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A comparison of the butterfly fauna of agricultural habitats under different management history in Finnish and Russian Karelia

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Butterfly communities were studied along field boundaries in agricultural habitats in Finnish and Russian Karelia. A total of 34 sites represented typical arable land in both countries, i.e. modern cereal and forage cultivation in Finland (n = 17) and old fashioned hay cultivation in Russia (n = 17). Transect count data obtained over three years (1997–1999) consisted of 55 species and 11 759 individuals: 53 species and 5382 individuals in Finland, and 49 species and 6377 individuals in Russia. Despite various differences in the long-term exploitation of arable land, the species composition and the total abundance of butterflies were rather similar in both countries, but the species richness and diversity were higher in Finland. The different structure of agricultural landscapes and differences between the two countries as regards the distribution of field vegetation and cultivation practices in the studied habitats were regarded as the main factors responsible for the result being contradictory to the authors' expectations.

Introduction

In the border district of Finnish and Russian Karelia, two factors furnish an excellent opportunity for evaluating the effects of agricultural management on the butterfly fauna. Firstly, in the past large parts of Karelia were under the same administration and management of Autonomous Finland (1809–1917) and Finland (1917–1944), but during the last 50 years the methods and the intensity of agriculture differed markedly between the adjacent areas in Finnish and Russian Karelia. Secondly, the area forms a natural unit with many biological features common to both sides of the present border (Ahti *et al*. 1968, Kotiranta *et al*. 1998).

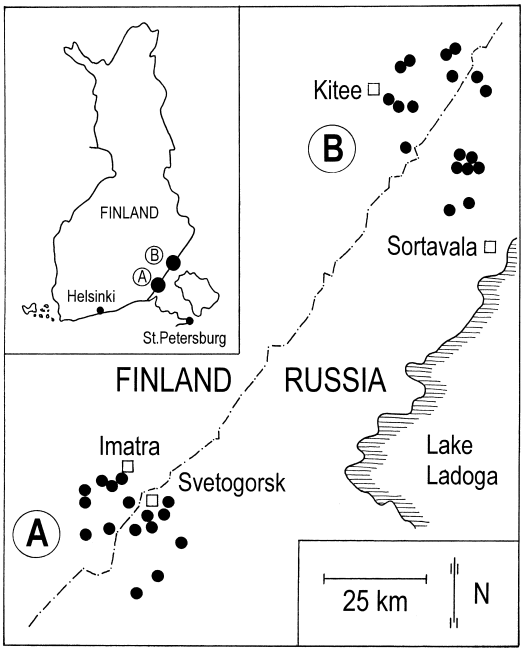

Fig. 1. The location of two study areas in the border district of Finland and Russia. There were 16 study sites in the southern (**A**) and 18 in the northern (**B**) area.

The traditional agricultural management, i.e. hay making and grazing by domestic animals, was widely practised in Finland until the early 20th century (Soininen 1974, Hæggström *et al.* 1995). This created a large number of semi-natural grasslands, such as meadows and wooded pastures, of high floral and faunal diversity (Anon. 2000). Since the 1950s, the rationalisation of agricultural methods, including intensive use of machinery and chemicals, has resulted in a considerable loss of semi-natural grasslands, and meadows in particular, in Finnish Karelia (Grönlund *et al.* 1998, Marttila *et al.* 1999). The majority of these habitats have been cultivated, abandoned or reforested (Mukula & Ruuttunen 1969, Raatikainen 1986).

In Russian Karelia, the rationalisation of agricultural methods has taken place on a much smaller scale than in adjacent areas in Finland (Nitzenko 1969, Isachenko 1996, Kotiranta *et al.* 1998). Most of the arable land is still under the traditional mowing or grazing management, hence the semi-natural grasslands have remained as a major element of the present landscape in Russian Karelia (Marttila *et al.* 1998).

In southern and central Finland, the loss of semi-natural grasslands and other changes in agricultural practices are regarded as one of the main reasons for the decline of the butterfly fauna (Marttila *et al.* 1991, Väisänen 1992, Mikkola 1997, Somerma 1997). According to Rassi *et al.* (2000), there are 18 endangered butterfly species in Finland, of which 13 are primarily threatened by the overgrowing of meadows and wooded pastures. In Russian Karelia, the changes in the butterfly fauna are not as well-documented and the present status of many rare species is not known (Ivanter & Kuznetsov 1995, Kotiranta *et al.* 1998).

We studied the butterfly communities in typical agricultural habitats in Finnish and Russian Karelia in order to test whether Finnish agriculture with its history of more intensive practices over the last 50 years has resulted in lower species richness and diversity among the butterflies than in those occurring in more traditionally managed arable land in adjacent areas in Russian Karelia. In addition, indicator and dominant species of modern cereal and forage cultivation in Finland, and indicators and dominants of old fashioned hay cultivation in Russia, were determined.

Material and methods

The study was carried out in two separate areas, both southern (Imatra–Svetogorsk region) and northern (Kitee–Sortavala region) ones located in the southern boreal climate zone (Ahti *et al.* 1968), in the border district of Finland and Russia (Fig. 1). A total of 51 sites representing typical arable land in both countries were selected subjectively, but in regard to the natural conditions (topography, soil moisture, adjacent habitats) in the sites, only those with a similar counterpart in the other country were approved for the study. As a result, 17 sites were rejected and the comparison was based on the remaining 34 sites. In Finland, 17 sites included the field boundaries of cereal fields (4), fallow fields (4), hay fields (2), meadows (2) and pastures (5). In Russia, the sites comprised the field boundaries of hay fields (7), meadows (6) and pastures (4).

Butterflies were studied with the transect count method (Pollard & Yates 1993). In each site all butterflies seen in front of the observer (5×5 metres) were counted along a 250–900 m line transect. The total numbers and lengths of censuses were 202 and 106.7 km in Finland and 202 and 138.2 km in Russia. All transects were censused between 2 Jun. and 23 Jul. 1997, 1 Jun. and 11 Aug. 1998; and 31 May and 4 Aug. 1999. Sites in southern and northern areas were studied every other week. Each week, the Russian sites were counted first and their Finnish counterparts were censused one to three days later. Counts were conducted primarily in the early afternoon (mean starting time: 1235 hrs in Finland, 1305 hrs in Russia) in satisfactory weather conditions in both countries (Table 1).

Table 1. Study sites (n = 34) and the average weather data during butterfly counts. The temperature (°C) was measured, and the windspeed (1–6, Beaufort scale) and sunshine percentage (0, 25, 50, 75, 100%) were estimated during each census.

Site	Transect length (m)	Number of counts	Wind speed (1–6)	Temperature	Sunshine percentage
FinSite1	850	17	2.8	22.9	91.2
FinSite2	300	16	2.7	22.0	84.4
FinSite3	550	12	2.9	23.4	85.4
FinSite4	350	8	2.6	22.3	87.5
FinSite5	750	17	2.9	22.0	80.9
FinSite6	750	13	3.4	23.2	86.5
FinSite7	500	10	2.8	22.6	90.0
FinSite8	550	13	2.7	21.8	80.8
FinSite9	450	8	2.3	23.1	81.3
FinSite10	500	15	2.6	22.1	81.7
FinSite11	400	9	2.3	22.6	86.1
FinSite12	250	11	2.5	22.5	88.6
FinSite13	250	9	2.9	21.6	72.2
FinSite14	500	9	2.3	22.7	91.7
FinSite15	500	10	2.4	22.7	80.0
FinSite16	650	11	2.4	21.5	70.5
FinSite17	500	14	2.8	22.2	80.4
***Mean**	**506**	**12**	**2.7**	**22.4**	**83.5**
***Standard deviation**	**172**	**3**	**0.3**	**0.6**	**6.0**
RusSite1	900	17	2.4	23.1	91.2
RusSite2	700	16	2.6	21.6	87.5
RusSite3	550	12	3.0	22.2	89.6
RusSite4	550	8	3.0	21.9	90.6
RusSite5	800	17	2.8	23.5	83.8
RusSite6	950	13	3.2	21.3	84.6
RusSite7	550	10	2.5	23.4	87.5
RusSite8	900	13	2.9	22.7	78.8
RusSite9	750	8	2.5	21.4	84.4
RusSite10	600	15	2.3	22.2	71.7
RusSite11	700	9	2.6	22.6	91.7
RusSite12	300	11	2.1	22.9	75.0
RusSite13	300	9	2.2	23.2	75.0
RusSite14	750	13	2.9	22.4	80.8
RusSite15	650	10	2.3	23.7	92.5
RusSite16	800	7	2.6	22.4	78.6
RusSite17	600	14	2.5	22.6	69.6
***Mean**	**668**	**12**	**2.6**	**22.5**	**83.1**
***Standard deviation**	**187**	**3**	**0.3**	**0.7**	**7.3**

The total numbers of individuals of each species were adjusted to the number expected per 1000 m in each site in order to avoid any bias from the different lengths of censuses. These relative values were used in all analyses to describe the butterfly community of a site, including the total abundance, the species richness, the species diversity, and the measure of dominance. The total butterfly abundance was the sum of all individuals observed in the site. The species richness, calculated using rarefaction (James & Rathbun 1981), was determined as the number of butterfly species expected in a random sample of 100 individuals in the site. Species diversity was calculated as $N_2 = 1/\lambda$, where λ is Simpson's index (Hill 1973). Dominance was examined on a logarithmic scale and the species were arranged in three classes of abundance (n). Depending on the total numbers of individuals recorded in the site (N), the ranges were given in a decreasing array as $N \geq n > N^{0.67}$ for dominant, $N^{0.67} \geq n > N^{0.33}$ for common and $N^{0.33} \geq n$ for scarce species. Differences between Finland and Russia were tested using the Mann-Whitney U-test (Brown & Rothery 1993).

Differences in species composition between Finnish and Russian Karelia were analysed using indicator species analysis (Dufrene & Legendre 1997). Only species observed at a minimum of five sites with an abundance exceeding 20 specimens were included in the analysis. The method combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group, in this case the Finnish and Russian sites. The method produces indicator values, ranging from zero (no indication) to 100 (perfect indication), for each species in both countries. The indicator values of species in the two countries were tested for statistical significance using a Monte Carlo technique (Davison & Hinkley 1997). A Monte Carlo p-value was determined as the proportion of randomised trials with an indicator value equal to or exceeding the observed indicator value, i.e. MCp = (1 + number of runs observed)/(1 + number of randomised runs). In the analysis, 1000 randomised runs were used.

Results

The transect count data consisted of 55 species and 11 759 individuals. The total numbers of species and individuals were 53 and 5382 in Finnish sites, and 49 and 6377 in Russian sites, respectively. In both countries, the most abundant species were *Aphantopus hyperantus* (3199), *Pieris napi* (2214) and *Thymelicus lineola* (1361), these constituting 58% of all the individuals observed. *Thecla betulae* (1 site), *Satyrium pruni* (1), *Cupido argiades* (1), *Boloria euphrosyne* (1), *Melitaea athalia* (7) and *Maniola jurtina* (1) were observed only in Finnish sites, whereas *Pyrgus malvae* (1) and *Limenitis populi* (1) were recorded only in Russian sites.

There was no difference in the total abundance of butterflies, but the calculated species richness and diversity were significantly higher in Finnish Karelia (Table 2). The number of dominant species was higher in Russia, while the number of common species was higher in

Table 2. A comparison of butterfly communities in agricultural environments between Finnish (n = 17) and Russian Karelia (n = 17). Significance (Mann-Whitney U-test): * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

	Finnish Karelia		Russian Karelia	
	Mean	SD	Mean	SD
Total abundance (ind. km^{-1})	48.1	24.2	48.9	19.7
Species richness (species/100 ind.)**	17.9	2.4	14.8	2.6
Diversity (N_2)***	7.1	2.0	4.2	1.4
Number of species/transect	23.4	6.2	22.2	5.6
Number of dominant species*	0.4	0.6	0.9	0.4
Number of common species**	3.5	1.8	1.9	1.1
Number of scarce species	19.5	6.1	19.4	5.4

Finland. A total of five dominant species were recorded overall. These included *A. hyperantus* (5 sites), *T. lineola* (1) and *P. napi* (1) in Finland, and *P. napi* (8), *A. hyperantus* (5), *Erebia ligea* (2) and *Euphydryas aurinia* (1) in Russia. No difference in regard to the number of scarce species was observed.

Indicator values for the 32 species recorded at a minimum of five sites with at least 20 individuals are given in Table 3. A total of 21 species (66%), six with a statistically significant difference, were more abundant in Finland, and 11 species (34%), three with a statistically significant difference, were more abundant in Russia.

Discussion

We have scant knowledge of the long-term trends of butterfly populations in Finnish agricultural habitats (Kuussaari *et al*. 2000). Russian

Table 3. Butterfly species (n = 32) observed in 5 study sites with at least 20 individuals. Relative abundances (individuals/1000 m) of the species are mean values from the study sites in both countries. Species are presented in order of the significance of their indicator values, from higher abundance in Finnish Karelia to higher abundance in Russian Karelia (separated with a dotted line). Significance (Monte Carlo test): * = $p < 0.05$, ** = $p < 0.01$.

	Relative abundance		Indicator value (%)		p =
	Finland	Russia	Finland	Russia	
Lycaena virgaureae	4.27	0.76	85	13	0.0010**
Boloria selene	1.54	0.43	78	18	0.0050**
Thymelicus lineola	7.23	3.38	68	32	0.0130*
Melitaea athalia	0.23	0.00	41	0	0.0130*
Ochlodes venata	1.99	0.78	68	26	0.0190*
Vanessa cardui	0.25	0.07	50	5	0.0220*
Argynnis adippe	0.42	0.17	50	19	0.1040
Lycaena phlaeas	0.24	0.07	32	4	0.1220
Argynnis aglaja	1.41	0.90	54	27	0.2060
Aglais urticae	0.24	0.05	29	6	0.2870
Polyommatus icarus	0.73	0.32	49	23	0.2910
Polyommatus amandus	2.56	1.96	53	43	0.5230
Vanessa atalanta	0.13	0.10	29	18	0.5720
Gonepteryx rhamni	1.22	1.11	49	37	0.5880
Brenthis ino	2.99	1.86	44	32	0.6230
Argynnis paphia	0.23	0.05	19	5	0.6790
Coenonympha glycerion	0.71	0.41	34	24	0.7340
Plebeius argus	0.13	0.09	21	15	0.7400
Lasiommata maera	0.22	0.17	20	15	0.8140
Leptidea sinapis	0.56	0.53	42	40	0.9250
Polyommatus semiargus	0.48	0.37	33	33	0.9970
Erebia ligea	1.96	4.12	30	52	0.8230
Lycaena hippothoe	0.82	0.84	41	45	0.8110
Aricia eumedon	0.14	0.16	8	12	0.7800
Euphydryas aurinia	0.19	1.32	1	15	0.4890
Aphantopus hyperantus	10.93	13.38	45	55	0.4060
Celastrina argiolus	0.08	0.15	13	30	0.3960
Pieris rapae	0.14	0.38	14	43	0.2340
Aporia crataegi	0.09	0.32	9	41	0.1930
Polygonia c-album	0.21	0.43	16	55	0.0350*
Anthocharis cardamines	0.02	0.14	1	42	0.0080**
Pieris napi	4.72	13.42	26	74	0.0010**

Karelia provides a remarkable opportunity in this respect, since there the traditional agriculture has been practised on a large scale right up to the present day. Thus, the study focused on a comparison of butterfly communities in arable land in general rather than in relation to the present management of the selected sites. A strict comparison in regard to the present management was not even reasonable. On the one hand, the present use of some sites in Finland varied from cereal field to hay field during the three study years. This is, and has been since the 1950s, a typical feature of more intensive agriculture in Finland. On the other hand, distorted results in one or other of the two countries would have occurred if the sites represented the same type of agricultural management in both countries. As far as the major components of the cultural landscapes are concerned, cereal fields outnumber the last thriving meadows in Finland, whereas the opposite is true in Russia (Marttila *et al.* 1998). Although the present management varied substantially, the comparison was validated by selecting the sites with similar natural conditions in both countries. For example, a dry meadow on a steep slope or a mesic field surrounded by forests in Finland both had as similar counterparts in Russia as possible. Thus, differences in butterfly communities, if any, should be related to factors other than the natural conditions of the habitats.

Finnish and Russian agricultural habitats were rather similar in terms of their species composition and the total abundance of butterflies, but contrary to our expectation, the species richness and diversity were higher in Finland. We suggest three general features which probably had different effects on the butterfly populations in the two countries and may thus be responsible for the unexpected result.

Firstly, Finnish and Russian sites differed in the degree of human disturbance. Ploughing (ten sites in Finland vs. two sites in Russia) and fertilising (14 vs. 5) were more common in Finland, whereas mowing (3 vs. 8) and hay burning in the spring time (0 vs. 8) were more characteristic of Russia. Although intensive management has a negative impact on butterflies (Saarinen 2002), ploughing and fertilising in Finland usually covered only a part of the site. In addition, cultivated plants and abandonment varied in some sites from year to year. Since the data over three years were combined in each site, Finnish agricultural habitats were dominated by fewer and less abundant species (altogether three dominant species, 51% of all individuals) than the Russian ones (altogether four dominant species, 65% of all individuals). In Russian sites, the mowing and hay burning probably reduced butterfly populations, as hay burning has a negative long-term effect on many butterfly species (Swengel 1996). Mowing causes a uniform breakdown of the vegetation structure, nectar sources are destroyed, and many of the earlier stages of butterflies are killed, leading to lower density in the butterfly community (Erhardt 1985, Gerell 1997, Bak *et al.* 1998).

Secondly, the distribution of the field vegetation differed between sites in Finland and Russia. In Russian sites, diverse vegetation was rather evenly distributed throughout the habitat, whereas many Finnish sites were characterised by monocultures surrounded by diverse vegetation in narrow field margins. In intensively managed arable land, the majority of butterflies can be recorded in narrow field margins, these being the primary uncultivated habitats suitable for butterflies (Dover 1990, Feber *et al.* 1994, Fry & Robson 1994). As all transects were primarily situated along field margins, transect counts in Finland probably consisted of a higher proportion of all individuals in the site compared to Russian ones. In addition, the Finnish transects were shorter due to the smaller size of the agricultural habitats in general, which might lead to a further increase in the relative abundances.

Thirdly, agricultural landscapes differ greatly between the two countries. In Russia, practically all the arable land is consistently used for hay production (Marttila *et al.* 1998, Regional Council of South Karelia 2000). In Finland, arable land is more fragmented and heterogeneous, consisting of several types of fields with cereals, fodder and oil plants, fallow fields and grazing leys (Raatikainen 1986). As a result, the number of agricultural habitats with diverse vegetation is lower (Jantunen & Saarinen 2001) and butterflies may be concentrated in smaller and more favourable areas than in Russian Karelia, where the variation in the quality of agricultural habitats is less pronounced and usually more related to natural conditions rather than the management. Consequently, species and individuals may be more widely distributed throughout the arable land in Russian Karelia.

The composition of the butterfly fauna was rather similar in both countries. The difference in the number of species resulted from a few rare or irregular species observed only in one site. The only exception was *Melitaea athalia*, which was recorded in seven sites in Finland but was not observed in Russia. The larval host plant requirements affect the habitat affinities of individual butterfly species (Smallidge & Leopold 1997, Fleishman *et al*. 1999). In this study, the species having the highest indicator values, i.e. *Lycaena virgaureae* in Finland and *Pieris napi* in Russia, correlated well with the abundance of their larval host plants, *Rumex acetosella* and *Barbarea vulgaris* (Jantunen & Saarinen 2001). *Thymelicus lineola*, *Ochlodes venata* and *Vanessa cardui*, which had a positive response towards modern cereal and forage cultivation, are among the species preferring intensively managed environments in arable land (Saarinen *et al*. 1998, Saarinen 2002). Migrants, which are usually eurytopic species capable of surviving in harsh environments, were somewhat more abundant in Finnish agricultural habitats under intensive management. This may affect the potential expansion of the species in the future.

Modern agriculture has different effects on faunal communities compared to less intensive methods of cultivation (Erhardt 1985, Smallidge & Leopold 1997). Although there have been various differences in agricultural practices in Finland and Russia over the last five decades, the butterfly fauna was fairly comparable on both sides of the border. These results are in line with recent studies on butterflies in Finnish agricultural landscapes under traditional or intensive management, indicating rather small differences between the management groups (Kuussaari *et al*. 2000, Saarinen 2002).

Our results implied that the importance of changes in agricultural practices in regard to butterfly decline is not yet fully understood. According to books on Finnish butterflies (Marttila *et al*. 1991) and threatened Lepidoptera in Finland (Somerma 1997), which cover 47 declined species (49% of 95 resident ones), changes in agricultural practices, and the loss of open meadows, in particular, are regarded as the most important factors causing the decline. In view of the number of such environments, the decline is obvious (Anon. 2000). However, for most groups of organisms, butterflies included, no quantitative data on the occurrence of species exist from the time of traditional agriculture in Finland. It is thus impossible to carry out quantitative comparisons between former and present populations. The national butterfly recording scheme in Finland confirms the declining trend between 1991 and 2000, since annual indices of distribution exhibited some decrease for 13 species and some increase for six species (K. Saarinen *et al*. unpubl.). However, none of the decreased species, inhabiting peat bogs and mires (5 species), sandy and warm meadows (5) and luxuriant forests (3), were primarily adapted to agricultural environments, which are the subject of this study. As Saarinen *et al*. (1998) suggested, it appears that field boundaries in Finnish agricultural environments still maintain enough suitable habitats for a wide variety of butterfly species.

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