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Effects of feral mink removal on seabirds, waders and passerines on small islands in the Baltic Sea

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Abstract

We studied the effects of removing introduced American mink (*Mustela vison*) on the number of birds breeding on small islands in the Baltic Sea. During autumn 1992–2001 mink were removed from a 72 km^2 area, while mink were not removed from a 35 km^2 control area. Second removal (125 km^2) and control areas (130 km^2) were established during 1998–2001. The breeding densities of ringed plover (*Charadrius hiaticula*), arctic skua (*Stercorarius parasiticus*), arctic tern (*Sterna paradisaea*) and rock pipit (*Anthus petrosus*) increased markedly in the removal areas in comparison to the control areas. Turnstone (*Arenaria interpres*), common gull (*Larus canus*) and wheatear (*Oenanthe oenanthe*) also appeared to increase. Two species already extinct in one of the removal areas, razorbill (*Alca torda*) and black guillemot (*Cepphus grylle*), returned to breed in the area. Breeding densities of great black-backed gull (*Larus marinus*), oystercatcher (*Haematopus ostralegus*) and white wagtail (*Motacilla alba*) were unaffected. We conclude that it is possible to remove feral mink from large archipelagos with many small islands, and that mink removal increases the breeding densities of many bird species in this habitat.

Keywords: Biodiversity in archipelago; Breeding densities of birds; Feral mink management; Introduced predator; *Mustela vison*

1. Introduction

Predation by introduced species on native fauna has caused considerable devastation in the global biodiversity via dramatic reductions in prey populations (Atkinson, 1996; Williamson, 1996; Bright, 1998; Manchester and Bullock, 2000). Lack of coevolution has certainly contributed to the overwhelming effects that introduced predators have had on their prey (Savidge, 1987; Fritts and Rodda, 1998; Short et al., 2002). Introduced predators are considered to be one of the most important threats to seabird and endemic bird populations, particularly for seabirds breeding on isolated small islands (Atkinson, 1996; Tucker and Evans, 1997; Martin et al. 2000; Dowding and Murphy, 2001). Control programmes to manage introduced predators have often turned out to be inconvenient and insufficient (Côté and Sutherland, 1997).

American mink (*Mustela vison*) were brought to Europe for fur-farming in the 1920s (Dunstone, 1993). In Finland, escaped animals from fur farms started to spread in the 1950s and by the 1970s the species had spread all over the country (Kauhala, 1998). American mink is a semi-aquatic, generalist predator and its main food consists of fish, birds (eggs, nestlings as well as adults), small mammals and amphibians. Birds constitute a large part of its diet during spring and summer (Gerell, 1967; Dunstone and Birks, 1987; Niemimaa and Pokki, 1990). Predation by feral American mink is thought to have led to local declines in a wide range of sea and wetland bird species throughout North Europe and the British Isles (e.g. Andersson, 1992; Kilpi, 1995; Craik, 1997; Ferreras and Macdonald, 1999; Hario, 2000; Nordström et al., 2002). Birds breeding on small islands in the Baltic Sea had not generally been in touch

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with ground-living predators before feral mink was introduced. Colonies of black guillemots (*Cepphus grylle*) and razorbills (*Alca torda*) in particular have locally suffered considerable declines (Olsson, 1974; Hario et al., 1986; Jönsson and Rosenlund, 1990; Hagemeijer and Blair, 1997), since these species often breed in cavities and adults are also in high risk of predation by mink. The population declines of alcids have been dramatic in the Archipelago National Park in southwestern Finland where our study areas are located: the numbers of breeding pairs of razorbills declined by 60% and the number of colonies by 78% between 1973–1974 and 1994, while numbers of black guillemots declined by 73% and the number of inhabited islands by 67% during the same time (Stjernberg et al., 1974; Miettinen et al., 1997). A major cause of these declines is apparently mink predation, because mink inhabited the southwestern archipelago of Finland in the 1970s (Kauhala, 1996, 1998). Predation by American mink has also been attributed to the decline of the water vole (*Arvicola terrestris*) in the United Kingdom (Rushton et al., 2000) and it is suspected to have contributed to the disappearance of European mink (*Mustela lutreola*) through competition and disease transmission in several European countries (Dunstone, 1993; Maran and Henttonen, 1995).

In the outer archipelago of the Baltic Sea, feral mink have few natural enemies and competitors. The white-tailed eagle (*Haliaeetus albicilla*) and the eagle owl (*Bubo bubo*) may act as top predators in this habitat (Korpimäki and Norrdahl, 1989; Sulkava et al., 1997), and the otter (*Lutra lutra*) may compete with the mink for space and food (i.e. fish) under certain circumstances, especially in winter (Erlinge, 1972; Chanin, 1981). However, the otter has been nearly extinct in the south western archipelago of Finland since the 1960s (Kauhala, 1996).

Here we present the results of a large-scale removal experiment of American mink which was conducted in a Finnish archipelago of the Baltic Sea. We compare changes in breeding densities of seabirds, waders and passerines in two areas where mink were removed with two comparable areas where mink were not removed.

2. Methods

2.1. Study areas

The study was conducted in the Archipelago National Park in the central northern part of the Baltic Sea, southwestern Finland (midpoint 59°N, 21°E, Fig. 1). Four groups of small, mainly rocky islands were selected: these consisted of two removal areas R1 and R2 with 60 and 62 islands respectively (in sea areas of 72 and 125 km^2 and totalling 1.15 and 1.08 km^2 land areas), and two controls C1 and C2 with 37 and 64 islands, respectively (in sea areas of 35 and 130 km^2 and totalling 0.57 and 1.07 km^2 land areas). Most of the islands are <2 ha and 60% are <7.5 m above sea level. They have sparse vegetation, mainly tiny patches of grass or juniper scrub (*Juniperus communis*) with solitary trees on larger islands.

2.2. Mink removal

Feral mink were removed mainly each autumn and early spring before birds started to breed from R1 during 1992 to 2001 and from R2 from 1998 to 2001. This was done by two gamekeepers and a tracking scent hound, which had been trained for the purpose. When mink are discovered they usually hide under a heap of stones or dense junipers. They were flushed out from these refuges using an air-blasting leaf-blower device and killed with a shotgun (Nummelin and Högmander, 1998; Nordström et al., 2002). Lethal IHJÄL®-traps were also used especially during winter. These traps are made to look like holes and were baited with fish. However, if a mink had been caught with a trap earlier, no bait was needed since mink were attracted by the mink scent in the trap. In the R2 area, trapping was a more important method, and was carried out with 6–7 traps on and around some large islands just outside the R2 area, from which mink may be dispersing.

The control areas were searched for any signs of mink (i.e. scats, killed prey items, sightings) during bird censuses. The total number of mink and possible fluctuations in the mink population are difficult to estimate because they may travel extensively in search of territories and their home ranges may be large (Gerell, 1969; Niemimaa, 1995). In spring 2001, we attempted to estimate the abundance of mink by using the trained scent hound in the C1 area, and to compare these results with visual signs found on the islands. Out of 40 islands, (each >1 ha), of the C1 area and its buffer zone, we randomly chose 12 islands.

2.3. Bird census

Birds were censused three times every breeding season, by walking through the islands while searching for nests and nestlings and counting adult birds. In the results we deal mainly with the common and regularly breeding species of seabirds, waders and passerines. We mainly followed the instructions given by Hildén et al. (1991) on censusing archipelago birds. In early May, we censused great black-backed gull (*Larus marinus*) and oystercatcher (*Haematopus ostralegus*). In the first quarter of June we censused ringed plover (*Charadrius hiaticula*), redshank (*Tringa totanus*), turnstone (*Arenaria interpres*), common gull (*Larus canus*), arctic tern (*Sterna paradisaea*), arctic skua (*Stercorarius para-*

siticus), black guillemot, razorbill and passerine species—meadow pipit (*Anthus pratensis*), rock pipit (*Anthus petrosus*), white wagtail (*Motacilla alba*) and wheatear (*Oenanthe oenanthe*). In early July, a third census was carried out, when the densities of late breeding pairs were counted. These were mostly waders or passerines that had not settled or been detected in the earlier census. Bird census started in the R1 area in spring 1993, in C1 in spring 1994 and in both R2 and C2 in spring 1998.

For gulls, terns and arctic skuas, the numbers of pairs were based on nest counts. For waders and passerines the density estimates are based on the number of pairs in suitable habitats and on parental behaviour or fledglings observed (Hildén et al., 1991). Breeding densities of black guillemots are difficult to estimate since the nests in our study areas are under loose boulders, and only a small fraction of the nests can be found. We estimated the numbers of pairs by multiplying the total number of birds seen in the colony by 0.5. This number might also include non-breeders and subadult birds, which are attracted to colonies (Hario, 2000). Black guillemots were counted within a few hours of sunrise, when the maximum number of birds is present in the colony (Hildén and Hario, 1993).

2.4. Statistical analyses

We used a general linear model to test for the effects of treatment (class variable; removal or control), year (covariate; 1993–2001) and their interaction on the total number of pairs breeding per km^2 land area for each bird species in R1 and C1 areas and R2 and C2 areas separately. We used the procedure GLM in the SAS statistical package version 8.01 (SAS Inc. Institute, 2000). In the homogeneity-of-slopes model we compared the regression lines for treatments in respect of time (i.e. year) and the main interest was in the treatment–year interaction. For some species the population change was not linear, and therefore we used a second order polynomial regression since it fitted the model best. To avoid results affected by chance we tested only species which in any year were breeding on at least 10% of the islands in either R1 or C1 areas (see e.g. common tern in Section 3). The results of R2 and C2 areas are interpreted as a replicate of the initial phase of the long-term removal experiment in R1 and C1 areas.

3. Results

3.1. Mink removal and occurrence

A total of 98 mink were removed from the R1 area between autumn 1992 and spring 2001, the majority (73%) of which were removed in the first year (Fig. 2). We estimated the hunting effort by the number of days spent in mink hunting (ca. 10 h per day). The mink capture rate per hunting effort reduced substantially after the first 2 years in the R1 area (Fig. 2). The mean size of islands where mink were removed was 3.87 ha (±0.30 SE), whereas the mean island size in the R1 area was 1.91 ha (±0.30 SE). We found at least five mink that had re-colonised the R1 area during the bird

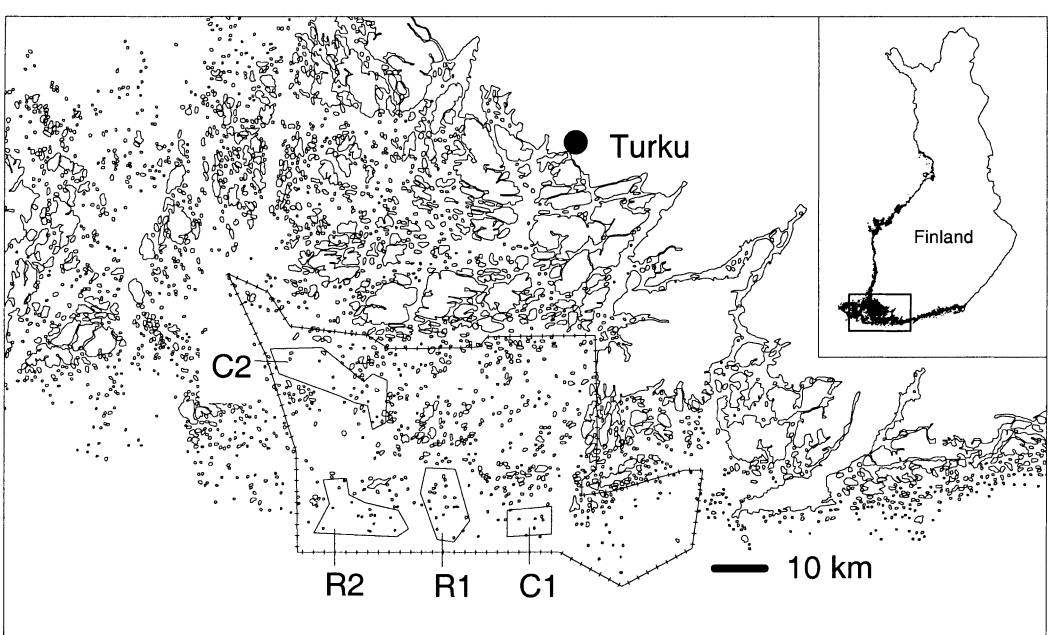

Fig. 1. The location of the two removal (R1 and R2) and two control (C1 and C2) areas in the vicinity of Turku, southwestern Finland. The boundary of the joint working area of the Archipelago National Park is marked with the crossed line. (National Land Survey of Finland no. 264/MYY/01).

breeding season, but these individuals were quickly removed.

From the R2 area a total of at least 50 mink were removed during autumn 1998–2001 with minimum annual numbers 13, 16 and 13. Four other mink were removed during summer in the bufferzone of R2. A few islands showed signs of mink in 1999 and 2001, but most of R2 was considered mink free.

In area C1 we found evidence of mink on nine of the 12 islands where searches were conducted in spring 2001: live mink on seven using the trained hound, signs of mink on five and neither signs nor live mink on three.

3.2. Breeding densities of birds

Mink removal had most positive effects on breeding densities of ringed plover, arctic skua, arctic tern and rock pipit in the R1 area in comparison to the C1 area (Figs. 3–5, Table 1). Breeding densities of turnstone, common gull and wheatear in the R1 area increased notably during the first few years, particularly for turnstone (Figs. 3–5), and because these increases were remarkably fast, there were significant effects of both treatment and year on the breeding densities, but not of the treatment–year interaction. Breeding density of redshank increased more in the R1 area than in the C1 area (Fig. 3), however this change was not significant. Arctic tern increased more than three fold in the R1 area compared with the C1 area (Fig. 4). Both common gull and arctic tern also increased in the C1 area, although not as much as in the R1 area and their breeding densities were actually slightly higher at the beginning of the experiment in R1 than in C1. Rock pipit increased substantially after mink removal (Fig. 5).

The arctic skua was the only species that showed a significant increase in breeding population in the second mink removal area ($F^{(\text{year})}_{1,4} = 19.18$, $P = 0.01$, $F^{(\text{treatment}\times\text{year})}_{1,4} = 7.94$, $P = 0.04$), even though the trends for many species in R2 and C2 areas were similar to the initial results in R1 and C1 areas (Figs. 3–5). The trends for ringed plover and redshank in particular are consistent with the results from R1 and C1.

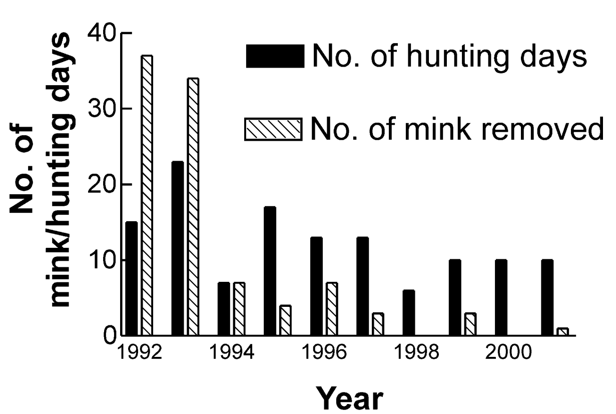

Fig. 2. Number of mink removed and an estimate of the hunting effort (number of hunting days per year) in the R1 area in 1992–2001. In 1992 mink were removed only during autumn.

Great black-backed gull, oystercatcher and white wagtail showed similar trends in all removal and control areas (Figs. 3–5), i.e. there was no evidence that these species benefited from mink removal. Breeding densities of meadow pipit decreased in R1 and C2 areas, whereas in other areas they remained fairly constant (Fig. 5).

A number of other species also bred in small numbers. Black guillemots returned to breed in the R1 area in 1994, and thereafter slowly increased in numbers. The majority (80%) of black guillemots in that area bred on one island only. Razorbills also returned to breed in area R1, though only two pairs were breeding by 1999. Both alcid species were found breeding on a few islands in areas R2 and C2, but during the four years no notable changes in population size or distribution were found there. Herring gull (*Larus argentatus*), lesser black-backed gull (*L. fuscus*) and common tern (*Sterna hirundo*) were found in a few colonies in all areas. Common tern increased from 0 to 48 pairs in the R1 area, but were concentrated mainly on just one island. Breeding densities of the hooded crow (*Corvus corone cornix*) and the whitethroat (*Sylvia communis*) were low, but both species are annual breeders in all areas: populations of hooded crow were more or less constant and populations of whitethroat showed between-year fluctuations in all areas.

4. Discussion

4.1. Methodology

Some methodological flaws in our experimental design may to some extent limit our final conclusions. These shortcomings came about in the early stage of the long-term removal and control areas (R1, C1): mink removal started before the bird censuses in the R1 area, and the C1 area was established only 1 year later. On the other hand, the results from area R1 are important and notable even without a comparison to the control area. However, we replicated the initial phase of the experiment by establishing one more removal and control areas in 1998 (R2, C2), where also breeding densities of birds were estimated in spring 1998 and mink removal was started in autumn 1998 in the R2 area. The trends of the breeding densities of most bird species in these new areas are essentially similar to those in the long-term removal and control areas.

4.2. Prey vulnerability

Species specific characteristics of the prey, like breeding phenology and body size, may both increase the risk

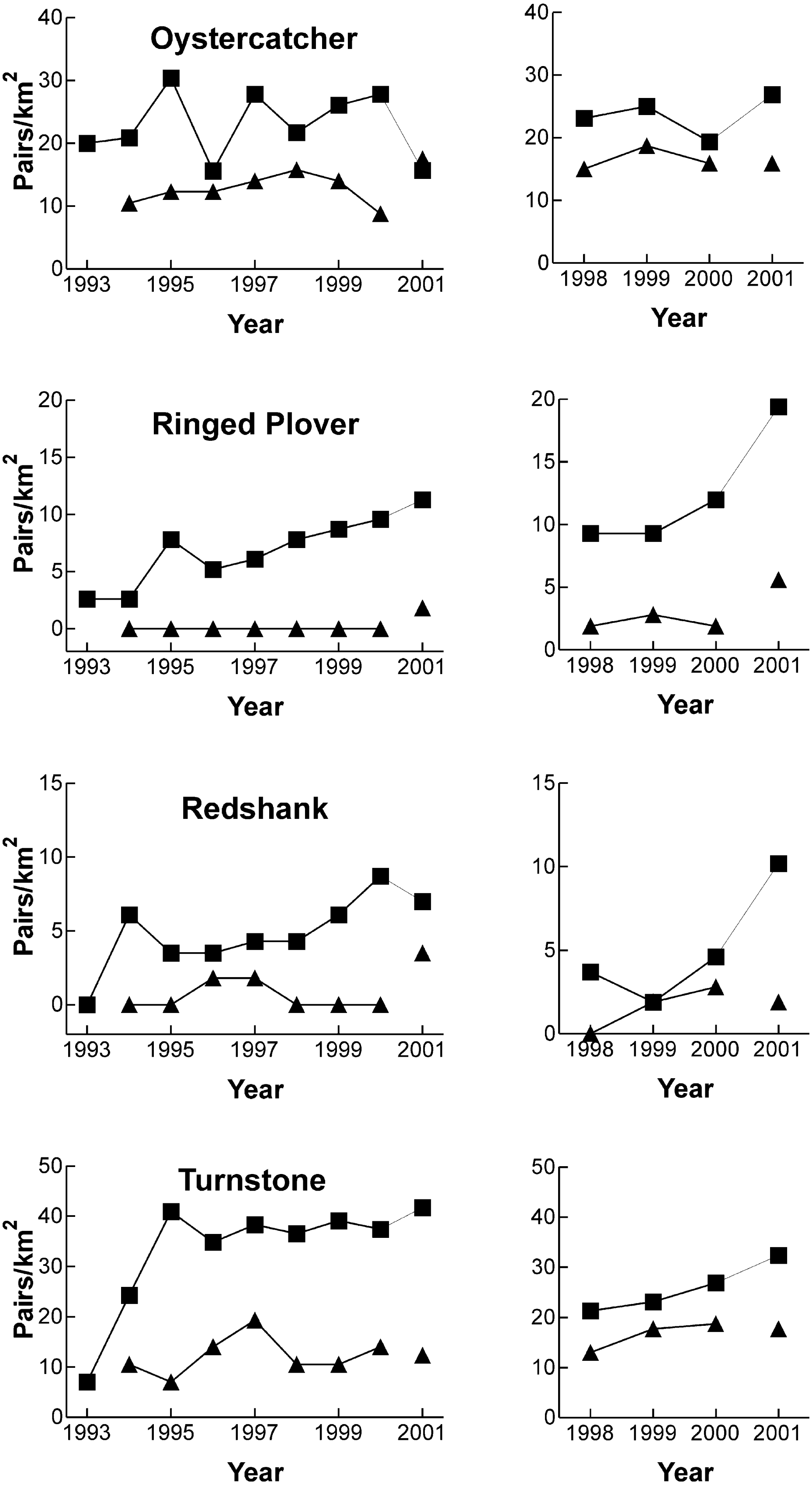

Fig. 3. Total breeding densities (pairs per km^2 land area) of waders: oystercatchers, ringed plovers, redshanks and turnstones in the mink-removal (filled squares) and control areas (filled triangles). The left panels are for the R1 and C1 areas in 1993–2001 and the right panels for the R2 and C2 areas in 1998–2001.

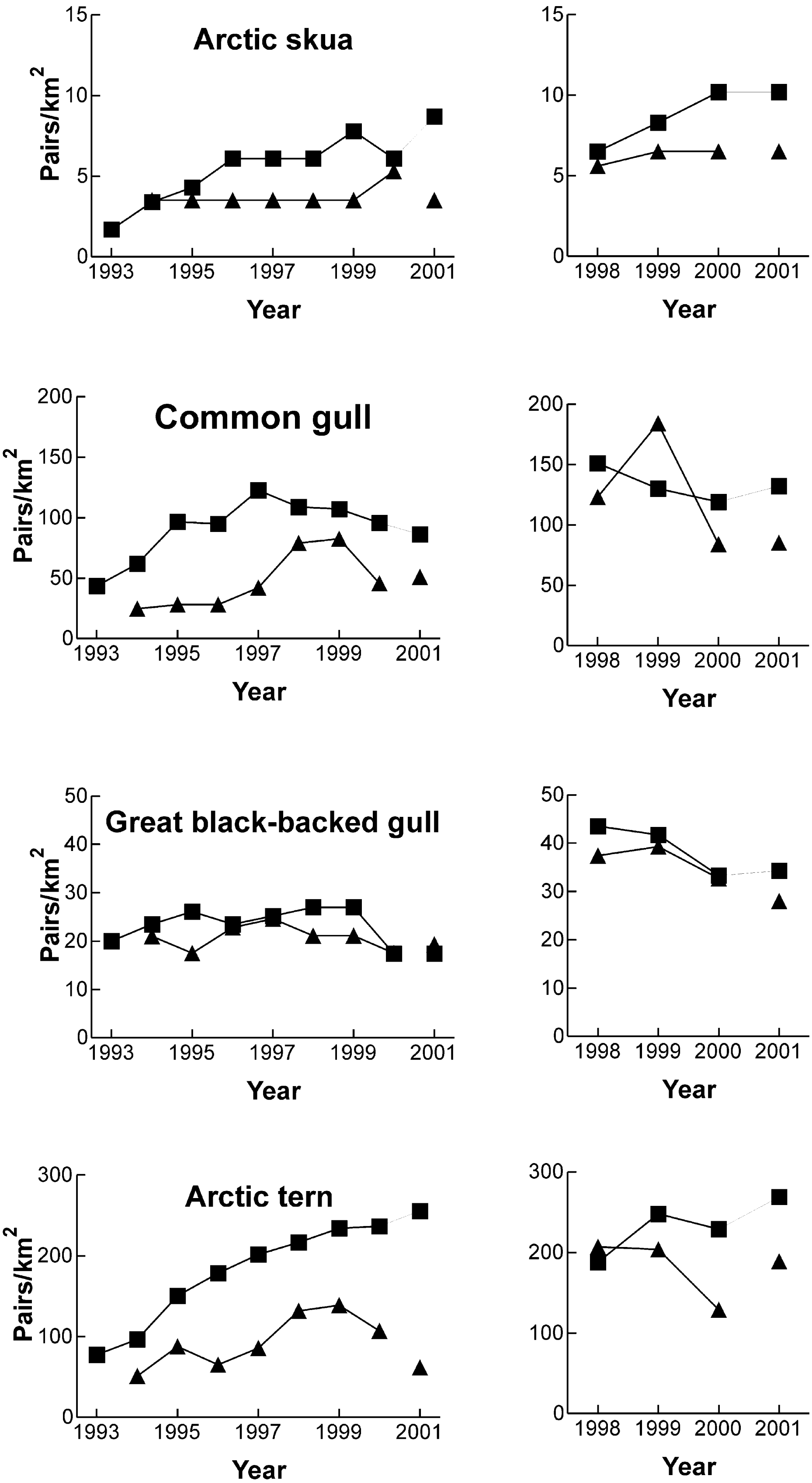

Fig. 4. Total breeding densities (pairs per km² land area) of larids: arctic skuas, great black-backed gulls, common gulls and arctic terns in the mink-removal (filled squares) and control areas (filled triangles). The left panels are for the R1 and C1 areas in 1993–2001 and the right panels for the R2 and C2 areas in 1998–2001.

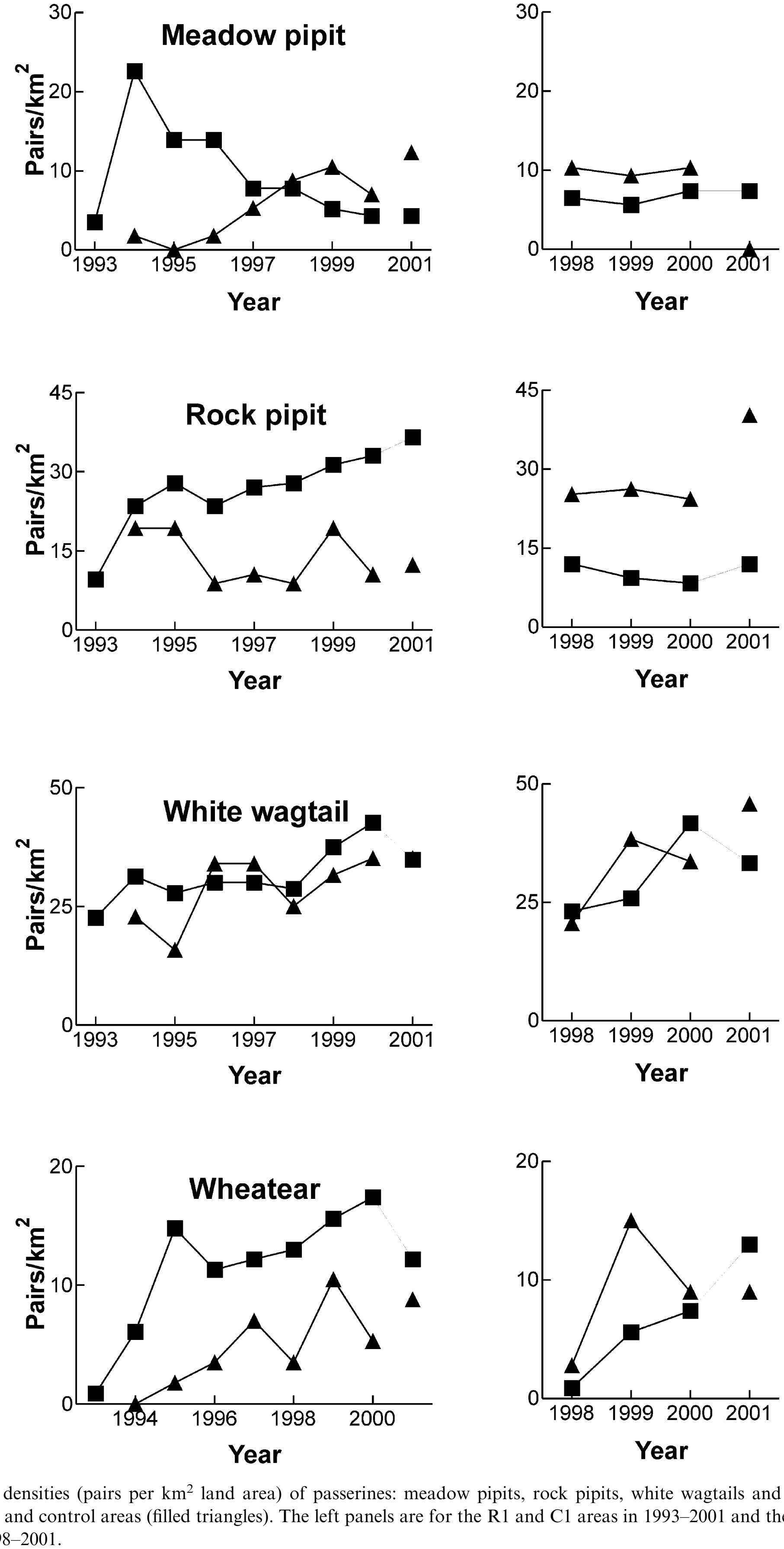

Fig. 5. Total breeding densities (pairs per km^2 land area) of passerines: meadow pipits, rock pipits, white wagtails and wheatears in the mink-removal (filled squares) and control areas (filled triangles). The left panels are for the R1 and C1 areas in 1993–2001 and the right panels are for the R2 and C2 areas in 1998–2001.

of predation. Mink kits are born in late May to June and their food requirements increase as they grow (Moors, 1980). Chicks of late breeding common gulls, arctic and common terns, turnstones and the arctic skuas hatch in June, and the breeding densities for many of these species showed strong responses to mink removal. Early breeders, such as the oystercatcher and the great black-backed gull showed quite stable breeding densities. Large body size may also decrease the risk of predation: the great black-backed gull and the oystercatcher showed no increase in breeding densities as a response to mink removal. Similarly, in the Mediterranean area, rats did not affect large bird species as seriously as smaller ones (Martin et al., 2000). In Western Isles, Scotland, smaller wader species [redshank, snipe (*Gallinago gallinago*) and dunlin (*Calidris alpina*)] were found to be more susceptible to nest-predation by introduced hedgehogs (*Erinaceus europaeus*) than the larger oystercatcher (Jackson and Green, 2000). Furthermore, in a previous paper (Nordström et al., 2002) we showed that waterfowl species that benefited [e.g. tufted duck (*Aythya fuligula*) and velvet scoter (*Melanitta fusca*)] from mink removal tended to be smaller and to breed later than species that showed no obvious response to mink removal [mute swan (*Cygnus olor*), greylag goose (*Anser anser*), common eider (*Somateria mollissima*) and the goosander (*Mergus merganser*)].

Table 1
ANOVA-table for the effects of treatment, study year and their interaction on the breeding densities of different bird species in the R1 and C1 areas

Species	Source	d.f.	*F*	*P*
Oystercatcher	Treatment	1	5.77	0.03
	Year	1	0.42	0.53
	Treatment × year	1	0.38	0.55
Ringed plover	Treatment	1	4.15	0.06
	Year	1	31.68	<0.0001
	Treatment × year	1	17.64	0.001
Redshank	Treatment	1	0.76	0.40
	Year	1	8.21	0.01
	Treatment × year	1	2.43	0.14
Turnstone	Treatment	1	15.24	0.021
	Year	1	11.28	0.006
	(Year) ^{2}	1	7.72	0.017
	Treatment × (year) ^{2}	1	2.00	0.18
Arctic skua	Treatment	1	1.62	0.23
	Year	1	25.28	0.0002
	Treatment × year	1	14.24	0.002
Gr. bl.-backed gull	Treatment	1	1.61	0.23
	Year	1	0.14	0.71
	Treatment × year	1	0.43	0.52
Common gull	Treatment	1	42.03	<0.0001
	Year	1	35.26	<0.0001
	(Year) ^{2}	1	25.63	0.0003
	Treatment × (year) ^{2}	1	2.81	0.12
Arctic Tern	Treatment	1	21.20	0.005
	Year	1	37.10	<0.0001
	(Year) ^{2}	1	19.38	0.0009
	Treatment × (year) ^{2}	1	13.07	0.004
Meadow pipit	Treatment	1	13.91	0.003
	Year	1	0.66	0.43
	(Year) ^{2}	1	0.59	0.46
	Treatment × (year) ^{2}	1	12.22	0.004
Rock pipit	Treatment	1	0.42	0.53
	Year	1	3.72	0.08
	Treatment × year	1	13.18	0.003
White wagtail	Treatment	1	1.30	0.27
	Year	1	17.28	0.001
	Treatment × year	1	0.20	0.67
Wheatear	Treatment	1	14.78	0.002
	Year	1	13.44	0.003
	(Year) ^{2}	1	7.29	0.02
	Treatment × (year) ^{2}	1	0.13	0.73

4.3. Mink-removal efficiency

Hunting with a trained hound and an air-blasting device proved to be an effective method of removing mink from islands. Hound searches in the C1 area in 2001, showed that the number of mink present may be higher than one would have concluded from the number of mink signs observed. The use of lethal traps may be an effective complementary method to remove mink, because they do not need much effort and may thus be used even on distant places.

Island characteristics, such as height, size, vegetation and isolation may influence the effects of predator removal on prey populations (Terbourgh et al., 1997; Martin et al., 2000; Owens and Bennett, 2000). On the basis of the distribution of mink removed in R1, it seems that mink are concentrated on larger islands with more diverse prey (fish, voles) during the non-breeding season when most birds are absent. Islands or island groups that are isolated or situated far from the mainland slow down re-colonisation of mink and may thus be most suitable for mink removal (Côté and Sutherland, 1997). Predator control may, however, only be a solution at the local level for small populations which often also suffer from habitat fragmentation; they may not be applicable at a larger scale and for large populations (Macdonald et al., 1999). We suspect that a large scale and successful mink removal program on mainland habitats may not be feasible.

4.4. Conservation prospects

Today, the management of introduced species to preserve native fauna is one of the main challenges for conservation biologists (Campa and Hanaburgh, 1999). Programmes to remove introduced predators should have clear objectives and be designed with care: they should consider the costs vs. benefits, the possible unacceptable effects on non-target species, and the possibility that the removed predator is not the cause of the decline in the prey population (Caughley and Sinclair, 1994).

In this study, we have experimentally shown that detrimental impacts of feral mink predation on bird populations can be considerable, and that it is possible to remove mink even from large archipelagos consisting of small islands and to keep these mink-free. This study showed that many bird species showed substantial population recovery (e.g. turnstone, arctic tern), within a few years of mink removal, while others (e.g. alcids) took much longer to recover. Most earlier predator removal experiments performed in natural habitats have shown positive effects on breeding success and post-breeding population sizes, but have failed to show an increase in the breeding population of the target bird species (Côté and Sutherland, 1997). The results from this study may be applied to control programmes of feral mink in coastal and island habitats. Our results indicate that there are good chances of success if programmes are well planned and cover several years. However, since total eradication of a mink population is unlikely, except maybe from highly isolated islands, removal of mink may have to be carried out repeatedly.

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