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Population Structure and Mobility of the Scarce Copper *Lycaena virgaureae* in the Herb Meadow Habitat of Northern Mongolia

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ABSTRACT

In the present study we aimed to investigate the population size and the dispersal ability of a common species *Lycaena virgaurea* within a natural herb meadow habitat in Northern Mongolia. Mark-release-recapture experiments were conducted during a 24 days study period between end of July and August in 2004. The total population size was estimated to be 2880 individuals and estimates of male and female populations showed no significant differences from a 1:1 ratio. Out of the 38.68% of all the marked individuals that were recaptured during the specified study period, the percentage of males recaptured atleast once were higher than those of the recaptured females (19.59:11.08). Mean distances moved between subsequent recaptures were significantly different for both the sexes (ANOVA, $F(1,31) = 18.60$; $p<0.001$). Mean distance between two successive captures in males and females were 141±129 and 89±85 m, respectively. The mean maximum distance moved by females was 705 m and by males was 633 m. The overall results indicated the restricted dispersal ability of the Scarce Copper (*Lycaena virgaureae*) within the study area inspite of large open populations of *Lycaena virgaureae* being supported within the natural landscape.

Key words: Movement, recapture, individuals, mean distance, dispersal

INTRODUCTION

Features of landscapes are the most important predictors of population and community ecology of species (Hunter, 2002; Tews *et al*., 2004). Most of the previous studies on butterfly ecology have attributed declining patch occupancy and increasing threat to survival to progressive habitat fragmentation. In addition, the extinction risk increased significantly with decreasing heterozygosity (Saccheri *et al*., 1998) and followed widespread destruction of the habitat (Pullin, 1997). In contrast to such features in Europe, Mongolia which is a landlocked country in the heart of Central Asia, still has some of the most intact ecosystems in the entire region of the Palaearctic zone. Geographically Mongolia is a relatively unbroken area between Siberia and China, but on the same latitude as parts of Central Europe and Northern United States. The Mongolian territory includes several natural zones like taiga forest, mountain forest steppe, meadow steppe and desert.

The Khan Khentey region in Northern Mongolia is one of the three core conservation zones within the 'Strictly Protected Area' of the Khentey mountain range. It covers an area of 12271 km^2 and is also known to be one out of the five different geographic regions in Mongolia's Northern forests. In the Khentey region the Western Siberian dark taiga forests with *Picea obovata*, *Abies sibirica*, *Pinus sibirica* and *Larix sibirica* meet the Eastern Siberian light taiga forests comprising

of *Betula platyphylla* and related species, *Larix* sp. and *Pinus sylvestris* (Ermakov *et al.*, 2002). Mongolia's forest-steppe zone forms the transition between the closed forests of the Siberian mountain taiga in the north and the steppe in the South. The Khentey region has this forest steppe zone with a high species richness due to the mixture of boreal, temperate and Daurian elements. The forest-steppe of the Khentey region is unique in the zonation from true Siberian taiga into the Daurian steppe with a mixture of dark taiga, light taiga and forest steppe vegetation types (Dulamsuren *et al.*, 2005). This region is also a biodiversity hotspot in Mongolia (Muehlenberg and Samiya, 2002). The West Khentey region is known to harbour a particularly high plant diversity with dominant dark taiga species including *Abies sibirica* and *Picea obovata* (Tsedendash, 1995). A very high vascular plant diversity has also been reported in this region (Dulamsuren and Muehlenberg, 2003; Dulamsuren *et al.*, 2004).

The butterfly fauna of Mongolia is known to be represented by 253 species but there are no endemic species (Korshunov and Gorbunov, 1995; Muehlenberg *et al.*, 2003) although some new records are also likely to be reported from the southern range of the Mongolian Altai (Churkin and Tuzov, 2003). Six species from the family Papilionidae are listed in the Mongolian Red Data Book (Shiirevdamba *et al.*, 1997). The butterfly fauna of the West Khentey region represents 60% of the total Mongolian fauna (Monkhbayar, 1999; Korshunov and Gorbunov, 1995). This butterfly community can be classified into four biogeographic categories with the largest representation by the palaearctic group (Muehlenberg *et al.*, 2000; Gantigmaa, 2005). These species are known to be typical for taiga forest, woodland and grassland biotopes and steppes. The West Khentey is considered to be of high conservation value because amongst the diverse flora and fauna, there are many species which are endangered or threatened elsewhere but are common in this region. The Scarce Copper *Lycaena vigaureae* is one such example which is threatened in Europe but large open populations are known to exist in the West Khentey region (Gantigmaaa, 2005).

Lycaena vigaureae is a typical grassland butterfly and has been listed as a very common species in West Khentey (Korshunov, 1977) This butterfly is widely distributed in Europe, Middle Asia and Mongolia (Tolman and Lewington, 1998). This species has declined in many parts of Europe (Ebert, 1993) and has been listed as vulnerable in Germany (Bundesamt fuer Naturschutz, 1998). It was documented in the Red Data Book of European Butterflies as lower risk, near threatened (Van Swaay and Warren, 1999). The characteristic natural habitats of *Lycaena virgaureae* are forest-open area-corridors, forest meadow, tree lines, forest edge and dry grasslands (Settele *et al.*, 1999) and tall herb communities, mesophile grassland, mixed woodland, broad-leaved deciduous forest and coniferous woodland (Van Swaay and Warren, 1999). In West Khentey, this species occurs in all kinds of biotope ranging from mesophile grasslands, dry slopes and flower rich meadows to forest clearings, forest margins and forest mantel (Gantigmaa, 2005). It is univoltine with adults usually flying from mid June to late August. Within the Asian part of Russia, it flies from late June until August (Settele *et al.*, 1999) and in North-western Europe, in one generation between July and August (Schneider *et al.*, 2003).

MATERIALS AND METHODS

Study area: Our study area was located on a herb meadow at an elevation of 960 m above MSL in western Khentey region of north Mongolia (Fig. 1). The West Khentey belongs to the Euroasiatic-Boreal-Forest region and is a sub-region of the East Siberian *Larix-Pinus sylvestris* forest zone of Khentey mountain taiga (NAM, 1990).

The forest structure in West Khentey region represents climax coniferous forests only in some patches, because fire causes mixed forest of variable succesional stages, such that the boreal coniferous forests are of high structural diversity and spatial heterogeneity due to the natural disturbances (Gunin *et al*., 1999; Goldammer and Furyaev, 1996). The river valley demarcates the hilly terrain characteristic of this region. This natural landscape includes grasslands (e.g., mountain dry steppe, meadow steppe, herb meadow, wet grassland dominated by *Carex* sp., peat meadow), the riparian woodland (e.g., dense *Betula fusca* shrubland with *Salix* sp., open riparian forest with *Larix sibirica* and *Betula platyphylla* as shrub layer, *Picea obovata* and *Populus laurifolia* dominated riparian forests (Dulamsuren, 2004).

Muehlenberg *et al*. (2000) described eight different types of vegetation in the West Khentey region: mountain taiga, mountain forest, meadow steppe, mountain dry steppe, shrub land, riparian woodland, herb meadows and wet grasslands. Typical habitats in West Khentey region are coniferous and deciduous forests with open areas of herbaceous plant meadows and meadow steppes on the terraces in the river valley, while at higher elevations there is a transition to xerophytic herbaceous communities on the southern slopes. Riparian woodlands and open riparian forests with *Larix sibirica* and *Betula platyphylla* are found in the river valleys. Grasslands with hygrophytic vegetation exist on the river terraces while xerophytic grassland habitats are found on the dry southern slopes.

The study site was a c.a 7 ha meadow in the river valley terrace. This site was specifically chosen due to the availability of many flowering plants and hence plenty of adult nectar resources. One of the important characteristics of this selected site was the vast expanse of natural, open areas bordered by different forest types on one side and the river on the other side (Fig. 1).

Study period: The entire study was conducted in the year 2004, extending over a one month period from end of July until end of August.

Movement patterns of adults: The movement patterns of *Lycaena virgaureae* was investigated from late July until end of August in 2004 at one open herb meadow habitat of West Khentey in northern Mongolia. During a four hour sampling per day under good weather conditions, two surveyors walked on foot and netted all individuals encountered. One person marked every captured individual and released it immediately at the place of capture. The exact GPS position of all individuals recorded during the mark-release-recapture study was plotted on a map, in order to get a measure of distances moved between subsequent captures. The second surveyor made a record of the date of capture, sex of the captured individuals, number of marked and released individuals and the GPS positions of the capture locations for each sampling day on the data sheet. Emigration and immigration patterns for the sampled population were not examined in detail.

Adult population size: The population size was estimated in 2004 for a period of 24 days by a mark-release- recapture study. During the flight period, the study site was visited daily under permissible weather conditions, between 11.00 and 15.00 h, from the end of July until the end of August. Sampling was not done on days when it was raining. On certain sampling days with very windy conditions prevailing, the observation hours could be shorter than the four hours sampling per day regime. Each adult caught was marked individually on the hind wing, using a fine-tipped permanent ink pen and released immediately at the place of capture. The sampling data was used to estimate the sex ratio. The analyses were performed by aggregating the sampling dates and

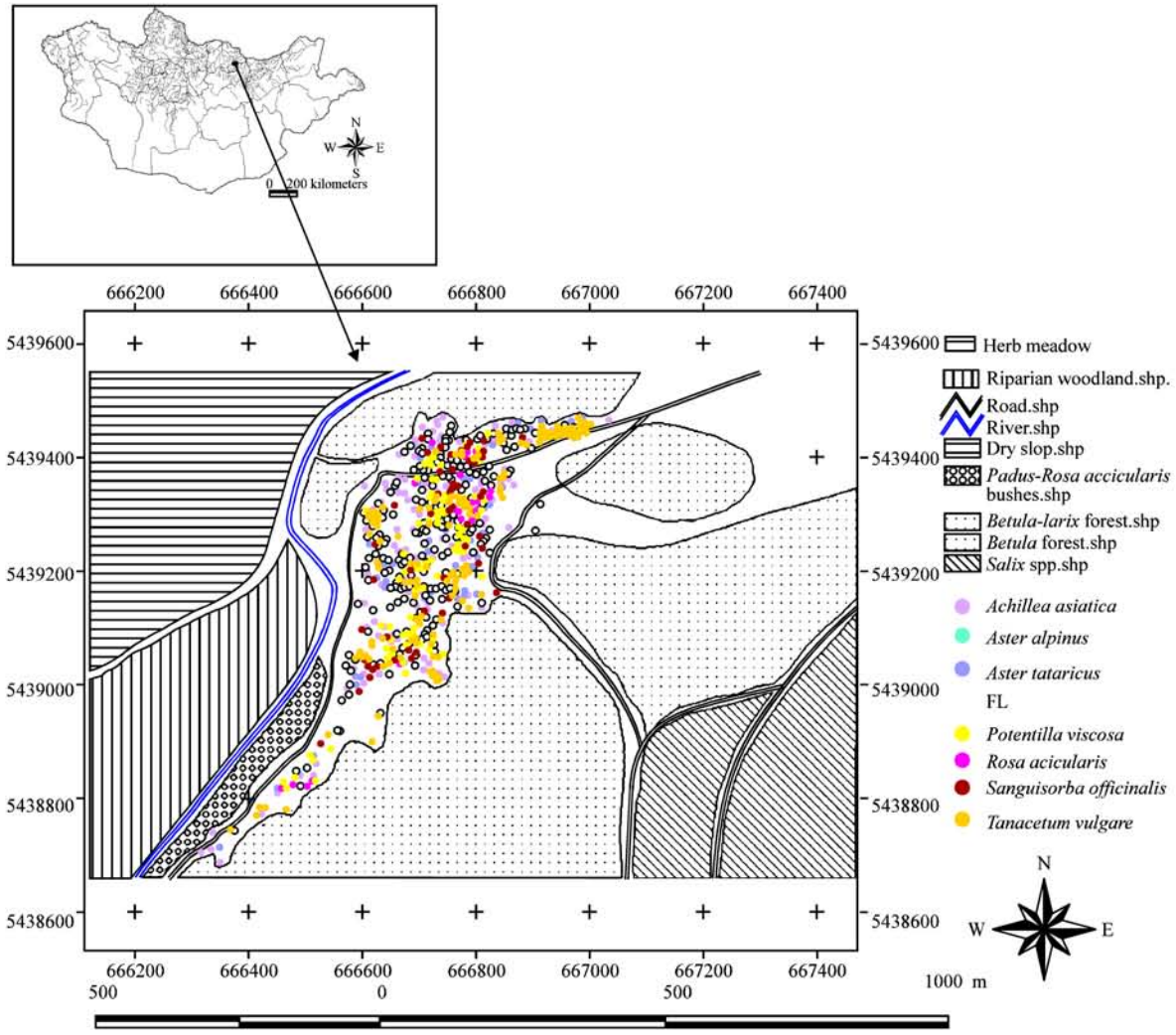

Fig. 1: Location of the study area in Mongolia. The Khentey is the southern extension of the Siberian taiga system. This region consists of a high mountain belt, a forest belt, forest-steppe and meadow steppe. The study site consisted of c. 10 ha area along the Eroo river and was located at 960 m above MSL on a herb meadow habitat in West Khentey. The coloured points indicate the distribution of some of the flowering plants within the study area

dividing the entire survey period into three discrete sections, with an approximately equal time interval of 9-10 days. Daily population estimates were calculated using the Jolly-Seber method (Krebs, 1998). Male and female population sizes were calculated by plotting the daily estimates obtained from the Jolly method. The overall population size was estimated by the Petersen method (Krebs, 2001).

Statistical tests: Statistical tests like the One-Way ANOVA for estimating the movement parameters were analysed in the program STATISTICA 7.1 (StatSoft, 1995).

RESULTS

Mark-release-recapture data: A total of 1345 individuals (758 females, 587 males) were marked during the nearly one month mark-release-recapture study period. 38.68% of all the marked individuals were recaptured within 4 weeks. 19.59% of males and 11.08% of females were recaptured at least once (Table 1). The maximum time interval between mark and recapture was 24 days for males and 22 days for females.

Movement of adults: Throughout the 24 days period, the mean distance moved by females in herb meadow was greater than the distance covered by the males. Most of the marked adults were recaptured from sites located nearby to their place of first capture (Fig. 2).

Our observations from Fig. 2 showed that the movement patterns of a majority of *Lycaena virgaureae* individuals were restricted to fairly small areas within the open landscape although there were no natural borders or barriers limiting their movements. For example, an individual marked by the symbol (★) was recaptured four times after the first release, but the total distance covered by this individual within the sampling period was only 56 m.

The distances moved between subsequent recaptures were significantly different for both sexes (male n = 150, mean 118±113 m, female n = 100, mean 163±143 m; ANOVA, F (1,248) = 7.75; $p<0.005$) (Table 2).

Table 1: The recapture records of *Lycaena virgaureae* in the herb meadow habitat of West Khentey. The survey was carried out between 25th of July-25th of August, 2004

	Male		Female		
Capture category No. of recaptures	n	%	n	%	Total
One time	115	19.59	84	11.08	199
Two times	24	4.08	13	1.71	37
Three times	10	1.70	3	0.39	13
Four times	1	0.17	0	0.00	1
Total No. of individuals recaptured	150	25.50	100	13.18	250
No of individuals not recorded	437	74.40	658	86.80	1095
Total No. of marked individuals	587		758		1345

n = No. of individuals recaptured

Table 2: The mean distance moved by *Lycaena virgaureae* individuals (both sexes) between subsequent recaptures during the 24 days sampling period

	Lycaena virgaureae			
Movement parameters	Male	Female	Total	p-value
Mean distance±SD (m)	118±113	163±143	136±128	0.005*
Mean distance between first and last recapture±SD (m)	104±71	149±133	126±107	0.26
Max. distance covered by an individual (m)	633	705	-	-
Mean distances moved by only once recaptured individuals (m)±SD	96±89	143±120	116±105	0.001*
Mean distances moved by twice recaptured individuals (m)±SD	185±153	225±162	199±155	0.46
Mean distances moved by three times recaptured individuals (m)±SD	174±117	388±287	223±181	0.06
Mean distance (m)±SD at short interval (recaptured after 1-2 days)	91±75	144±121	109±96	0.05*
Mean distance (m)±SD at longer interval (recaptured after more than 10 days)	190±140	236±210	208±171	0.33

SD: Standard deviation, *Significant

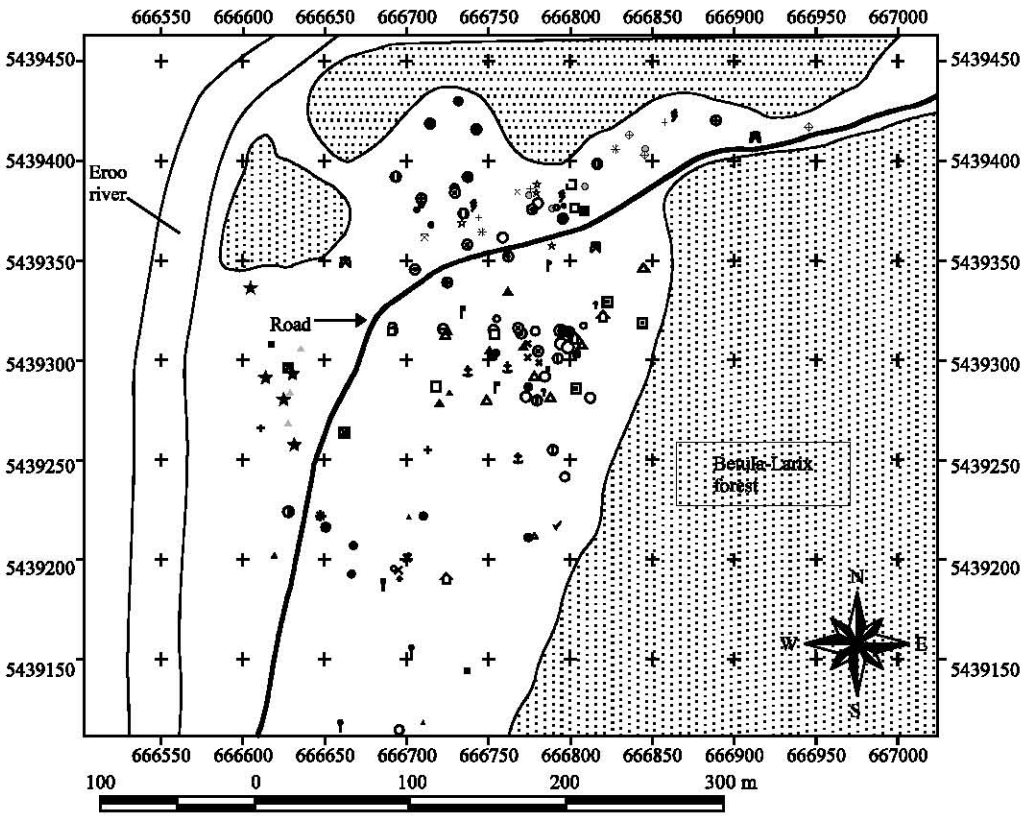

Fig. 2: Map showing the distribution of *Lycaena virgaureae* in one habitat type. Butterflies were recorded in an open herb meadow. Each type of symbol indicates the GPS position of a different captured individual for each sampling day within the study site

Mean distance between two successive captures was significantly different (ANOVA, F (1,31) = 18.60; $p<0.001$) for both the sexes (141±129 m for females; 89±85 m for males). For the time interval between subsequent recaptures, mean distances moved by females was greater than that moved by the males (Table 2). The females moved at a constant rate whereas males increased their distance in time between recaptures (for males 91±75 m at short intervals compared with 190±140 m at longer intervals recaptured after more than 10 days; ANOVA, F (1,38) = 9.12; $p<0.004$). The mean distances moved by females was not significantly different (ANOVA, F (1,38) =2.74; $p<0.1$) between time intervals. The greatest distance between recaptures was 705 m for females and 633 m for males. Marked individuals moved freely throughout the mark-recapture circuit, but females had moved much farther than the males when recaptured within different time intervals (Fig. 1). However our overall mark-release- recapture results showed significant differences between mean distances moved by males and females (Table 2). Fifty one percent of the linear distances moved by *Lycaena virgaureae* were more than 100 m and 29% were found to be less than 50 m. The mean distances between first and last recapture was not significantly different for both sexes (149±133 m for females; 104±71 m for males; ANOVA F (1,28) = 1.30; $p<0.26$). However, the overall mean distances moved by *Lycaena virgaureae* was significantly different for the different times of recapture. The maximum range was calculated for individuals that were captured for three or more times (174±117 m for males and 388±287 m for females).

The total distance covered by L*ycaena virgaureae* was significantly higher than the distance between the first and last recapture (ANOVA, F (1,98) =12.20; p<0.0007). This could be considered to indicate that *Lycaena virgaureae* was more or less confined in its habitat within a restricted area range.

Adult population size: The adult counts of *Lycaena virgaureae* indicated that the males not only emerged earlier but were also captured more frequently than the females. The individual counts for the males could reach a higher value even much before a single adult female was first encountered. The estimated population size was not significantly different between the sexes (ANOVA, F (1,46) = 3.24; p<0.07) throughout the entire sampling period which also covered their flight period, but males were found to appear earlier and the females were found to stay longer in the habitat (Fig. 3).

The estimates of male and female populations suggested a slight preponderance of females, but statistical examination showed no significant differences from a 1:1 ratio. The estimated total population in the study site was 2880 (recapture calculation by the Petersen method). Although the Scarce Copper is known to fly in West Khentey for one generation between middle of July till end of August, however our results showed that the highest abundance was recorded around the beginning of August (Fig. 3). The total numbers of individuals which were recorded between 02-08 August were approximately representing 30% of all captured individuals.

During the survey period of *Lycaena virgaureae*, the population size of males was found to be dominant in the end of July and most of the males were observed to be visiting *Achillea asiatica, Potentilla fragarioides* and *Aster tataricus*. Forty six percent (n = 761) of all the butterflies were captured from the feeding plants. The most preferred nectar source was *Achillea asiatica* (25% of total number of captured individuals were using this plant). The majority of the males (59% as compared to 49% for females) were either in flight or perched on vegetation at the time of encounter. Estimated size of one population during peak flight period ranged between 842 and 2358 individuals. The estimated density was 0.047 individuals m^{-2}.

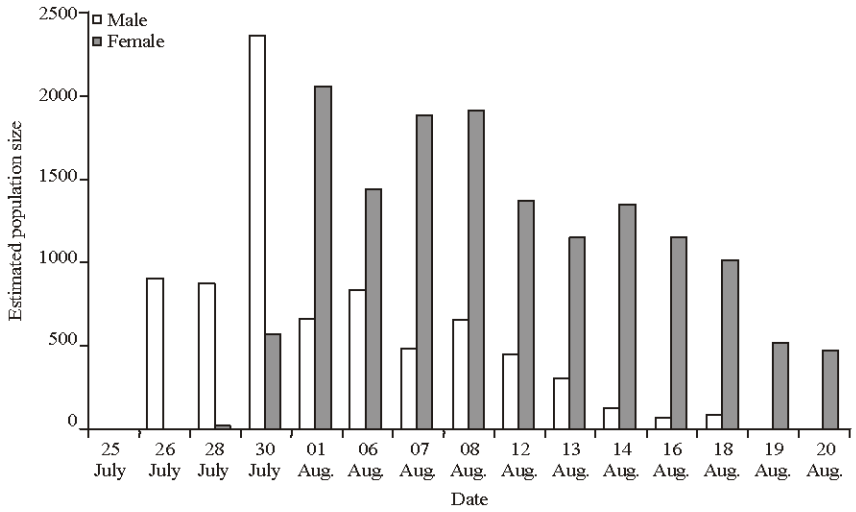

Fig. 3: Estimated population size of *Lycaena virgaureae* recorded between 25th July and 25th August, 2004. Daily change in the size of the adult population is estimated by the Jolly-Seber method

DISCUSSION

Movements of adults: Butterfly communities which inhabit natural landscapes are thought to be more mobile than those inhabiting human dominated, fragmented landscapes (Bergman *et al.*, 2004). In this present study, the mobility of *Lycaena virgaureae* was studied in a natural open landscape having a rich herb vegetation cover in Northern Mongolia. Present results supported previous studies which reported that the proportion of recapture was higher for males than females (recapture ratio of 26:13%) as their mobility was found to be more restricted in comparison to that of the females (Brakefield, 1982; Pullin, 1997; Fischer *et al.*, 1999). A similar result was also detected in the population studies on *Boloria eunomia* (Mennechez *et al.*, 2003). The overall low recapture rate of *Lycaena virgaureae* could be attributed to their greater dispersal ability. However, another factor affecting their low recapture frequency could be the configuration of the study sites (Fischer *et al.*, 1999; Schneider *et al.*, 2003) and the sampling intensity (Auckland *et al.*, 2004). Present results on the dispersal parameters for both the sexes showed that the mean movement distances for males was 118±113 m and for females was 163±143 m. This implied that the females exhibited greater dispersal ability in comparison to the males.

Mean distance movement values for *Lycaena virgaureae* recorded in our present study could be comparable to those reported in other studies although there were differences in the size of the study area (Schneider *et al.*, 2003). However, the overall adult movement patterns could be considered to be limited as our results showed the maximum distance range for males was 633 m and for females was 705 m. Therefore, we could consider our results to be contradictory to the findings of Schneider *et al.* (2003) where the Scarce Copper showed much greater movement ability than expected from the results of previous studies although the comparatively large size of the study area was a crucial determining factor irrespective of the high cover of suitable habitat which was also evident in our study. These findings are supported by Mennechez *et al.* (2003), who concluded that the butterflies moved larger distances in fragmented landscape than in a continuous system of undisturbed landscape. Habitat suitability as another important factor influencing the dispersal ability of the adults can be cited from the findings of Shreeve (1992) who observed that the area occupied by a population must consist of habitats which fulfill the adults' functional categories such as mating, egg-laying and foraging. Similar observations on habitat quality as an important factor that drives the distribution of butterfly species were reported by Hanski (1999) and Thomas *et al.* (2001). In this study area, the existence of undisturbed grassland habitats across the natural landscape of West Khentey could have been a very favourable condition not only for supporting the Scarce Copper population but also for restricting their movements within the habitat. While many Palaearctic butterfly species are known to be specialised in only one habitat type within fragmented landscapes long distance movements across several habitat patches has also been reported to be crucial in determining the persistence of some species in highly fragmented landscapes (Baguette *et al.*, 2003; Bergman, 2001; Pullin, 1997).

In our study within a natural landscape, the overall percentage of recapture (38.68%) was higher as compared to a 29% recapture rate in intensively used semi-natural grasslands (Schneider *et al.*, 2003). This result can be considered to give support to the fact that the adult mobility was not so much restricted as unlike in a disturbed landscape where it was observed that some individuals belonging to very sedentary species could move over larger distances but such individuals usually showed no predictable direction in their movements and majority of them even did not attempt to return to their original habitat (Shreeve, 1992). So we could consider our investigations to be important in representing the differences in movements patterns of the same

Palaearctic species (*Lycaena virgaureae*) but from two different types of landscape (Schneider *et al*., 2003; Douwes, 1975).

Our investigations clearly indicated the lower movement ability of the Scarce Copper within the natural landscape of Mongolia as compared to the higher movement ability of the same species within the fragmented and human dominated landscape in Europe.

Adult population size: In our present study we tried to investigate the role of nectar plants availability in naturally open habitats and how it could influence the adult population size of *Lycaena virgaureae*. This species could be categorised as commonly available in the West Khentey region as results from previous studies have reported on the existence of large open populations (Gantigmaa, 2005). Most individuals of many species appear to stay within a relatively small area called the home range. However, all those individuals must have particular living space (e.g., space with available resources for their life) in order to coexist within a community (Porter *et al*., 1992). Despite their ability to fly, most adult butterflies tend to stay within specialised microhabitats where the resources (adult nectar and larval hostplants) are abundant (Warren, 1992).

The population size of *Lycaena virgaureae* might be affected by the availability of its nectar plant. Our field observations showed a positive correlation between the female population size of *Lycaena virgaureae* and the abundance of its foodplants *Achillea asiatica* and *Aster tataricus*, but males were significantly correlated with *Potentilla fragarioides* (Douwes, 1975). This may be interpreted as the effect of flowering phenology of the nectar plants or palatability of those plants. The peak flowering period of *Potentilla fragarioides* is in July (Qin *et al*., 2003). The sex ratio of *Lycaena virgaureae* had changed over time, with males emerging earlier during the flight period and females emerging two weeks after that of the first appearance of males. Males were commonly found basking on the vegetation, whereas females were observed mostly during flight.

This study was the first of its kind in the West Khentey region of Mongolia for investigation on the population structure of a butterfly species within a very natural landscape with least human disturbance. This Palaearctic species being near threatened in Europe was selected as a model for our studies and we found a comparatively higher mobility of the existing population within our study area although on a relatively smaller scale. Our present investigations can have a lot of implications for future studies on population biology and other ecological aspects of the butterfly fauna in West Khentey.

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