Risk induced by a native top predator reduces alien mink movements

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Summary

1. Nonlethal predation effects may have stronger impacts on prey populations than direct predation impacts, and this should also apply to intraguild predation. The consequences of such interactions become especially important if invasive, and potentially destructive alien predators act as intraguild prey.

2. We studied the predation-risk impacts of a re-colonizing native top predator, Haliaeetus albicilla (white-tailed sea eagle), on the movements of Mustela vison (American mink), an alien predator in Europe. We radiocollared 20 mink in two study areas in the outer archipelago of the Baltic Sea, South-west Finland, during 2004 and 2005. In the archipelago, mink home ranges incorporate many islands, and mink are most predisposed to eagle predation while swimming between islands. Observed swimming distances of mink were compared to distances expected at random, and deviations from random swimming were explained by mink distance from nearest eagle nest, number of eagle observations near mink location, and mink home-range size.

3. Mink reduced their swimming distances with increasing sea eagle predation risk: for females, the reduction was 10% for an increase of 10 eagle observations, and 5% for each kilometre towards an eagle nest. Conclusions for males were restricted by their small sample size.

4. Our results suggest that female mink modify their behaviour according to eagle predation risk, which may reduce their population growth and have long-term cascading effects on lower trophic levels including bird, mammal and amphibian populations in the archipelago. Ecosystem restoration by bringing back the top predators may be one way of mitigating alien predator effects on native biota.

Key-words: intimidation, intraguild predation, introduced species, predator–prey interaction, trophic cascades

Introduction

Nonlethal effects of predation, where prey alter behaviour or use of space to reduce the risk of being preyed upon, have gained increasing attention in recent decades (Lima 1998). In support of theory that suggests increasing activity increases predation risk, many studies have shown that prey reduce their movement under higher perceived predation risk (for review see Lima & Dill 1990; Caro 2005). Increased activity augments prey detectability (Taylor 1984), and may result in higher probability of encounters with mobile predators (Anholt & Werner 1995), which in turn may increase the risk of being killed by predators (Norrdahl & Korpimäki 1998a; Banks, Norrdahl & Korpimäki 2000). Indeed, nonlethal impacts of predation on prey demographics may be even stronger than the impacts of direct predation, and these effects tend to cascade through food chains (Preisser, Bolnick, & Benard 2005).

Although predation is most often viewed as an action between two trophic levels, predation risk may also operate within trophic levels, termed intraguild predation (hereafter IGP; Polis, Myers & Holt 1989; Arim & Marquet 2004). Similar to two-trophic-level predation, IGP may alter the activity, space use and other behavioural responses of IG prey, which may lead to a reduction in their population size and may launch trophic cascades (e.g. Polis & Holt 1992; Crooks & Soulé 1999; Henke & Bryant 1999). Such interactions may promote the persistence of prey populations. Most studies on IGP have been made in aquatic systems or on mammals.
Eagle predation risk reduces mink movements


Very few studies have focused on the behavioural effects of IGP; however, the nonlethal consequences of IGP become especially important if invasive, and potentially destructive alien predators constitute an IG prey (Glen et al. 2007). Alien vertebrate predators have been shown to have a more suppressive impact on native prey populations than native predators (Salo et al. 2007), affecting communities worldwide. One of the most successful invaders in Europe is Mustela vison Schreb. (American mink; hereafter mink), a North American mustelid, which was introduced to Europe as a fur animal in the 1920s (Dunstone 1993). Mink is a semi-aquatic generalist predator with very versatile habitat requirements and high reproductive potential (Dunstone 1993). Feral mink have become established throughout Northern Europe and West Europe (Bonesi & Palazon 2007), including even Lapland and many coastal areas and islands. They are common in the southwestern archipelago of Finland, where they negatively affect the populations of voles, amphibians and many breeding bird species (Nordström & Korpimäki 2004; Banks et al. 2008).

On mainland, mink face competition and predation from other species, but in the outer archipelagos of the Baltic Sea, mink are the only common mammalian predators. The main enemy of feral mink in the archipelagos is Haliaeetus albicilla L. (white-tailed sea eagle; hereafter sea eagle), the largest raptor in Northern Europe. Its diet consists mainly of fish and birds (Fischer 1982; Sulkava, Tornberg & Koivusaari 1997), but it also preys on small and medium-sized carnivores, including mink and Vulpes vulpes (Sulkava et al. 1997). While the proportion of mammalian mesopredators in sea eagle diet is small, the densities of these prey species are usually an order of magnitude lower than the densities of other prey, and the sea eagle may still act as an important mortality and risk factor for mink. Like many other European populations, the Finnish sea eagle population suffered a drastic decline in the 1960s and 1970s (Helander, Marquiss & Bowerman 2003), but has rapidly increased due to efficient conservation programmes: there were 75 occupied sea eagle territories in Finland in 1990 whereas the corresponding number was 249 in 2004 (Stjernberg et al. 2005). The sea eagle population consists both of nesting eagle pairs and of nonbreeding subadult floaters, which mature at the age of 5 to 6 years (Fischer 1982).

In the outer archipelago of the Baltic Sea, mink home ranges consist of many islands as most islands are too small to provide a continuous prey supply. On land, mink can promptly hide in refuges, but mink are particularly vulnerable to eagle predation while swimming. They can dive, but are unable to do so for long periods: most dives last less than 30 s (Dunstone 1993, Hays et al. 2007). Sea eagle predation risk may therefore alter mink activity, and in this study, we will test the prediction that mink reduce swimming between islands as sea eagle predation risk increases.

Materials and methods

STUDY AREA AND MINK RADIOTRACKING

The study was conducted in two areas, Brunskär in Korpoo and Vänö in Dragsfjärd, which are situated on both state and private lands in the Archipelago National Park joint working area in the Baltic Sea, South-west Finland (Fig. 1). Brunskär covers 117 km$^2$, with 3.4 km$^2$ land area and a mean island size of 1.9 ha (range 0.16–24 ha). Vänö covers 60 km$^2$, with 2 km$^2$ land area and a mean island size of 1.1 ha (range 0.15–21 ha). Most islands are small and rocky, and their sparse vegetation is characterized by grasses (Poaceae, Cyperaceae) and a shrub layer consisting of Vaccinium uliginosum L., Calluna vulgaris (L.) Hull, Empetrum nigrum L. and Juniperus communis L. A few of the largest islands have solitary trees, mainly

Fig. 1. Location of the two study areas in the Finnish south-west archipelago. B, Brunskär and V, Vänö. (© National Land Survey of Finland 763/MYY/06).

Pinus sylvestris, Sorbus aucuparia, and Alnus glutinosa (L.) Gaertn. Day length in May–August varies from 16 to 19 h and the length of dusk and dawn from 1 to 2 h. Both are longest in mid-June, therefore the night in midsummer lasts less than 2 h. Mean temperature in May–August is 12.9 °C, with a monthly radiant flux of 41 mm and mean wind speed of 5.5 m s⁻¹ (Drebushchak et al. 2002).

In total, 20 mink were radiocollared in 2004 and 2005 (Table 1). In June–July 2004, five female and three male mink were caught in Vänö area either in box traps baited with dried fish and mink scent or by flushing them out of dens into a hand-held net. In May–June 2005, trapping took place in both study areas, and eight female and four male mink were captured using the flushing (a leaf-blower) technique. Trained dogs were used to locate mink on the islands.

Mink were anaesthetized immediately after capture with a combination of medetomidine hydrochloride (Domitor® 1 mg mL⁻¹, Orion Pharma, Espoo, Finland) and ketamine (Ketalar® 50 mg mL⁻¹, Pfizer, Helsinki, Finland). The animals were sexed, weighed, and fitted with a waterproof radiotransmitter attached to a collar (Teflon Collar, model TW-4, Biotrack Ltd, Poole, UK). The weight of the collar was ~10 g which was 2% of the weight of the lightest female in the study. After handling, the anaesthesia was reversed with atipamezole hydrochloride (Antisedan® 5 mg mL⁻¹, Orion Pharma), and the animals were allowed to recover for about 20–30 min before release at the place of capture. All animals recovered well from the treatment. Permission to catch and anaesthetize animals was held by the Lab-Animal Care & Use Committee at the University of Turku. Permission to catch and anaesthetize animals was held by the permission to catch and anaesthetize animals was held by the permission to catch and anaesthetize animals was held by the Lab-Animal Care & Use Committee at the University of Turku. Permission to catch and anaesthetize animals was held by the Lab-Animal Care & Use Committee at the University of Turku.

Radiocollared mink were located using receivers (Sika, 138–174 MHz, Biotrack Ltd) connected to three-element Yagi antennas (Biotrack Ltd). We located the animals at least twice per day, in the morning and evening. In most cases, locations were made by 'homing' from the downwind side of a denning animal and recording the coordinates. Occasionally, we also made direct observations of active mink either on land or from the boat. Locations obtained within 24 h of the collaring procedure were ignored in analyses to account for the impact of collaring on the animals’ movements (Gere 1969). The final data set included 18 mink, as two males were omitted: M13 was a juvenile, and M19 disappeared 2 days after collaring.

### Table 1. Summary table of mink radiocollared in the outer south-western archipelago of Finland in summers 2004 and 2005. ID column gives the sex and identification number of each individual, M, male; F, female. Two male mink were omitted: M13 was a juvenile (Vänö, 2004), and M19 disappeared 2 days after collaring (Brunknár, 2005). The P values denote the statistical significance of comparing observed mean swimming distances to the distribution of expected mean swimming distances; P < 0.05 shows that a mink is swimming significantly less than expected at random. The distribution of random expected distances was obtained through a resampling process with 1000 iterations.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area</th>
<th>ID</th>
<th>Tracking time (days)</th>
<th>No. of movements used</th>
<th>Home range (land area in hectares)</th>
<th>No. of sea eagle observations</th>
<th>Mean distance (metres) from sea eagle nest</th>
<th>Observed mean swimming distance (metres)</th>
<th>Expected mean swimming distance (metres)</th>
<th>P</th>
<th>Collar fate</th>
</tr>
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<td>37</td>
<td>12</td>
<td>14·9 11</td>
<td>6348</td>
<td>142·1 317</td>
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<td></td>
<td></td>
<td>F2</td>
<td>22</td>
<td>3</td>
<td>14·1 10</td>
<td>6246</td>
<td>66·9 100</td>
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<tr>
<td></td>
<td></td>
<td>M3</td>
<td>64</td>
<td>19</td>
<td>51·3 5</td>
<td>5565</td>
<td>1007·7 1434·7</td>
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<td></td>
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<td>6</td>
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<td>5510</td>
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<td></td>
<td>F15</td>
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<td>7</td>
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<td>9</td>
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<td>2247</td>
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<tr>
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<td>6</td>
<td>3</td>
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<td>3782</td>
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<td></td>
<td></td>
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<td>13</td>
<td>8·9 1</td>
<td>3548</td>
<td>96·8 233·0</td>
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<td>Removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M22</td>
<td>5</td>
<td>4</td>
<td>25·7 0</td>
<td>4440</td>
<td>672·1 788·5</td>
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<td>0·329</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>M23</td>
<td>9</td>
<td>8</td>
<td>60·6 1</td>
<td>3486</td>
<td>1002·0 1681·4</td>
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<td>0·083</td>
<td>Failure?</td>
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<tr>
<td></td>
<td></td>
<td>F24</td>
<td>35</td>
<td>12</td>
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<td>7273</td>
<td>124·8 208·7</td>
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<tr>
<td></td>
<td></td>
<td>F25</td>
<td>33</td>
<td>9</td>
<td>15·3 0</td>
<td>6441</td>
<td>165·4 422·7</td>
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<td></td>
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<td>2</td>
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<td>5762</td>
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</table>

25 h. Observed mink swimming distances were calculated from these locations as the minimum swimming distance between two consecutive locations (i.e. we assumed the mink to use land bridges whenever possible). The number of movements used in the analysis for each individual is presented in Table 1. Mink are mainly nocturnal (Dunstone 1993), although female mink may not be as strictly nocturnal as males (Gerell 1969). As most of the shifts between islands occurred between dusk and dawn, the observed swimming distances based on locations taken in the evening and in the morning were considered as reliable estimates of the actual movements of the animals during that time. For males, this was confirmed by continuous radiotracking which produced a close correlation between observed and actual swimming distances (Pearson correlation, \( r = 0.999, \ P < 0.0001, n = 15 \)). There is not enough data from females to confirm such a correlation.

**PREDATION-RISK INDICES**

Sea eagles were regularly observed while travelling and radiotracking mink in our study areas. We recorded all sea eagle sightings, and for each observation the date, time, and eagle age (juvenile/subadult/adult) were registered. Sea eagle activity period begins before sunrise and continues after sunset (Fischer 1982). We observed sea eagles at all times between 3:00 and 23:00 but they may also be active during the darkest hours (night-time observations were limited by our working hours). Therefore, the activity periods of sea eagles and (especially female) mink overlap.

To compare study areas, the daily number of eagle observations was related to the distance (kilometres) travelled by boat that day in each area. Occupancy and productivity of all sea eagle territories were checked annually by the members of the World Wide Fund for Nature’s Finnish sea eagle conservation team (see Stojbern er et al. 2005 for a nationwide report). During both study years, there were four occupied sea eagle nests in or near our Brunskär study area and one occupied nest in Vänö.

Sea eagle predation risk was estimated by calculating two distinct variables for each mink individual: (i) the mean distance (metres) of mink locations from the nearest occupied eagle nest, and (ii) the mean number of eagle observations within 1-km radius of mink locations. These indices, distance from eagle nest and number of eagle observations, were not correlated (Spearman correlation, \( r = 0.17, \ P = 0.50, n = 18 \)).

**STATISTICAL ANALYSES**

We created a null distribution of random mink movement with a re-sampling programme (Blank, Seiter & Bruce 2001). For each recorded location, a range of all possible swimming distances was calculated as the distance from the island where the animal was located to all other islands in its home range, including a distance of zero to account for the possibility that the animal did not leave the island. Since these expected swimming distances were calculated between islands in each individual’s home range, which was defined by radiotracking, they are all within the capability of the mink in question. For each observed location, one of the expected swimming distances was randomly selected. These expected distances (one for each observed movement) were averaged to provide an average randomly expected movement for each individual. This resampling procedure was repeated 1000 times for each animal to produce a distribution of randomly expected mean movement distances. We then compared the observed mean movement of each individual to the distribution of expected movement to evaluate the assumption that movement between islands is costly (observed movement < expected movement). A mink moving significantly less than would be expected by chance is indicated by the observed swimming distance being a rare event (< 50 of 1000 iterations gives \( P < 0.05 \); see Blank et al. 2001). Three females (F4, F18, F26; Table 1) were excluded from these comparisons as they were never observed swimming; that is, their home range consisted of one island only, whereby the value for both observed and expected swimming distance was zero. The overall difference between observed and expected movements was quantified with a paired \( t \)-test.

Knowing that mink swim less than expected by chance, we tested whether sea eagle predation risk and other factors could explain variation in mink swimming distances. This was carried out by comparing the observed and expected swimming distances of each animal calculated as (obs-exp)/exp, that is, the proportional deviation from randomly expected swimming distances. Increasingly negative values indicated the degree to which a mink was swimming less than was randomly expected. A mixed effect general linear model was built using sex, distance from eagle nest, number of eagle observations, home-range size and their interactions as fixed independent variables. However, due to a significant interaction between sex and home range (\( F_{1,162} = 42.7, P < 0.0001 \)), the sexes had to be analysed separately in a mixed-effect linear regression model. Study area and its interactions with the main factors were entered as random factors, but in the end only study area was included, as none of the interactions improved model fit. Number of movements was used as a weighing factor. All tests were conducted with SAS STATISTICAL PACKAGE, version 9.1 (SAS Institute, Cary, NC, USA). In all tests, the level of significance was set at \( < 0.05 \).

**Results**

Sea eagles were observed with equal frequency in both study areas (2005, Vänö \( n = 41, 0.049 \) eagles km\(^{-1} \) day\(^{-1} \); Brunskär \( n = 44, 0.031 \) eagles km\(^{-1} \) day\(^{-1} \); \( t \)-test with Satterthwaite approximation, \( t = -3.56, d.f. = 26.3, P = 0.19 \)), but more subadult eagles were encountered in Vänö than in Brunskär (\( \chi^2 \)-test, \( d.f. = 1, \chi^2 = 4.128, P = 0.042 \)). Subadults were often observed further away from nest sites than were adult eagles (Wilcoxon 2-sample test for eagle observations in 2004–2005; subadults: \( n = 24 \), mean distance ± SE 3895 m ± 354, adults: \( n = 36 \), mean distance ± SE 2539 m ± 488; \( Z = 4.14, P < 0.0001 \)).

In general, male mink had home ranges four times larger than females (mean size ha ± SE: males 34.3 ± 9.3, \( n = 5 \); females 9.4 ± 1.3, \( n = 13 \)), and they were also swimming longer distances than were females (mean observed swimming distance m ± SE: males 749 ± 161, females 106 ± 33; Wilcoxon 2-sample test \( Z = 2.86, P = 0.004 \)). Comparing observed mink swimming distances to the distribution of random distances (Table 1) showed that most mink tended to swim less than was expected at random. A paired \( t \)-test showed that the overall trend of mink swimming distances was significantly less than expected by chance, as the mean difference between observed and expected distances was \(-125.5 \) m ± 41.9 SE (\( t = -3.00, d.f. = 17, P = 0.008 \)).

For females distance from eagle nest, number of eagle observations, and home-range size all had significant
relationships, whereas for males only the number of eagle observations and home-range size revealed significant relationships (Table 2). The positive slope of distance from eagle nest showed a 5% reduction of female swimming distances for each kilometre towards an eagle nest (Fig. 2a). Female swimming distances were also reduced by 10% when the number of eagle observations increased by 10 (Fig. 2b). For males, the slope for the number of eagle observations was surprisingly positive, but the sample size was small ($n = 5$), and there was very little variation in the number of eagle observations between males (range 0–5; fig. 2b). Larger home-range size corresponded to reduced swimming distances in both sexes; for females a 10-ha increase in home-range size corresponded to a reduction of 32% in swimming distances, whereas the equivalent change was only 6% for males (Fig. 2c).

Omitting the three females with zero swimming distances did not change the results. None of the explanatory variables were intercorrelated ($P > 0.36$). We also tested for the possibility of fewer mink radio locations having been collected in areas of high eagle activity but this appeared not to be the case (Spearman rank correlation, $r_s = 0.28$, $P = 0.26$ for the number of eagle observations, $r_s = 0.04$, $P = 0.87$ for the distance from eagle nest).

### Discussion

The general tendency of mink to swim significantly less than expected at random suggests that swimming between islands is indeed a costly behaviour, even though it is vital from the mink perspective to access food resources on different small islands. In the presence of sea eagles, swimming between islands should be associated with additional costs. Therefore, we predicted that mink would reduce swimming when the predation risk from sea eagles is high. Our results were partly consistent with these predictions. Female mink reduced their swimming significantly with increasing number of eagle observations and decreasing distance to a sea eagle nest. Results for males were inconclusive because of small sample size and small variation in relation to predation-risk indices.

The white-tailed sea eagle is the native top predator in our study ecosystem. Breeding sea eagles are central-place foraging predators, which means that the probability of encountering breeding eagles increases closer to their nest where these predators continuously return to. From the prey perspective, this may create a predictable ‘predation-risk landscape’ during the breeding season (e.g. Norrøn & Korpimäki 1998b, Thomson et al. 2006). However, in addition to nesting eagle pairs, there are also subadult nonbreeding floater eagles, and the chance of observing them in our study areas was negatively correlated to the distance from nearest eagle nest. This may explain why both of our predation-risk indices had a significant effect on females, although they were not correlated.

There were notable intersexual differences in our study; male mink had home ranges four times larger than females, and were also swimming much greater distances than females. Like other mustelids, male and female mink show marked sexual dimorphism (Dunstone 1993). Male mink weigh almost twice as much as females and therefore are expected to have greater energy demands and consequently larger home ranges (Dunstone 1993), also observed in other studies (Gerell 1970; Birks & Linn 1982; Yamaguchi & Macdonald).

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**Table 2.** Estimates and $P$ values of variables for the models explaining deviation from random swimming distances in female and male mink. Area was included as a random factor, and the models were weighed by the number of movements for each mink.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Variable</th>
<th>Estimate</th>
<th>SE</th>
<th>Numerator d.f.</th>
<th>Denominator d.f.</th>
<th>$F$</th>
<th>$P$</th>
</tr>
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<td>Females ($n = 13$)</td>
<td>Distance from eagle nest</td>
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<td>&lt; 0.001</td>
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<td>11·7</td>
<td>36·1</td>
<td>&lt; 0.001</td>
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<td></td>
<td>No. of eagle observations</td>
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<td>0.004</td>
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<td>1</td>
<td>11</td>
<td>0.006</td>
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<tr>
<td></td>
<td>Home-range size</td>
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<td>44·6</td>
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<td>8</td>
<td>12·32</td>
<td>0.425</td>
</tr>
<tr>
<td></td>
<td>No. of eagle observations</td>
<td>0.011</td>
<td>0.001</td>
<td>1</td>
<td>5</td>
<td>80·8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Home-range size</td>
<td>−0.008</td>
<td>&lt; 0.001</td>
<td>1</td>
<td>5</td>
<td>5421·1</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

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**Fig. 2.** Deviation of female (○, $n = 13$) and male (■, $n = 5$) mink swimming distances in relation to (a) the distance from nearest eagle nest; (b) the number of eagle observations within 1-km range of mink home range; (c) home-range size. Asterisks denote the two females without kits.
It should also be noted that there were marked individual differences in mink behaviour. In other systems, it has been shown how differences in body condition drive individual differences in behaviour (e.g. Sinclair & Arcese 1995; Heithaus et al. 2007), whereby individuals in poor condition are more likely to take the risk of predation in their search for good foraging areas. Clearly, it would be informative to incorporate the role of individual condition on future studies of mink behaviour under a range of predation intensities.

Female mink reduced their swimming distances with increasing home-range size more than males did. The movements of reproducing female mink are probably restricted as they have to return to feed their kits frequently. It is also possible that we may have been unable to detect such short, frequent movements between the nest island and other islands, as they are not necessarily revealed by locating the animal only in dusk and dawn. Future studies will greatly profit from the advancement of miniature data loggers, whereby it is possible to record, for example, the diving behaviour of mink (Hays et al. 2007) and to obtain far more detailed data on the amount of time individuals spend swimming. Our data set also included two nonreproducing females, and their values fall below the regression line (Fig. 2), indicating that they are generally swimming less than reproducitively active females do. This can be expected, as the energy demands of a nonreproductive female fall behind those of a male and a reproductively successful female (Yamaguchi & Macdonald 2003).

In an observational study, it is possible that the results are also caused by confounding variables; for example, larger home ranges could independently favour higher sea eagle activity and a lower frequency of mink movement, or fewer radio locations of mink could be collected in areas of high eagle activity. However, all these relationships were tested for and no correlation was found. An alternative explanation for the observed reduction of swimming distances of mink is food competition between mink and sea eagles. Both species rely mainly on fish and birds in their diet (Fischer 1982; Niemimaa & Pokki 1990; Pälvi Salo & Mikko Toivola, unpublished data), whereas sea eagles catch Esox lucius and a wide variety of Anatidae (Niemimaa & Pokki 1990; Pälvi Salo & Mikko Toivola, unpublished data), whereas sea eagles catch Esox lucius and a wide variety of Anatidae (Sulkava et al. 1997). However, mink also prey heavily on voles, and on smaller fish such as Perca fluviatilis and Cottidae (Niemimaa & Pokki 1990; Pälvi Salo & Mikko Toivola, unpublished data), whereas sea eagles catch Esox lucius and a wide variety of Anatidae (Sulkava et al. 1997). This diet separation probably diminishes the possibility of serious food competition. Another possibility is that sea eagle activity in a certain area could make prey unavailable for mink, because eagle predation would evoke anti-predator behaviour of prey in that area. However, the limited diet overlap suggests that this is unlikely. In addition, sea eagles move over large distances in short periods of time, which should even out the risk.

The numerical effects of IGP on IG prey are quite well known already (e.g. reviews in Polis et al. 1989 and Sergio & Hiraldo 2008), but studies showing behavioural responses of IG prey are few. Our study provides evidence that mink appear to avoid a risky way of moving when under predation risk from an intraguild predator. Earlier studies have shown, for example, that IG prey try to avoid sites frequently visited by their IG predator (Arjo & Pletscher 1999; Mitchell & Banks 2005), that IG prey reduce their hunting activity after an artificial increase of predation risk from IG predator (Durant 2000), and that transplanted IG prey disperse quickly from an area with a high density of IG predators (Doncaster 1992).

We suggest that sea eagle predation risk may lower the detrimental effects of alien mink on bird, small mammal and frog populations. For example, increasing sea eagle predation risk could make the potential cost of swimming to some more isolated islands too high for the mink, which would provide high-quality (low risk) refugia for mink prey. There might also be large-scale impacts on prey populations, if the restriction of female mink movements leads to impaired nutrition and further to reduced reproductive output, which could ultimately slow mink population growth. There is accumulating evidence that ecosystems where top predators are present sustain more biodiversity than comparable areas without apex predators (Henke & Bryant 1999; Sergio et al. 2006), possibly because intraguild predation may launch trophic cascades.

The invasion of mink into the archipelagos of the Baltic Sea may have been aided by the low population densities of sea eagles in the 1960s and 1970s. If the ongoing increase of sea eagle population could launch trophic cascades as suggested above, the return of the native top predator, the sea eagle, would not only be a success story of conservation efforts in itself but it would also help mitigate the adverse effects of alien mink, thereby increasing the biodiversity of the archipelagos of the Baltic Sea. In this scenario, ecosystem restoration by bringing back the top predators may be one way of mitigating alien predator effects on native biota.

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