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Long-term dynamics and biodiversity changes in small mammal communities in a mosaic of agricultural and forest habitats

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The long-term dynamics of small mammal communities inhabiting a mosaic of agricultural and forest habitats, that is, mixed forest, lakeside alderwood forest and arable land, set aside in the second period of the study, was analysed. No cyclicity was recorded in the numbers of the dominating species, that is, the bank vole (*Myodes glareolus*) and the yellow-necked mouse (*Apodemus flavicollis*). Fallowing of the arable land resulted in a decline in diversity and species richness of small mammals in the habitat mosaic under study. The greatest changes were recorded in the community inhabiting a narrow belt of spatially heterogeneous alderwood along the lakeshore. In this community, a considerable increase in the number of yellow-necked mice and a general increase in the dominance of forest species took place. We suggest that the fallowing of extensive arable lands, taking place in Poland for the last two decades, constitute an attractive source of food for small mammals and may lead to a considerable decline in small mammal species diversity within the landscape or even cause local extinctions in some species.

Introduction

Most long-term studies of small mammals are dedicated to the analysis of dynamics of individual populations and particularly to analyse population cycles (e.g. Huitu *et al*. 2003, Hörnfeldt 2004, Korpimäki *et al*. 2005). However, to our knowledge, there are no studies involving the analysis of long-term variability in the structure of multi-species communities of small mammals and its causes. At the same time, such analysis seem to be of special importance not only for learning mechanisms of the functioning of multi-species communities and the relationships among species within them but also because of rapid changes in the environment caused by humans. In the present study, we conducted an analysis of data on species composition and numbers of small mammal communities, collected over thirty years in a mosaic of agricultural and forest habitats in a Polish landscape in one of the areas in which hundreds of hectares had been set aside as a result of the social, economic and political changes taking place in Poland in the 1990s.

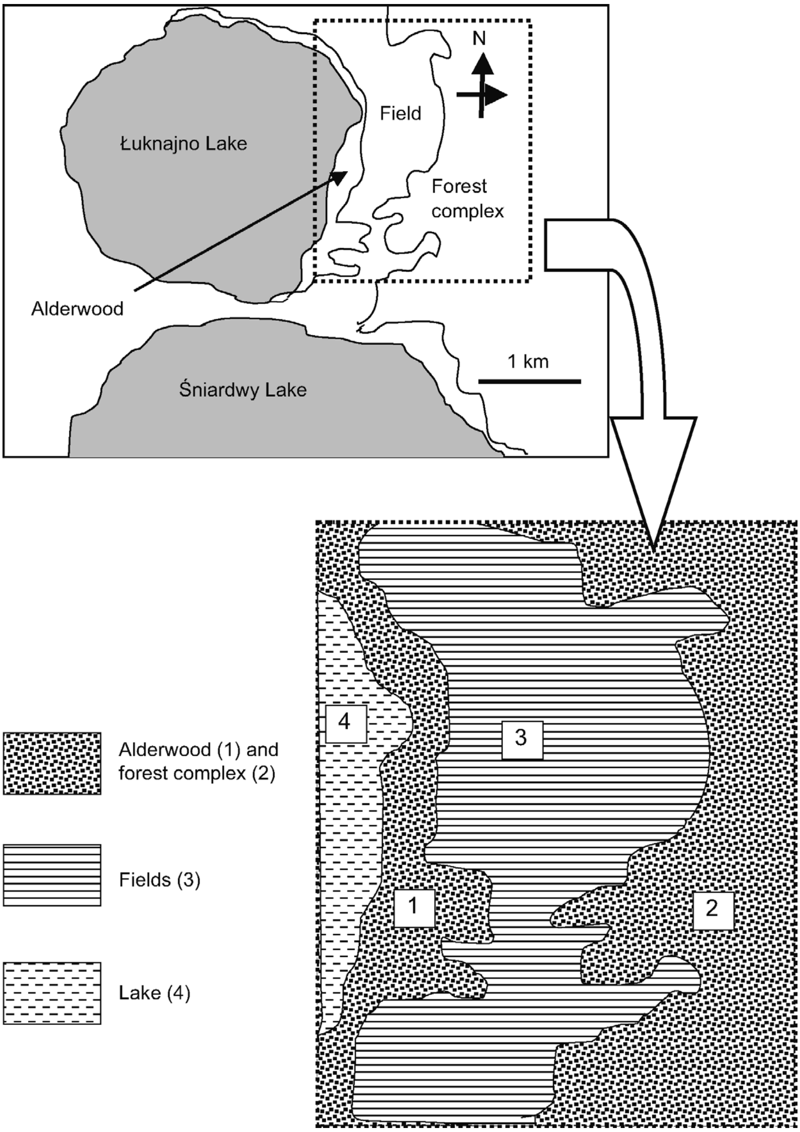

Fig 1. Map of the study area.

Study area and methods

The material used for the study originates from studies conducted by students and employees of the Department of Ecology at the University of Warsaw from 1977 to 2006 in north-eastern Poland, in the immediate vicinity of the Łuknajno Biosphere Reserve (53°48´N, 21°34´E), within an agricultural and forest mosaic composed of the following habitats: a belt of alderwood along the lakeshore, arable fields fallowed since 1991, and an extensive stretch of forest (Fig. 1). Within the belt of alderwood approximately 40–60 m wide, with a clear humidity gradient growing towards the lake shoreline, the common alder (*Alnus glutinosa*) predominated in the tree layer, rowan (*Sorbus aucuparia*), black dogwood (*Frangulus alnus*) and currant (*Ribes rubrum*) predominated in the undergrowth and the ground cover constituted mostly of nettle (*Urtica dioica*). An alderwood is a type of forest with very rapid succession leading to typical forest habitat. However, the studied lakeshore belt remained unchanged during the thirty years of study, because of year-to-year changes in lake water levels regulated by humans. In the field, sized approximately 120 ha, cereal (wheat, oats, rye, maize) and potatoes were intensively cultivated. In 1991 the land was fallowed and the process of secondary succession began. Forest aged approximately 80 years was a fragment of an extensive forest stretch (approximately 3000 ha) composed mainly of Scots pine (*Pinus sylvestris*). In the undergrowth, hazel (*Corylus avellana*), rowan (*Sorbus aucuparia*) and spindle trees (*Evonymus verrucosa*) predominated, whereas the ground was covered mainly by wild strawberry (*Fragaria vesca*), hepatica (*Hepatica nobilis*) and woodsorrel (*Oxalis acetosella*).

Animals were live-trapped in the summer (July–August) with the CMR method in plots sized 1–3 ha, in trapping series lasting from 5 to 10 days. The data were used for determining the percentages of individual rodent species in their communities and their numbers. In some years, studies were carried out with traps arranged in lines; those data were not taken into account when estimating species numbers, instead they were used only to determine animal presence or predominance in a community. The available data on *Insectivora* allowed us only to determine presence or absence of a given species within the area under study.

Results

The highest small mammal species richness and species diversity was found in the belt of alderwood along the lake, particularly prior to the fallowing of the agricultural land adjoining the alderwood. The occurrence of all 12 species recorded throughout the study period all over the study area was recorded there (Fig. 2). After the fallowing of the agricultural land, small mammal species diversity in the alderwood declined considerably (the average Shannon-Wiener index before fallowing was 0.96 and after fallowing 0.51). Also, a clear predominance of two forest species — the yellow-necked mouse (*Apodemus flavicollis*) and the bank vole (*Myodes glareolus*) — was found. The average number of species recorded in the agricultural habitat in a single trapping series declined more than two fold (7.9 prior to and 3.2 after fallowing). Bank vole and yellow-necked mouse densities considerably varied between years. No cyclicity or synchronization in the dynamics of the two species was observed in the course of those changes. The average density found prior to fallowing and after it did not differ significantly in the bank vole population (43.3 and 55.1 ind. ha^{-1}, respectively), however, it increased significantly (Student's *t*-test: $0.001 < p < 0.002$) in the yellow-necked mouse (4.6 and 20.1 ind. ha^{-1}, respectively) (Fig. 3).

Such major changes after fallowing were not recorded in the forest (Fig. 2). In the forest habitat, a clear predominance of the bank vole and yellow-necked mouse was found both before and after fallowing, and few individuals of other species were found. The average number of species recorded in this habitat in a single trapping series declined significantly ($0.01 < p < 0.02$) (4.2 before *vs*. 3.0 after fallowing). The dynamics of the yellow-necked mouse and bank vole in the forest did not change in a significant way after fallowing. The densities of the two species varied in subsequent years (ranging from a few to several tens of individuals), however, similarly to the lakeside, no clear cyclicity or synchrony in changes in population density were found for any of the two species (Fig. 4).

In agricultural fields the common vole (*Microtus arvalis*) predominated, also the striped filed mouse (*Apodemus agrarius*) and the yellow-necked mouse were found there. After fallowing, a clear dominance of the common vole continued, also the occurrence of the bank vole and yellow-necked mouse was evident (Fig. 2). Small mammal species richness was low both before and after fallowing of the fields (the average number of species recorded in that habitat in a single trapping series was respectively 3.0 and 3.5).

Discussion

An agricultural field is a habitat characterized by considerable seasonal variability following agricultural activities (sowing, harvesting, ploughing, etc.), however, providing excellent food resources for many animal species during most of the vegetative season. Thus, changes in agricultural land use, particularly the abandonment

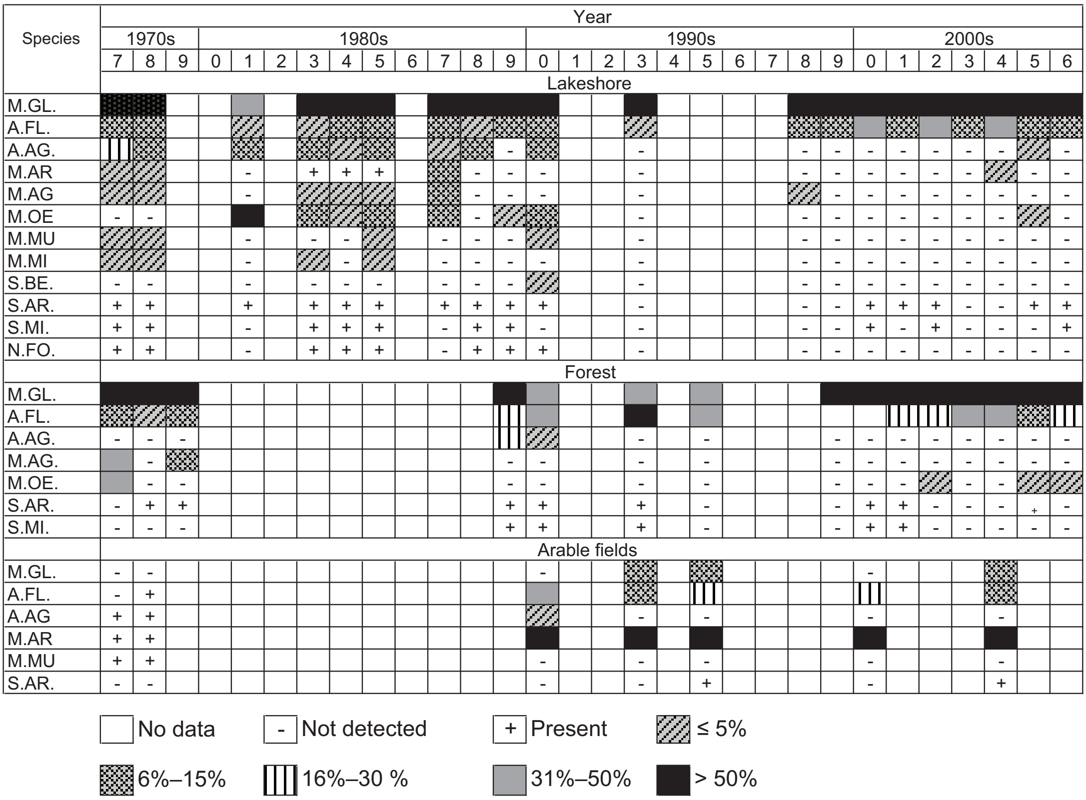

Fig. 2. Occurrence and dominance of species in the habitats under study. M.GL. = *Myodes glareolus*, A.FL. = *Apodemus flavicollis*, A.AG. = *Apodemus agrarius*, M.AR. = *Microtus arvalis*, M.AG. = *Microtus agrestis*, M.OE. = *Microtus oeconomus*, M.MU. = *Mus musculus*, M.MI. = *Micromys minutus*, S.BE. = *Sicista betulina*, S.AR. = *Sorex araneus*, S.MI. = *Sorex minutus*, N.FO. = *Neomys fodiens.* Data sources: Banach *et al*. (1979), Kozakiewicz (1985, 1987), Banach (1987), Kozakiewicz and Jurasińska (1989), Kozakiewicz *et al*. (1992), M. Brzeziński & T. Gortat (unpubl. data), B. Giera (unpubl. data), G. Godlewski (unpubl. data), J. Jamińska (unpubl. data), M. Kaczuro-Kaczyńska (unpubl. data), K. Kiersztyn (unpubl. data).

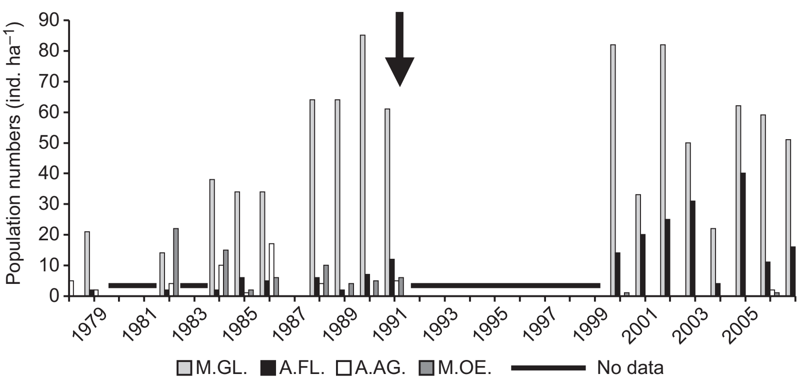

Fig. 3. Dynamics of numbers of selected species in the lakeshore habitat. Arrow indicates fallowing of the arable fields. Names of species as in Fig. 2. Data sources: Kozakiewicz (1985, 1987), Kozakiewicz *et al*. (1992), M. Brzeziński and T. Gortat (unpubl. data), G. Godlewski (unpubl. data), L. Kwiatkowska (unpubl. data), A. Stanisze-wska (unpubl. data), Suska M. (unpubl. data).

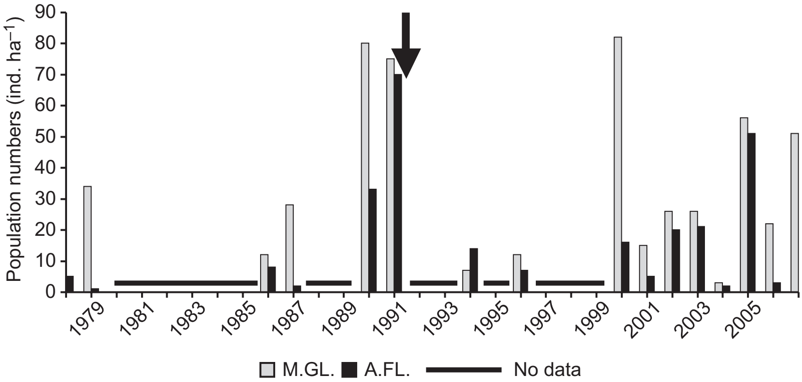

Fig. 4. Dynamics of numbers of selected species in the forest habitat. Arrow indicates fallowing of the arable fields. Names of species as in Fig. 2. Data sources: Banach (1987), Kozakiewicz and Jurasińska (1989), M. Brzeziński and T. Gortat (unpubl. data), B. Giera (unpubl. data), G. Godlewski (unpubl. data), J. Jamińska (unpubl. data), M. Rogozińska (unpubl. data).

of agricultural fields, may lead to major changes in populations of many animal species. The effect of agricultural extension has been studied mainly on birds (e.g. Henderson *et al*. 2000a, 2000b, 2001, Santos 2000, Stoate 2001) and invertebrates (e.g. Honěk (1997).

Numerous authors have stressed the exceptional value of cereal seeds as food for many small mammal species — e.g., Andrzejewski (1975) made bank voles breed at the time of the year when those animals do not breed by providing bank voles with oats. Szacki (1999) recorded cases of animals leaving the forest to feed in adjoining agricultural fields by tracking the movements of the yellow-necked mouse in a mosaic of agricultural and forest habitats with radiotelemetry. Particularly in summer, excursions of small mammals leaving their habitats to feed in adjoining agricultural fields were recorded, among others, by Banach *et al*. (1979), Pelikan (1986) and Kozakiewicz *et al*. (1993). Thus, it is very likely that the occurrence of as many as 12 small mammal species in the mosaic of habitats under study was possible due to the use of food resources available in the agricultural field. The effect was particularly clear in the community of small mammals inhabiting the forest belt along the lakeshore. This resulted from the fact that the habitat in question was very narrow and all animals living there had easy access to food resources in the field. The impact of the agricultural field on small mammal populations seems to be evidenced also by a clear decline in species richness in the lakeside habitat recorded after fallowing of the fields. Also, internal variation in local conditions, resulting from a ground humidity gradient, which provided conditions enhancing the division of space between competing species, might be an additional factor contributing to the occurrence of the species-rich community of small mammals in the lakeshore habitat (Kozakiewicz 1985, 1987). The small mammal community inhabiting the lakeshore habitat seems to remain much more species-rich than the forest community because of that very factor. It is also very likely that the narrow strip of the lakeshore habitat is enriched in species by the so-called “barrier effect” as it “catches” groups of migrants dispersing from other habitats towards the lake. An interesting finding is that after fallowing of the fields, a considerable increase in the yellow-necked mouse numbers took place in the lakeside habitat. This increase likely took place as a result of easier movements of the mice from the forest to the lakeside via the fallowed field in comparison to the cultivated field, which (particularly in autumn after harvesting) was an extensive, hostile stretch of land devoid of vegetation that might be difficult for small mammals to cross. Also, Hansson (1987) pointed out the possibility of free wandering across fallowed agricultural fields by forest small mammal species, including the yellow-necked mouse. A considerable increase in yellow-necked mouse numbers in the lakeshore habitat, which took place after fallowing of the agricultural fields might also be one of the causes leading to a decline in small mammal species diversity in that habitat. Numerous authors (e.g. Gliwicz 1981) suggest that the yellow-necked mouse is a strong competitor as it is able to compete other species out of the habitat it occupies.

According to Jędrzejewski and Jędrzejewska (1998), the multi-year dynamics of forest rodents (bank vole, yellow-necked mouse) in the Białowieża Forest is characterized by 4–7-year long periods of moderate density and two years of rapid increase in numbers resulting from mass production of tree seeds. We have not recorded such cyclicity in the dynamics of those species within the study area, either in the lakeshore habitat or in the forest and we have not recorded even clear synchrony of changes in the numbers of the species under study. A likely cause for this is the possibility of making use of food resources in the agricultural fields which are abundant and accessible every year.

Based on the data presented in this study, we suggest that the occurrence of closely located agricultural fields had a significant impact on small mammal species richness in the forest and lakeshore habitats, and fallowing the fields and a related lack in the possibility of making use of food resources previously provided by the fields, has resulted in a change in the community structure and a general decline in species diversity in the habitat mosaic under study. Throughout the last two decades in Poland, there has been a growing tendency to limit the areas of arable lands through fallowing. According to the Polish Central Statistical Office (www.stat.gov.pl), in 1999 fallow lands made up 1.1% of the total area of agricultural lands in Poland, and by 2002 their share grew to as much as 13.6%. In light of this and our results, one may believe that fallowing extensive arable land may lead to a decline in small mammal species diversity in a large part of Poland and may even lead to local extinctions in some species.

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