i b b y et al. 1992). However, owing to the specific characteristics of Słońsk, a large area with variable water levels during the breeding season, it was necessary to develop specific counting methods depending on the current flood levels (B a r t o s z e w i c z et al. 2000). These included:

- for ducks, counting males or pairs along line transects or study plots and results scaled up to cover the whole flooded area;
- for coot, counts of all visible birds and nests along fixed transects and results similarly scaled up to cover the whole flooded area;
- for other species, counts of all adults or territorial pairs in the whole reserve.

To determine the breeding success of waterfowl, nests on artificial nesting structures were monitored. At the beginning of the nesting season all wooden boxes and platforms within the study area occupied by birds were located. During incubation, nests were checked 2–4 times to record success and possible reasons for loss. Investigations were made every 10–14 days. Each nest was checked at the beginning of incubation, during incubation and, if successful, at the end. The reason for nest loss was determined by the type of damage, egg biting or direct observation of predators at the nest.

Results

Mink numbers and mortality

In Słońsk Reserve, the mink population index increased during the years 1996 to 1999. In 1996, two mink were killed on the road surrounding the reserve and this number increased in consecutive years up to 10 individuals in 1999. From October 1998 to April 1999, a total of 46 mink were caught 95 times (5 individuals were trapped within the reservoir in wooden boxes for ducks, 41 mink were caught on the shore habitat). In the shore plot, the trapping success was high in October–November (5.5 mink/100 trap-nights), decreased in January–February (3.2 mink/100 trap-nights) and increased again in March and April (4.9 mink/100 trap-nights). On the shore plot, maximum density was 4.2 mink/km^2 during autumn–winter (including all individuals), whereas in spring the maximum density was only 2.6 mink/km^2 (Table 1). In the reservoir plot, 3–4 individuals per survey were observed in autumn–winter, whereas in spring there were 4–5 individuals. Assuming the higher value, the density was calculated as 0.3 mink/km^2 in autumn–winter and 0.4 mink/km^2 in spring (Table 1).

By considering all shore and reservoir habitats in the reserve and from the density of mink in these two habitats, the total number of mink inhabiting the Słońsk Reserve was estimated at 69 in autumn–winter and 50 individuals during spring (Table 1). Thus, the total number of mink decreased between autumn–winter and spring by 28%. The daily survival rate of 14 collared mink in each season declined slightly from 0.989 (95% CI 0.980–0.997) in autumn winter to 0.977 (0.957–0.997) in spring ($Z = 1.08$, $p > 0.05$). Likewise, the probability that a mink would survive the whole season declined from 0.1351 (95% CI 0.028–0.672) in autumn–winter to 0.1203 (0.019–0.772) in spring. Therefore, of the 59 mink that inhabited the shore (see Table 1) only 8 mink were estimated to survive until autumn–winter. In spring, of the 37 mink that lived on the shore only 5 individuals would survive to the end of the season. Along the shore of the Reserve an average of 34 mink lived for the whole season in autumn–winter, and 21 mink in spring. Similar results were obtained using the mark-recapture model. Estimated number of mink on shore plot was 14 in autumn–winter and 10 in spring, and along the shore of the Reserve 35 mink in autumn–winter and 24 in spring. The estimated number of mink using the from capture-release model was 3% higher in autumn–winter and 12% higher in spring than that estimated from the number of captured and surviving. For further estimations, the higher numbers of mink obtained by mark-recapture were used.

Table 1. Numbers of captured and radiotracked American mink *Mustela vison*, their density (per 1 km^2) on two study plots and estimated number of mink in the whole Słońsk Reserve in 1998-1999.

Study plot	Number of mink caught or observed in the studied area		Density of mink per 1 km^2 in the studied area		Total number of mink in the whole Reserve[a]	
	Autumn - winter	Spring	Autumn - winter	Spring	Autumn - winter	Spring
Shore	24	15	4.2	2.6	59	37
Reservoir	3-4	4-5	0.3	0.4	10	13
Total	28	20			69	50

[a] total areas for calculation of density were: shore - 14.05 km^2; reservoir – 32.55 km^2.

Diet composition of American mink

The diet of American mink consisted of three main prey (mammals, birds and fish) and the proportion of each group varied between seasons and plots (Table 2). Mammals constituted from 32 to 56% of all food biomass eaten by mink in autumn–winter, declined to 20–26% in spring and again increased in summer (18–51% of prey biomass). The share of muskrat in mink diet varied from 7 to 26% of biomass consumed in various seasons and plots (Table 2). In autumn–winter muskrat were more frequently taken in the reservoir plot than on the shore plot ($G = 11.3$, $df = 1$, $p < 0.001$). On both plots *Microtus* voles were often eaten in autumn–winter than in spring and summer (shore plot: $G = 22.4$, $df = 2$, $p < 0.001$; reservoir plot: $G = 35.9$, $df = 2$, $p < 0.001$). Among 285 samples of scat that included *Microtus* remains, the species of vole was determined in 83 cases. In 82 cases, they were root voles *Microtus oeconomus* and in one case, a field vole *Microtus arvalis*. In autumn–winter, only the harvest mouse *Micromys minutus* occurred in mink scats with high frequency (10%) but it made up only 1–2% of the biomass consumed.

Fish were the second most important component in the mink diet in autumn–winter. During that season fish was the more significant food of mink on the shore (62% biomass) than inside the reserve (24%; $G = 16.9$, $df = 1$, $p < 0.001$). The share of fish, however, declined in spring and summer as compared to autumn–winter (shore plot: $G = 36.1$, $df = 2$, $p < 0.001$; reservoir plot: $G = 18.8$, $df = 2$, $p < 0.001$). In 162 cases, the species of fish was identified. Mink most often consumed roach *Rutilus rutilus* and white beam *Blicca bjoerkna* (31 and 15% of recognised specimens, respectively), but they also hunted chub *Leuciscus cephalus* and bleak *Alburnus alburnus* (4 and 3% of identified fish). From non-cyprynids fish, mink often hunted perch *Perca fluviatilis* (40% identified fish).

In autumn–winter, birds comprised only 4–16% of the biomass consumed. In spring and summer, however, birds were the staple food of mink and they formed 35–60% of the biomass consumed (shore plot: $G = 45.2$, $df = 2$, $p < 0.001$; reservoir plot: $G = 28.8$, $df = 2$, $p < 0.001$; Table 2). In spring, coots were the most frequent avian prey, making up 48% of the total biomass consumed in the reservoir plot, and comprising 29% of the biomass consumed along the shore ($G = 4.9$, $df = 1$, $p < 0.05$). Birds of the order Anseriformes were found in 15% of scats where they made up 13% of the food biomass. Grebes and passerine birds formed only a minor part of the diet (Table 2). From among 85 predated birds found in mink caches, 74% were coots, 12% were mallard ducklings, 5% were starling *Sturnus vulgaris*, and 1% greylag geese, shelduck, adult mallard, garganey *Anas querquedula*, tufted duck *Aythya fuligula*, and great crested grebe *Podiceps cristatus*.

The food niche of American mink was wide and its breadth oscillated from 2.22 in autumn–winter on the shore plot (when fish dominated in mink diet) to 4.13 on the reservoir plot (when mammals, birds and fish were of their higher abundance).

American mink predation on birds and muskrat

In autumn–winter, mink were estimated to have killed 70 coots, 34 ducks, and 19 grebes, whereas more muskrats were killed in the Słońsk Reserve (124, Table 3). In spring, however, mink removed many more birds than muskrats. During this season, mink took 44 muskrats, but killed 278 coots, 93 ducks and about 9 grebes (Table 3). In the Słońsk Reserve, three groups of birds dominated the community: ducks, grebes, and rails (Table 4). Despite the high number of coots killed by mink in spring, these predators were able to remove 7.8% of adult coots nesting in the reserve and only 1.8% of breeding adult grebes. However, mink removed a much higher percent of the Anseriformes population (excluding geese and swans) – 11.2% of birds breeding in the reserve.

Comparison of the proportion of bird groups removed by mink with their relative availability indicated that the bird species were taken in proportion to their estimated

Table 2. Diet composition (%Occ – percentage occurrence in scats and %Bio – percentage biomass consumed) of American mink on shore and reservoir plots in the Słońsk Reserve in three seasons (1998-1999). N – number of scats analysed. Food niche breadth calculated for 6 prey groups after L e v i n s (1968). B index could vary from 1 the narrowest niche) to 6 (the widest niche possible).

Food categories	Autumn –winter				Spring				Summer			
	Shore N=267		Reservoir N=204		Shore N=100		Reservoir N=384		Shore N=37		Reservoir N=21	
	%Occ	%Bio	%Occ	%Bio	%Occ	%Bio	%Occ	%Bio	%Occ	%Bio	%Occ	%Bio
Muskrat	7.9	7.2	14.2	26.0	8.0	8.4	10.2	12.5	21.6	10.5	9.5	15.9
Microtine voles	53.9	20.0	47.5	24.4	22.0	11.8	5.2	2.4	0	0	9.5	1.1
Other mammals[a]	18.7	4.4	18.6	5.5	12.0	5.6	9.3	5.4	7.8	7.2	57.1	33.8
Total mammals	66.3	31.6	70.6	55.9	38.0	25.8	24.0	20.3	27.7	17.7	76.2	50.8
Coot	3.4	1.5	16.7	9.9	39.0	29.0	68.0	48.4	64.9	34.0	47.6	23.9
Ducks	3.0	0.9	7.8	4.2	15.0	12.5	11.9	8.6	2.7	0.5	0	0
Grebes	1.1	0.2	0.5	0.6	1.0	0.2	1.8	1.6	0	0	42.9	21.4
Passerines	1.5	0.5	0	0	5.0	2.8	2.4	0.9	0	0	0	0
Undet. birds	4.5	0.5	6.4	1.0	5.0	1.5	4.2	0.7	5.4	0.1	9.5	0.2
Total birds	14.6	3.6	31.9	15.7	65.0	46.0	85.9	60.2	73.0	34.6	90.5	45.5
Amphibians	3.7	2.8	5.4	3.7	20.0	15.7	4.7	3.9	8.1	4.7	4.8	0.6
Fish	45.3	61.9	20.1	24.3	22.0	12.3	13.0	15.5	21.6	37.5	9.5	3.1
Invertebrates	2.6	0.1	1.0	0.2	5.0	0.2	3.9	0.1	34.7	5.5	0	0
Plant material	0	0	0.5	0.2	0	0	0	0	0	0	0	0
Mean biomass consumed per scat (g)	27.2		22.7		15.1		18.3		18.6		17.9	
Food niche breadth	2.22		4.13		3.47		2.44		3.55		2.82	

[a] Other mammals: *Micromys minutus* – 53 occurrences in the pooled samples of 1013 scats, *Mustela* spp. - 31, *Apodemus* spp. - 19, *Arvicola terrestris* -13, *Rattus* spp. - 12, *Clethrionomys glareolus* - 5, *Sorex* spp. - 1.

Table 3. Predation by American mink on three groups of birds and on muskrats in autumn-winter and in spring in the shore area, the reservoir area, and in the whole area of the Słońsk Reserve. To estimate mink predation, the numbers of mink obtained by mark-recapture were used.

Food categories	Autumn-winter			Spring		
	Shore	Reservoir	Total	Shore	Reservoir	Total
Coot	29	41	70	146	132	278
Ducks	16	18	34	68	25	93
Grebes	12	7	19	2	7	9
Muskrats	61	63	124	24	20	44

population size. Mink preyed on coots in same proportion as they occurred within the bird community (73.1% of the number of birds killed by mink and, 70.4% of the entire bird community excluding swans and geese – Table 4; Ivlev's electivity index D = 0.07). Mink removed a smaller proportion of grebes (2.3% of the number of birds removed) in comparison to their importance in the bird community (9.7%; D = -0.64). In contrast Anseriformes composed 19.9% of the community but 24.6% of the birds removed by mink (D = 0.14).

In 1998 and 1999, a total of 76 nests on straw platforms and 62 nests in boxes were checked. Breeding success varied depending on the type of nest but in both cases the main causes of loss were predation by American mink and crow *Corvus corone*. Low breeding success occurred on straw platforms; only 13.6% of greylag broods (N = 67) and three out of nine mallard broods were successful. At least 37%, and possibly as many as 71% of the nests on straw platforms were destroyed by mink (Fig. 2). In wooden nest boxes, 48.2% of mallard (N = 56) and two out of six shelduck nests were successful. American mink depredated between 22 and 40% of the nests in wooden boxes (Fig. 2). They took mainly eggs, but occasionally adult birds and nestlings, as well.

Table 4. Number of breeding pairs of water birds occuring in the mink diet during two consecutive years in the Słońsk Reserve.

Species	Year		Average
	1998	1999	
Podiceps griseigenai	24	15	19.5
P. cristatus	48	58	53
P. nigricollis	170	+	170
Tachybaptus ruficollis	1	4	2.5
Total Podicipedidae			245
Tadorna tadorna	15	7	11
Anas platyrhunchos	250	140	195
A. querquedula	30	16	23
A. clypeata	20	35	27
A. strepera	145	80	112
Aythya ferina	45	65	55
A. fuligula	45	115	80
Total Anatidae (excluding geese)			503
Anser anser	280	300	290
Fulica atra	750-950	600	1775

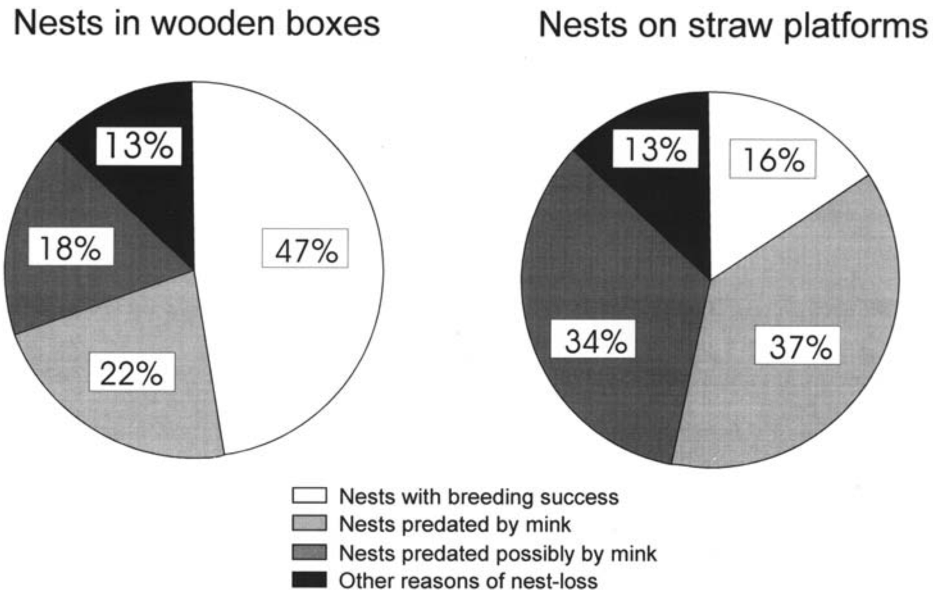

Fig. 2. The breeding success of three species of waterfowl and reasons of their nest-losses in nest boxes and straw platforms in the Słońsk Reserve in two years (1998–1999).

Discussion

Density of American mink populations was usually calculated based on the trapped number of animals (S m a l 1991, H a l l i w e l l & M a c d o n a l d 1996). In our study we used various methods depending on study area. In the reservoir plot we count observed mink. From autumn to summer almost all the reservoir is flooded and there are only a few trees standing in water. Still fewer trees have cavities, therefore mink inhabiting the reservoir occupied only duck nest boxes and straw platforms. In such conditions, the counting of mink numbers in nest boxes and strow platforms was possible, and we believe the estimated numbers are realistic. Live-trapping in shore was very intensive, so if combined, the number of trapped animals with those being radiotracked, the estimated density of mink was reliable as compared to capture-recapture estimation.

In Europe, the density of American mink varies widely, mainly depending on habitat conditions. Along rivers and inland lakes, the density usually does not exceed 10 mink/10 km shore (B a l e r s t e t et al. 1990, B a l c i a u s k a s & U l e v i c i u s 1994, H a l l i w e l l & M a c d o n a l d 1996, S i d o r o v i c h et al. 1996, S i d o r o v i c h 1997, B r z e z i ń s k i 1998). The highest density on rivers and lakes was noted at the Glore River in Ireland: 13.7 mink/10 km on average (S m a l 1991). In the Słońsk Reserve mink density was much higher, especially on the shore plot. Individuals stayed for a very short time within the study area (on average one month), so the high density was probably due to immigration from adjoining areas. Dispersing of juveniles in autumn–winter and roaming pattern of breeding males in spring influenced the low survival rate.

Birds were the dominant component of mink diet during the spring and summer and they represented 35–60% of the biomass consumed. Mink switched to birds in this season probably because the density of birds increased in spring and summer. Predation by mink also increased when the birds had limiting mobility due to incubation, brood rearing or moulting (Arnold & Fritzell 1987, Sargeant et al. 1973). Such a high proportion of birds in the diet of mink inhabiting European inland water has not been noted previously (Gerell 1968, Chanin & Linn 1980, Lodé 1993, Brzeziński 1998, Maran et al. 1998, Sidorovich et al. 1998), although in Manitoba, one of the most important places for breeding waterfowl in the North America, birds made up 40% of the mink diet in spring (Arnold & Fritzell 1987). In other studies, a similarly high share of birds in mink diet were noted on the coast and in islets with numerous sea bird colonies (Niemimaa & Pokki 1990, Clode & Macdonald 1995). In those studies, however, birds contributed less to the mink diet than in the Słońsk Reserve. On the coast, mink primarily hunted gulls and terns (Birks & Dunstone 1985, Arnold & Fritzell 1987, Craik 1990) and at lakes they preyed mainly upon coots, ducks, and grebes (Bignal 1978, Brzeziński 1998). The importance of particular bird groups varied between different water reservoirs. Ralliformes were an important part of mink diet in south-west England (Day & Linn 1972) and Anatidae were eaten more frequently than other birds in Scotland (Akande 1972). In Słońsk, mink hunted coots in proportion to their availability, but they took ducks in a slightly higher proportion than their availability.

Nesting success of ducks usually varies from 10 to 30% (Beauchamp et al. 1996). To keep a stable population, the breeding success of ducks should exceed 15% (Klett et al. 1988). In Milicz fishponds (southern Poland), the breeding success of tufted duck, pochard and gadwall averaged 40–45%, in for mallard and ferruginous duck it was 53% (Stawarczyk 1995). In the Słońsk Reserve, in 1978–1980, the breeding success of mallards was 31–49% (Majewski 1986), and in 1994–1998 the average was 50% (40–67%; Kuczyński 1999). Thus, in the Słońsk Reserve breeding success of mallards still remains at the similar level it was prior to the arrival of American mink. Thus, it can be concluded that mink did not have a significant influence on their breeding success.

The breeding success of geese however, in the reserve was much lower during our study than that recorded before mink appearance. In Słońsk Reserve, in years 1994–1996, the average success was 30% (25–48%), and it was still higher in straw platforms (55%; Osiejuk 1998). In this study (1998–1999), only 14% of nests on straw platforms were successful. In other regions, as many as 34–78% of pairs of geese had successfully hatched eggs (Newton & Krebs 1974, Witkowski 1983, Nilsson & Persson 1994, Kristiansen 1998).

The numbers of many water bird species (coot, mallard, garganey and shoveler) have been decreasing slightly at Słońsk during the last 30 years (Kuczyński et al. 1997). However, the number of birds nesting in the Reserve has not changed since the appearance of mink 10 years ago (Osiejuk et al. 1998 and unpubl. materials). This is compatible with European trends (Rose 1996). In Słońsk Reserve, after marked decreases in the numbers of breeding greylags during the 1970s, the geese numbers has fluctuated around 300 pairs for the past 10 years. Spring floods that damage nests and intensive mink predation have resulted in low productivity of geese. Long term trends in grebe numbers vary among species. The numbers of great-crested, red-necked and little grebes have decreased. The number of breeding pairs of black necked grebe fluctuates markedly (T. S. Osiejuk, unpubl. materials). Thus, the reduction in the number of grebes as well as changes in the numbers of other species are most likely a consequence of habitat and range changes, and not due to the arrival of a new predator species during the last decade.

Generally, the Słońsk Reserve is an optimal habitat for waterfowl and the density of water birds can remain constant despite decreasing population trends in the whole region and many bird species seen to sustain the impact of an additional recently arrived predator. However, if waterfowl number continue to decline in the future, then increased predation by the introduced mink could worsen their situation.

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