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Changes in distribution of the European badger *Meles meles* in Finland during the rapid colonization of the raccoon dog

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Distribution of the badger *Meles meles* in Finland was studied using game inquiries. The northern distribution limit of the badger has moved about 100 km northwards since the mid-1940s, and the frequency of occurrence has increased. Thus, the distribution area is larger and less fragmented today than it was a few decades ago. The increase in badger population has been particularly clear near the northern distribution limit. Climate seems to be the most important factor affecting the distribution area of the badger in Finland. Near the northern limit of distribution, climate, too, partly explained the change in badger occurrence. The onset of spring and the length of the snow-free period are important for species that sleep in winter; if the summer is very short the young do not have enough time to accumulate fat reserves for the winter. Habitat changes (the extent of fields) may also have affected the occurrence of the badger. The availability of wild berries may also have had some effect on badger numbers. Both badgers and raccoon dogs have increased in most provinces during the study period. Thus, the rapid increase of the raccoon dog population has not caused a decline in the native badger population of Finland.

1. Introduction

The geographical distribution of the badger *Meles meles* covers large areas of Europe and Asia; in Finland the badger lives near the northern limit of its distribution. In many areas the preferred habitats of the badger are deciduous forest, agricultural land and grassland with abundant earthworms *Lumbricus terrestris* (e.g. Kruuk 1978, Kruuk et al. 1979, Lindström 1989, Seiler et al. 1995). Thus, in Finland the badger probably lives in a marginal environment, mainly in boreal forest where earthworms are scarce, and its population density is thought to be low compared with that of badger populations in continental Europe and England.

The distribution area of the badger in Scandinavia (Sweden and Norway) has expanded several hundred kilometres northwards during this century, mainly since the mid-1940s (Bevanger

& Lindström 1995). In the beginning of the century badgers were found only in southern parts of Scandinavia except probably some scattered populations up to 63°N (Collett 1911–1912, Ekman 1922). Badgers are now found even above the Arctic Circle (Bevanger 1985, Bevanger & Lindström 1995).

The distribution and abundance of the badger in Finland have been poorly known. Siivonen (1972) and Siivonen and Sulkava (1994) give a rough picture about the distribution area in Finland, but hardly anything is known about the possible changes in distribution or abundance. The raccoon dog *Nyctereutes procyonoides* rapidly colonized Finland since the mid-1950s, and the effect of this introduced carnivore on the native badger population is a question often raised; these two carnivores potentially compete for food or den sites. Both species are omnivorous and both feed e.g. on berries, invertebrates and small mammals in Finland (Kiljunen 1973, Kauhala et al. 1993, Kauhala & von Rége, unpubl.). The badger and the raccoon dog both live in dens where they sleep in winter, too.

This paper examines: 1) the present distribution and abundance of Finland's badger population, 2) whether the badger has expanded its distribution in Finland during the last few decades as it did in Scandinavia, 3) the reasons behind the possible expansion and change in numbers, and 4) whether the rapid increase of the raccoon dog caused a decline in Finnish native badger population or not.

2. Methods

Distribution and abundance of the badger in Finland were studied using game inquiries carried out by the Finnish Game and Fisheries Research Institute in 1945–93. Inquiry forms were sent to observers (about 500 persons, 23–106/province) each year in March. The observers gave their opinions on the abundance of various game species in their particular observation area. They estimated the abundance as: 0 = species does not occur in the area, 1 = rare, 2 = moderate, and 3 = abundant. On the basis of these inquiries the frequency of occurrence and an abundance index were calculated for each species by province and year. Frequency of occurrence (FO) gives the percentage of observers who report that the species is found in the area, and the abundance index (AI) gives the relative abundance of the species (for calculation of AI, see e.g. Helle & Kauhala 1987, 1991).

The abundance indices present some problems, because opinions regarding abundance levels are subjective and a person's opinion may change with time (see e.g. Lindén 1988). The reliability of abundance indices of the raccoon dog could be tested by comparing the abundance index with a trap index (data from the province of Häme 1987–91). The trap index gives the number of raccoon dogs trapped per 100 trap nights in September–November. These two indices correlated positively (r = 0.93, P = 0.023, n = 5). I also compared the indices regionally (data from 10 provinces; means for 1986–91), and this also gave a positive correlation (r = 0.84, P = 0.002, n = 10).

Because I had no means to test the reliability of the abundance index of the badger, I use here mainly the frequency of occurrence. Whether badgers are found in the area or not is easy to detect, and hence, the frequency of occurrence should be reliable. The results based on abundance index should be interpreted with caution.

The significance of the possible change in badger occurrence was tested in 9 provinces of Finland (continuous badger data available from 1966 to 1993) using Spearman's rank correlation analysis because the distribution of badger FO was not normal in all provinces. However, I also calculated the slope of regression lines (regression of FO against time) in order to illustrate the rate of increase. Correlations between badger FO and raccoon dog AI in the 9 provinces were also calculated using Spearman's correlation test.

The possible effects of environmental variables (both climatic and biotic) on a change in badger occurrence (FO) were tested using stepwise regression analysis in 9 provinces (all data available from 1967 to 1993). These analyses were done in spite of the fact that FO values were serially correlated; I wanted to find out variables which would explain the trend in badger occurrence. (It is highly improbable that there are sharp fluctuations in badger occurrence from one year to the next and, therefore, I did not use the rate of change in FO). I also tested the effect of environmental variables on variation in regional density (FO and AI) of the badger (10 provinces included).

Independent variables were selected in the regression analyses on the basis of a correlation matrix. Independent variables were: annual mean temperature, duration of snow cover (days), mean temperature in April, rainfall in summer (June–August), abundance index of the raccoon dog and that of wild berries (bilberries *Vaccinium myrtillus* and lingonberries *V. vitis-idaea*) the previous autumn.

All climatic variables were from the previous calendar year and the data were taken from meteorological yearbooks (Finnish Meteorological Institute 1967–93). Duration of snow cover and mean temperature of April reflect the length of winter/the onset of spring which probably are important for the badger (Lindstrîm 1989). Annual mean temperature reflects the harshness of climate in general. Rainfall in summer may be important for the badger because it may affect the amount of earthworms available for the badger.

The abundance indices of the raccoon dog and berries were obtained from game inquiries. The effect of the raccoon dog was tested both without a time lag and with a time lag of one year. Berries are included because they may be important food for the badger (Lindström 1989).

The effect of the area of fields on the possible trend in badger occurrence was also tested; badgers may benefit from the increase in the field area because in fields there are abundant earthworms (Stöp-Bowitz 1969). Yearly data on the area of fields were available from 1974–88 (Tilastokeskus 1974–88), thus, only this period could be included in this analysis.

3. Results

3.1. Badger distribution

The northern distribution limit of the badger has moved about 100 km northwards in Finland since the mid-1940s and is today between 64°N and 65°N (Fig. 1). The first verified observation of a badger from the main island of Åland is from April 1994 (Häggblom 1994). The frequency of occurrence has increased in most provinces studied (Fig. 2, Table 1). The increase has been most prominent in the northeastern provinces (area II in Fig. 3). Thus, the distribution area of the badger is larger and less fragmented today than it was a few decades ago. Frequency of occurrence is higher today in southern Finland than near the northern distribution limit (Fig. 3). The abundance index has slightly increased in the northernmost provinces of the study area (Fig. 2, Kauhala 1995).

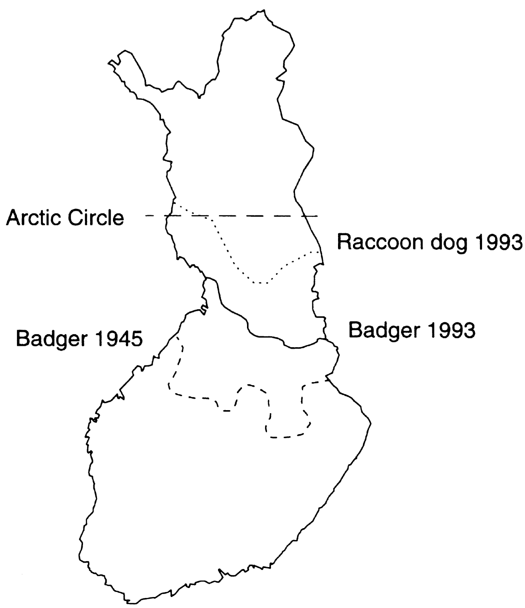

Fig. 1. Northern limit of distribution of the badger in 1945 and 1993 and that of the raccoon dog in 1993 in Finland.

3.2. Factors affecting badger numbers

3.2.1. Regional variation in badger numbers

Annual mean temperature offered a fairly good explanation of the regional variation in frequency of occurrence ($R^2 = 0.65$, $F = 13.0$, $P = 0.009$)

Table 1. Change in frequency of occurrence (FO) of badgers in different provinces of Finland from 1966–70 (period I) to 1989–93 (period II). Table includes results of correlation and regression analyses (correlation analysis: r_S = Spearman correlation coefficient and P = significance, regression analysis: b = slope). (For calculation of frequency of occurrence, see e.g. Helle & Kauhala 1991, and for location of areas and provinces, see Figs. 2 and 3).

Province	period I	period II	change (%)	r_S	P	b
Area I:						
Häme	92.2	100.0	+ 8.5	0.81	0.000	0.33
Mikkeli	97.6	99.0	+ 1.4	0.09	*ns*	0.10
Kymi	95.2	99.0	+ 3.3	0.32	*ns*	0.23
Turku–Pori	95.4	100.0	+ 4.8	0.67	0.000	0.28
C. Finland	89.2	96.2	+ 7.8	0.65	0.001	0.48
Vaasa	81.0	93.0	+ 14.8	0.81	0.000	0.85
Area II:						
N. Karelia	65.8	96.2	+ 46.2	0.93	0.000	1.43
Kuopio	51.6	74.2	+ 43.8	0.68	0.000	1.33
Oulu	17.6	44.0	+ 150.0	0.72	0.000	0.99

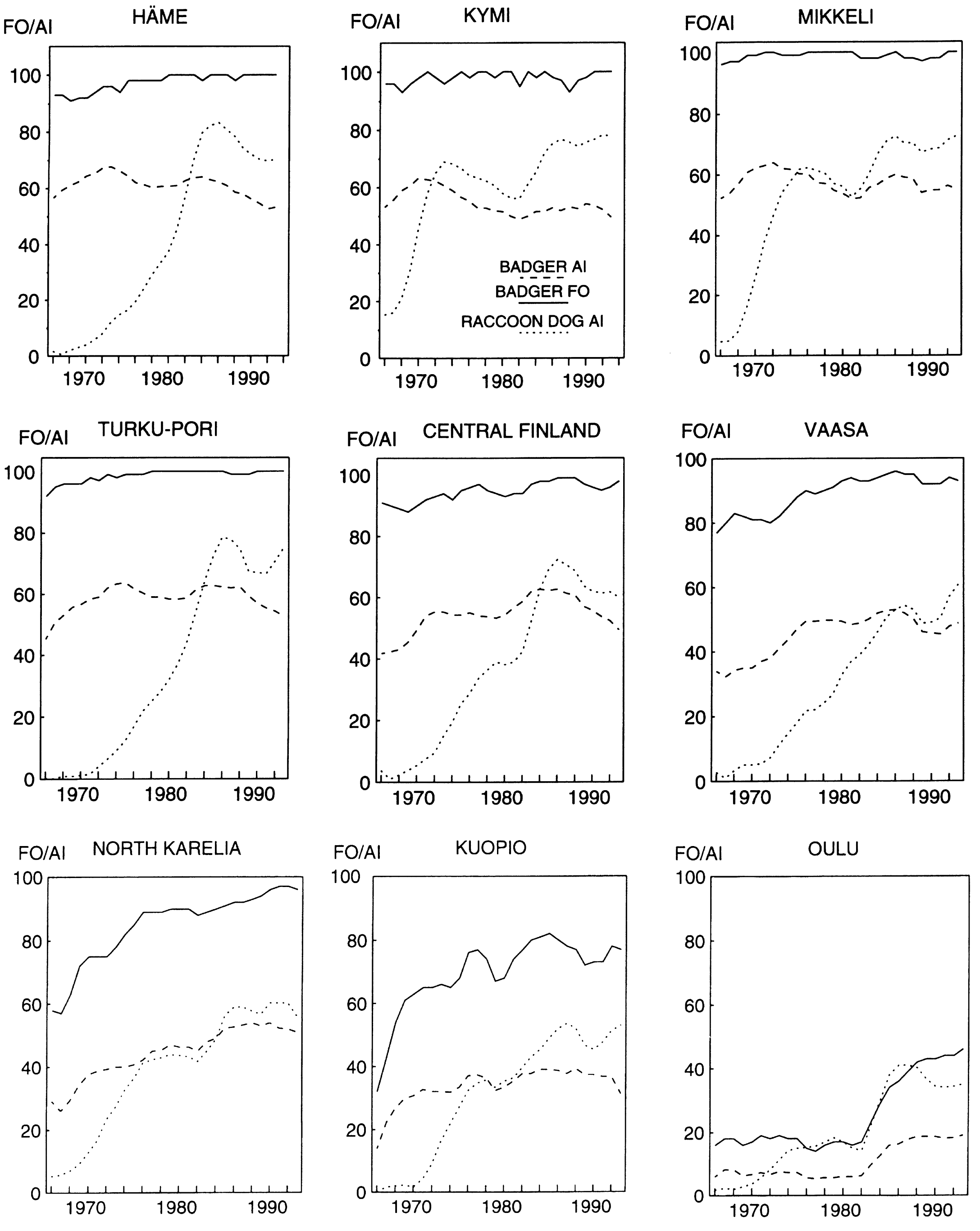

Fig. 2. Frequency of occurrence and abundance index of the badger and the abundance index of the raccoon dog in 9 Finnish provinces in 1966–93. Frequency of occurrence and abundance index are obtained from game inquiries (for calculation of the indices, see e.g. Helle & Kauhala 1991). For location of provinces, see legend of Fig. 4.

and in abundance index ($R^2 = 0.80$, $F = 32.1$, $P = 0.0005$) of the badger (Fig. 4); the higher the mean temperature, the denser the badger population.

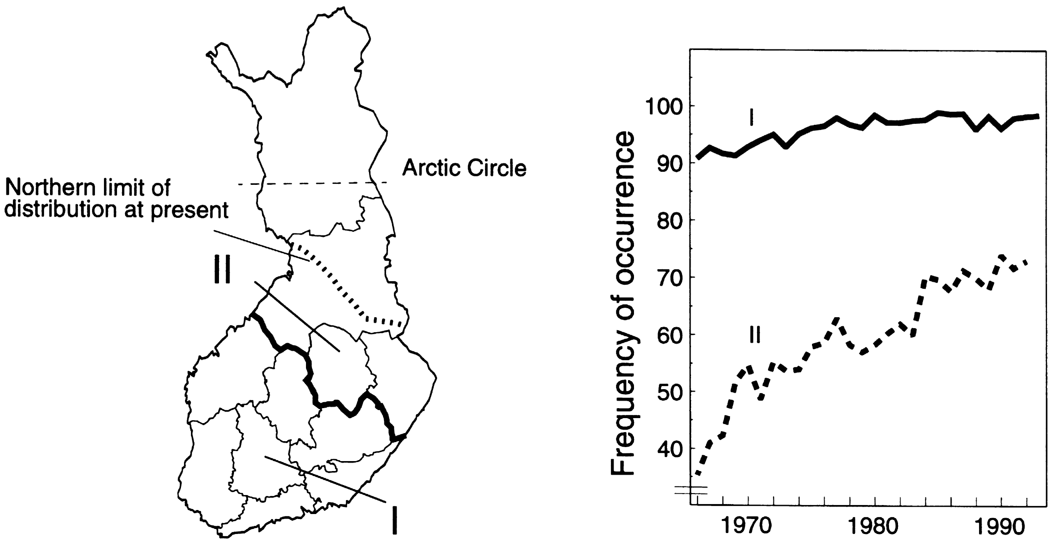

Fig. 3. Change in frequency of occurrence of the badger in two areas of Finland from 1966 to 1993. Frequency of occurrence is obtained from game inquiries (see e.g. Helle & Kauhala 1991).

3.2.2. Change in badger occurrence with time

In the following I present the numerical results of the stepwise regression analyses; in Discussion I consider the real significance of the results.

The mean temperature of April explained 25% of the change in FO in North Karelia during the whole study period 1967–93 ($F = 8.5$, $P = 0.007$). Duration of the snow cover explained 15% of the change in FO in Oulu ($F = 4.3$, $P = 0.049$). In the other provinces none of the variables explained significantly the change in badger FO in 1967–93.

In the province of Oulu the area of fields explained 81% of the change in badger occurrence in 1974–88 ($F = 53.7$, $P = 0.00001$). In the province of Vaasa it explained 30% and in Central Finland 27% of the change in badger FO (Vaasa: $F = 5.1$, $P = 0.044$, C. Finland: $F = 4.9$, $P = 0.046$). In North Karelia and Kuopio, however, there was a negative correlation between badger occurrence and the extent of fields (N. Karelia: $r = -0.67$, $P = 0.007$, Kuopio: $r = -0.61$, $P = 0.016$).

I also divided the study period into two parts according to the development of the badger population (on the basis of Fig. 2). In North Karelia annual mean temperature offered a partial explanation on the change in badger occurrence during the latter half of the study period (in 1980–93) ($R^2 = 0.33$, $F = 5.8$, $P = 0.032$). In the province of Oulu the abundance of wild berries explained 53% of the change in badger FO ($F = 11.4$, $P = 0.007$). None of the variables explained the change in FO in other provinces or periods.

Badger and raccoon dog populations both increased in the provinces of central and northern Finland (excluding Lapland) (Table 2, Fig. 2). The frequency of occurrence of the badger correlated positively with the abundance index of the raccoon dog in all provinces except the provinces of Kymi and Mikkeli.

Table 2. The results of correlation analyses (Spearman rank correlation) between the frequency of occurrence (FO) of the badger and the abundance index of the raccoon dog (with no time lag) in different provinces in Finland in 1967–93. For calculation of abundance index and frequency of occurrence, see e.g. Helle & Kauhala 1991.

Province	r_S	*P*
Turku–Pori	0.61	0.002
Häme	0.86	0.000
Mikkeli	0.10	*ns*
Kymi	0.17	*ns*
Central Finland	0.76	0.000
Kuopio	0.75	0.000
N. Karelia	0.94	0.000
Vaasa	0.85	0.000
Oulu	0.67	0.001

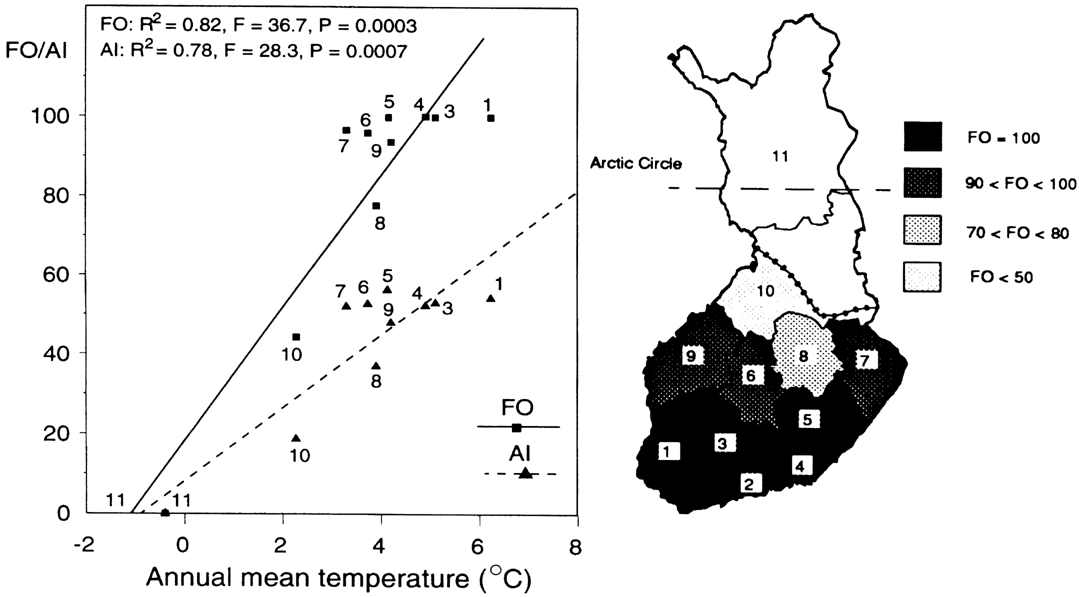

Fig. 4. Relative density (based on mean frequency of occurrence in 1991–93) of the badger in Finnish provinces and dependence of frequency of occurrence (FO) and abundance index (AI) of the badger on annual mean temperature. Frequency of occurrence and abundance indices are obtained from game inquiries (for calculation of the indices, see e.g. Helle & Kauhala 1991). The maximum for both indices is 100. Provinces: 1 = Turku–Pori, 2 = Uusimaa, 3 = Häme, 4 = Kymi, 5 = Mikkeli, 6 = Central Finland, 7 = North Karelia, 8 = Kuopio, 9 = Vaasa, 10 = Oulu and 11 = Lapland. Equations: FO — mean temperature: $Y = 16.7X + 18.3$, AI — mean temperature: $Y = 0.28X + 0.24$.

4. Discussion

Climate seems to be the most important factor affecting the distribution area and regional variation in badger density in Finland. The onset of spring and the length of the snow-free period are important for the badger: at northern latitudes the badger sleeps in winter, and cubs in particular have difficulty accumulating enough fat during the autumn. If the summer is short, cubs are not able to accumulate large fat reserves and so cannot survive the long winter. Lindström (1989) also concluded that the length of the growing season/duration of snow cover is important for the badger at northern latitudes.

Near the northern limit of the distribution area, in particular, warming of the climate may have affected the increase in badger occurrence. The increase in badger occurrence has been clear in area II where snow cover duration has decreased during the study period (Table 3). Also annual mean temperature has increased in all provinces studied indicating that the climate is warming. Annual mean temperature in area II is now about the same as it was in southern Finland in the late-1960s (Table 3). Although the climate has been warming also in southern Finland, its effect on badger population is not so clear because FO was > 90% in southern Finland already in the 1960s. Thus, the trends in badger occurrence and climate most probably are connected, although it is difficult to prove. One of the reasons behind the expansion of badger distribution in Scandinavia, too, may have been warming of the climate and lengthening of the growing season (Bevanger & Lindström 1995).

Climate is the most important factor affecting regional variation in raccoon dog density, too (Helle & Kauhala 1991, Kauhala & Helle 1993, 1995). Both of these species sleep during the winter, and thus, the young of both species have the same problems when summers become short and winters long. Hence, neither of these species have been able to colonize Lapland permanently. The distribution area of the raccoon dog extends a little farther north than that of the badger (see

Fig. 1); the badger sleeps longer than the raccoon dog, and thus, badger cubs have even shorter time to prepare themselves for the winter than raccoon dog pups have.

The change in the area of fields may also have been one reason for the change in badger numbers especially in the province of Oulu. The northern boreal forest is not an ideal habitat for the badger; in fields there are more earthworms (Stöp-Bowitz 1969) which are important food for badgers (e.g. Kruuk 1978, Lindström 1989). Also in Scandinavia one reason for the increase in badger occurrence might have been the change in the habitat: the increase of the mosaic of forests and fields and in the area of abandoned fields (Bevanger & Lindström 1995). However, in North Karelia and Kuopio the relationship between badger occurrence and the area of fields was negative. The area of fields decreased during the study period while badger population increased. This may indicate that the extent of fields as such is not the most important factor; fragmentation of fields/forests may be more important. It is also possible that the relationship between the fields and FO is not real.

According to Bevanger and Lindström (1995), the decrease in the hunting pressure and the decrease in the number of predators, such as wolfs (*Canis lupus*) may have affected the increase in badger numbers in Scandinavia. In Finland, too, badgers have few natural predators nowadays which may be one reason behind the increase of badger population.

Both badger and raccoon dog populations increased since the early 1960s in most provinces in Finland. Thus, badger numbers have not declined in most provinces during the study period in which the raccoon dog population rapidly increased. Although these species are potential competitors they are able to live in the same area in Finland and even both increase in numbers at the same time. Both species are omnivorous in Finland (Kiljunen 1973, Kauhala et al. 1993) but the raccoon dog specializes more on plants and small mammals and the badger more on invertebrates (Kauhala & von Rége, unpubl.) which may help them to avoid competition.

The fact that both species sleep in winter is also important; at northern latitudes winter usually is the critical season when food is scarce and competition most severe. The winter sleep may, in fact, be one of the most important reasons behind the rapid increase of the raccoon dog population in Finland. In south/central Sweden raccoon dogs escaped from farms as early as the 1970s (Domarhed 1987) and a rapid population increase was expected. However, such a rapid increase probably has not taken place in Sweden (Isacson 1988, E. Lindström, in litt.). One reason may be the dense badger population in southern Sweden and the fact that raccoon dogs and badgers are active in winter in areas where winters are

Table 3. Annual mean temperature (°C) in 1965–69 and 1988–92 in different provinces, the slopes of regression analyses (b) when mean temperature and snow cover duration were regressed against time.

Province	Annual mean temperature 1965–69	1988–92	*b*	Snow cover duration *b*
Area I:				
Turku–Pori	3.34	6.22	0.08	– 0.17
Häme	3.28	5.14	0.04	0.05
Mikkeli	2.42	4.26	0.04	– 0.05
Kymi	3.12	5.00	0.04	– 0.11
C. Finland	2.06	3.78	0.03	0.04
Vaasa	1.82	4.16	0.05	0.75
Area II:				
North Karelia	0.70	3.48	0.10	– 0.31
Kuopio	1.94	4.02	0.05	– 0.33
Oulu	0.70	2.36	0.03	– 0.51

not very harsh. Consequently, competition between these species may be more severe, and this may prevent the rapid increase of the raccoon dog population.

Abundance of berries explained some of the change in badger occurrence in one case. Berries may be important for the badger in autumn when it is accumulating fat reserves for the winter (see also Uppsäll 1987, Lindström 1989). Harris (1982) found that fruit was the main component of badger diet in Bristol (England) in autumn when badgers were storing fat. Availability of berries the previous autumn explained most of the annual variation in, and the increase of raccoon dog numbers in Finland in the 1980s, too (Kauhala & Helle 1993, 1995).

Rainfall in summer may reflect the amount of earthworms available for the badger, and it has been found to be important for the badger in England (Woodroffe & Macdonald 1995). In Finland rainfall in summer had no effect on badger populations, probably because badgers in Finland are more omnivorous and eat less earthworms than they do in many places in England. However, Harris (1982) found that badgers also in suburban Bristol had a diverse diet and earthworms were not especially important for them although abundant earthworms were available.

Altogether few correlations (8.0%) were significant when variables affecting change of FO with time were tested. This may indicate that badger population is rather stable in most provinces, probably because the rate of reproduction is low and dispersal ability limited among badgers (see e.g. Ahnlund 1980, Neal 1986, Lindström 1989). However, the increase of the population during the study period in area II is clear, and most probably affected by climate and maybe also by habitat changes.

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