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Full Length Research Paper

Habitat association and movement patterns of the violet copper (*Lycaena helle*) in the natural landscape of West Khentey in Northern Mongolia

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We studied the habitat association and movement patterns of the Lycaenidae species, *Lycaena helle* using the mark-release-recapture method in a heterogenous natural habitat of West Khentey in Northern Mongolia. Butterfly individuals were collected using nets during a standardized one hour sampling in different biotopes. *L. helle* was found to predominantly inhabit the wet mesophile grasslands and herb meadows, although moderate occurrences were also recorded in the riparian woodlands, birch forests of the river valley and in the mixed forests of *Larix sibirica* and *Betula platyphylla.* We investigated the movement patterns of the Violet Copper within ecologically open landscape and recorded individual occurrences across the different habitat types of West Khentey. The mean distances between first and subsequent captures were found to be greater for both the sexes (107 ± 76 m for females and 44 ± 41 m for males). The single greatest movement between recaptures was 386 m for females and 163 m for males. We could conclude from our studies that *L. helle* had a more closed distribution range within the natural landscape of our study area as the high plant diversity could be considered to be an important factor restricting their movement patterns as unlike that of their counterparts in fragmented landscapes of Central Europe.

Key words: Lycaena helle, habitat occupancy, mobility, natural landscape

INTRODUCTION

Lycaena helle (Denis and Schiffermuller, 1775) is a very rare butterfly species in Central Europe (Fischer et al., 1999) and has been listed as endangered in Germany (Bundesamt fuer Naturschutz, 1998). This species is living in small populations on fragmented and isolated habitat islands in Central Europe (Fischer et al., 1999, van Swaay and Warren, 1999).

Anthropogenic activities like afforestation, peat extraction and management methods for improving cattle grazing like drainage, burning and chemical treatments have largely contributed to habitat loss and degradation throughout Central Europe (Kudrna, 1986). The local extinction and decline of many butterfly species are related to changes in habitat quality (van Swaay and Warren 1999, Summerville et al., 2002, Rodriguez et al., 1994).

Many authors documented the influence of landscape patterns on butterfly community (Schneider et al., 2003; Natuhara et al., 1999; Saarinen, 2002; Dover et al., 1997; Schneider and Fry, 2001; Pullin, 1997; Rodriguez et al., 1994; Summerville and Crist, 2003; Summerville and Crist, 2004). Sparks and Carey (1995) found an influence of the floral composition on butterfly diversity. Soederstroem et al. (2001) showed that tree species diversity and cover had a positive effect on butterfly species, but high proportion of large trees had a negative effect on butterfly species richness. Dover et al. (1997) discussed the importance of shelter in the open countryside for butterflies. Features of landscape are the most important predictors that influence the population and community ecology of species (Hunter, 2002; Tews et al.,

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2004; Rodriguez et al., 1994; Pullin, 1997; Root, 1972; Ehrlich and Murphy, 1987; Dennis and Eales, 1997).

In contrast to the central European landscape, Mongolia which is a landlocked country in Central Asia but biogeographically located in a similar Palaearctic zone as Europe has more pristine habitats and biotopes. There is also a close similarity in the Palaearctic faunal composition, specifically in case of the butterfly fauna, where some species which are listed as critical and endangered in Central Europe or even reported to be extinct have been found to be common in Mongolia (Muehlenberg et al., 2000). The diverse biomes in Mongolia range from taiga forest, mountain forest steppe, meadow steppe and desert. The forest zone covers approximately 5% of the country's total geographical area and are mainly concentrated in the northern part and also forming the southernmost edge of the largest continuous forest system on earth, the Siberian taiga. Unlike other countries, Mongolia with its rich cultural heritage and unique ecosystems has integrated sustainable development into nature conservation (MNE, 1996).

The main aim of this study was to investigate the occurrence of Violet Copper in different habitat types within the natural landscape of West Khentey. In contrast to the human modified landscape in Europe, the Khentej habitats represent natural conditions least altered by human activities. Our specific objectives were: (1) to characterise the influence of landscape structure and vegetation on Violet Copper population by comparing their habitat occupancy and; (2) to determine the mobility of Violet Copper in natural landscape.

METHODS

Study area

The southern areas of Siberian region are located in Mongolia and comprises of high mountainous areas of northern Mongolia, the basin of Lake Khubsgul, Orkhon-Selenge, and Khentey Mountains. The Khentey and Khubsgul belong to high mountain region and are still covered in large parts with primary boreal forest. This region is the coldest area in Mongolia and is known to have continuous and isolated regions of permafrost (Gantsetseg and Sharkhuu, 2002). The Khan Khentey is a strictly protected area having global importance for biodiversity conservation due to its largely natural landscape (Muehlenberg and Samiya, 2000) . The West Khentey which is a part of the Khan Khentej mountain range belongs to the Euroasiatic-Boreal-Forest region and is located in the transition zone between the closed forest of the Siberian mountain taiga in the north and the Central Asian steppe in the south (Dulamsuren, 2004). Our field work was carried out near Khonin Nuga Research Station (49 4' 48" N, 107 17' 15" E). The zonal vegetation of the study area primarily consists of dark taiga forests with *Pinus sibirica*, *Abies sibirica* and *Picea obovata* in the upper montane belt, light taiga forests with *Larix* and *Betula platyphylla* or *Pinus sylvestris* in the northern and eastern slopes of the lower montane belt as well as meadow and mountain steppes on the southern and western slopes of the lower montane belt (Dulamsuren et al., 2004; 2005a, b).

The vegetation pattern in the Khentej region strongly depends on altitude and exposition and is known to represent a separate floristic bioregion. In the transition forest steppe zone, forests are found only on the northern slopes while on the southern slopes, high insulation which dries out the soil moisture has facilitated the dominance of steppe vegetation (Valendik et al., 1998). Muehlenberg et al. (2000) described eight different types of vegetation in the West Khentey: mountain taiga, mountain forest, meadow steppe, mountain dry steppe, shrublands, riparian woodland, herb meadows and wet grasslands. The forest area in West Khentey region has only some patches of climax coniferous forests, because a history of frequent fires has been known to cause mixed forest of variable successional stages, such that 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 mountain taiga belt in the Khentey region ranges from about 1200 to 1600 m above sea level with extensive *P. sibirica* forest covering the northern, northwestern and western slopes. The mountain forest (about 800-1200 m above sea level) consists of Larix sibirica and B. platyphylla forests on the northern and western slopes. The meadow steppe is not covered by trees although trees were known to exist in former times. The species composition in these grasslands mainly comprised of *Aster alpinus*, *Campanula glomerulata*, *Trisetum sibiricum* and *Lilium pumilum*. The mountain dry steppe occur on the southern slopes where trees are not known to exist and in these patches elements of the Daurican, Central Asiatic and Manchurian elements have immigrated. Shrubland which borders the lower mountain stratum in the valley has only a few species like *Betula fructicosa*, *Busseola fusca*, *Crataegus sanguinea* and *Salix sp.* forming a dense growth. The riparian woodland is dominated by such tree species like *Populus laurifolia*, *Betula platyphylla* or *Populus obovata*. The herb meadows in the river valley have such dominant species like *Filipendula palmata*, *Filipendula ulmaria*, *Heracleum dissectum*, *Achillea alpine*, *Gerum alleppicum*, *Sanguisorba officinalis*, *Lilium dahuricum* and *Elymus dahuricus*. The wet grassland is characterised by *Carex meyeriana*, *Carex dichroa*, *Carex enervis*, *Carex caespitose*, *Carex schmidtii*, *Ligularia sibirica*, *Caltha palustris*, *Halenia corniculata* and *Comarum palustre*.

Climate

The climate of Khentey region is characterised by cold and dry winters with mean January temperatures as low as -23 to -28 C (Tsendedash, 1995; Tsegmid, 1989). Frost occurs from end of August to early June on 280-300 days/year (Tsedendash, 1995). Mean maximum monthly temperatures range from -22.1^{O} C in January to 19^{O}C in July. Temperature extremes are 36.4^{O}C in June and -40.1^{O}C in January. Mean annual precipitation in the Khentey region is higher than in other parts of Mongolia, ranging from 380 to 450 mm**.** Most of the rainfall occurs in summer between June and August. Dewfall is frequent from spring to autumn (Velsen-Zerweck, 2002; Gantigmaa, 2005).

Study site

The mobility of adult Violet Copper was recorded in open areas of herbaceous plant meadows with shrub layers. These natural habitats were heterogeneous with shrubs and herb meadows (HM) on the terrace in the river valley and mountain dry steppe (MDS) on southern slopes (Figure 1). The size of this habitat is less than 10 ha, but it includes grassland with two different plant communities of herb meadow (e.g. *Iris sanguinea* and *Alopecurus arundinaceus* community) and *Carex*-rich wet grassland (bog area). The shrub layer had such species like *Salix sp*. and *Padus asiatica* (Dulamsuren, 2004).

Mountain dry steppe (MDS) had a sparse vegetation cover

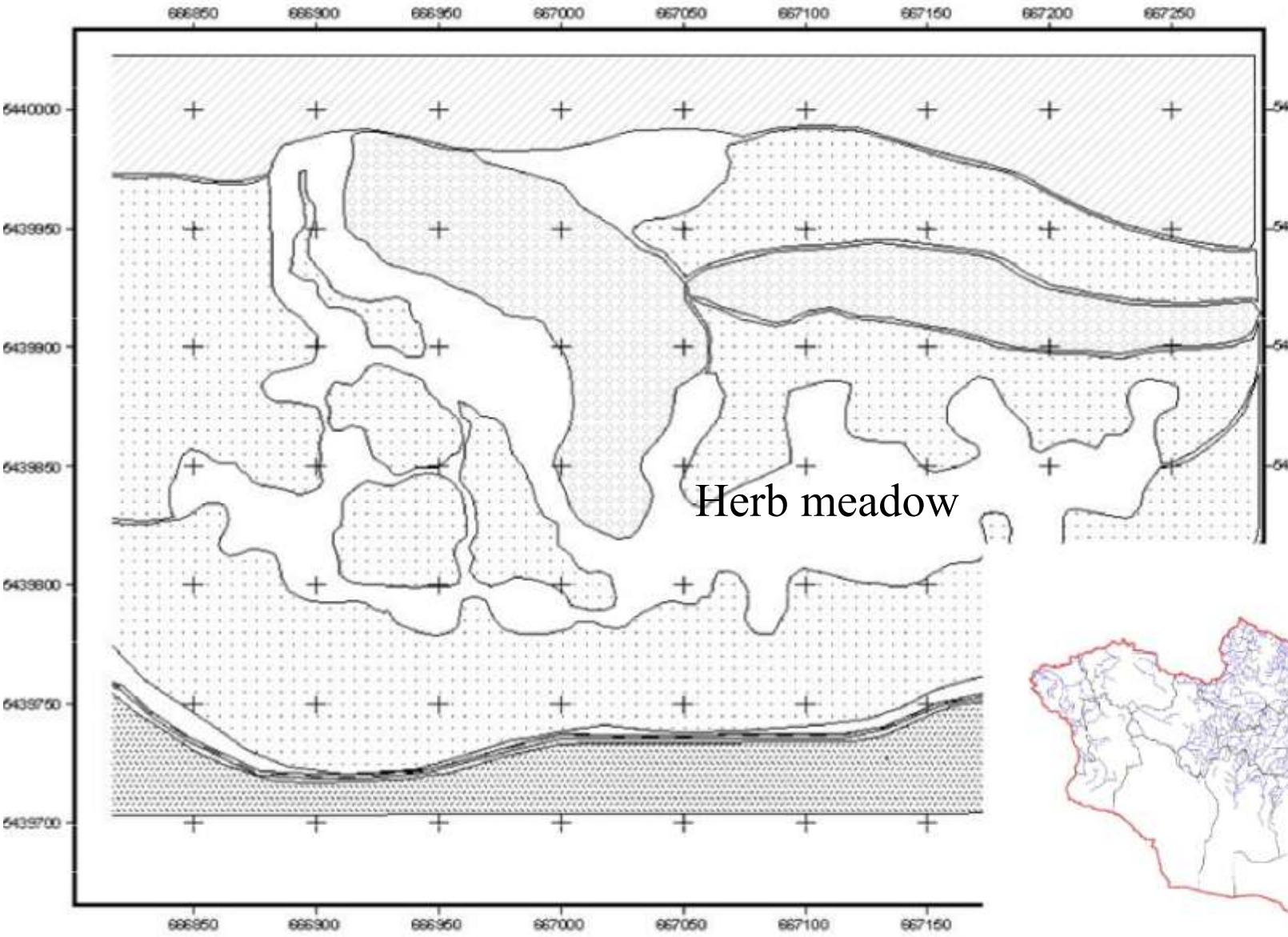

Figure 1. Study area showing the mosaic of natural habitats which are heterogeneous with shrubs and herb meadow on the terrace in the river valley.

Table 1. Number of encountered individuals of *L. helle* in different habitat types of West Khentey.

	Standardised 1 h sample	
Habitat types	**Number of individuals**	**Percentage of individuals (%)**
Birch forests of the valley	8.66± 13.27	11
Mesophile grassland	24.75 ± 17.19	42
Mixed Forest	4.0 ± 1.4	3
Riparian woodland	9.5± 9.19	11
Moist clearings in forest	8.33 ± 7.76	8
Herb meadow with shrubs	28.50 ± 30.4	24
Mountain dry steppe	1.0± 0.00	0.01

Table 2. Recapture rate of *L. helle* in the study sites of West Khentey.

	L. helle		
Capture-mark-recapture results	**Male**	**Female**	**Total number of individuals**
Marked individuals	187	205	392
Recaptured individuals	49	35	84
Recapture rate (%)	26%	17%	21%

dominated by *Potentilla - Carex*, *Potentilla acaulis*, *Potentilla viscosa*, *Artemisia* sp., *Koeleria macrantha*, *Poa*, *Thymus*, *Pulsatilla*, *Oxytropis sp*, and *Lilium pumilium*. In contrast, the herb meadow (HM) showed a predominantly *Carex-Artemisia sp*. association, including other important genera of larval food plants, such as *Bromus*, *Galium*, *Achillea*, *Poa*, *Equisetum*, *Dianthus*, *Polygonium*, *Sanguisorba*, *Vicia*, *Spiraea*, *Scutellaria*, *Potentilla*, and *Carum sp*. *Carex sp* were found to be widely distributed in both habitats and were utilised as foodplants by many species of butterflies.

Habitat association and movement patterns of adult Violet Copper

Field data on habitat association of Violet Copper were collected from different habitat types. During a two-year study period (2004-2005) all observations on the movement patterns of L. helle were made during the month of June, covering a 21 days sampling regime. We investigated the vegetation structure in each habitat type and during a standardised one hour sampling in each habitat, we counted the total number of individuals encountered by the netting method. This amounted to three hours of sampling per day in all the habitat types. During sampling an approximate area of 50 m^2 in each habitat type was covered on foot by two individuals. For the mark-recapture method, one observer marked the individuals and released them at the point of capture. The exact GPS position of all individuals recorded during the mark-release-recapture studies was plotted on a map, in order to get measurement estimates of straight distances moved between the subsequent captures.

RESULTS

Habitat association of adult Violet Copper

Our findings indicated that the Violet Copper (*L. helle*) was found in almost all habitat types (ANOVA; F (6, 10) = 1, 04; p<0.4) of West Khentey (Table 1).

This species was predominantly found in wet mesophile grasslands and herb meadows. Its occurrence in the riparian woodlands, birch forests of the valley and mixed forests of *L. sibirica* und *B. platyphylla* were comparatively lower, while occurrence in the mountain dry steppes was almost negligible

Mark-release-recapture

Overall 392 individuals of *L. helle* were marked during the mark-recapture study, of which 205 were females and 187 were males. Of these, 84 individuals (21%) were re-captured at least once within a period of 20 days. 26% of males and 17% of females were recaptured at least once (Table 2). The maximum time interval between mark and recapture was 18 days for males and 13 days for females.

The recapture rate of males was comparatively higher than that of the females. 24.5% of total recaptured individuals were encountered three times, 4.6% more than 4 times.

Movement patterns of adult Violet copper

Recapture results showed great differences between mean distances moved by males and females (ANOVA; F (1.89) = 13.50; p<0.001) (Table 3). The mean distance between first and subsequent recaptures were greater for both sexes (107 ± 76 and 44 ± 41 meters for females and males respectively) than reported in other studies (Fischer et.al., 1999). 42.5% of the *L. helle* individuals moved linear distances which were less than 40 m, 22% of the individuals moved less than 100 m and 35.5% of the

Table 3. The mean distance moved by Lycaena helle in different habitat types of West Khentey.

Mobility parameters	Male	Female	Total
Mean distance between first and subsequent recapture	44 ± 41	107 ± 70	79 ± 711
Mean distance ± SD (m)	59 ± 41	181 ± 74	09 ± 83
Mean distance ± SD (m) between two marginal points for multiple recaptures	63 ± 33	211 ± 54	116 ± 83
Mean distance between first and last recaptures ± SD (m)	53 ± 32	144 ± 69	92 ± 68
Maximum distance (m)	163	386	386

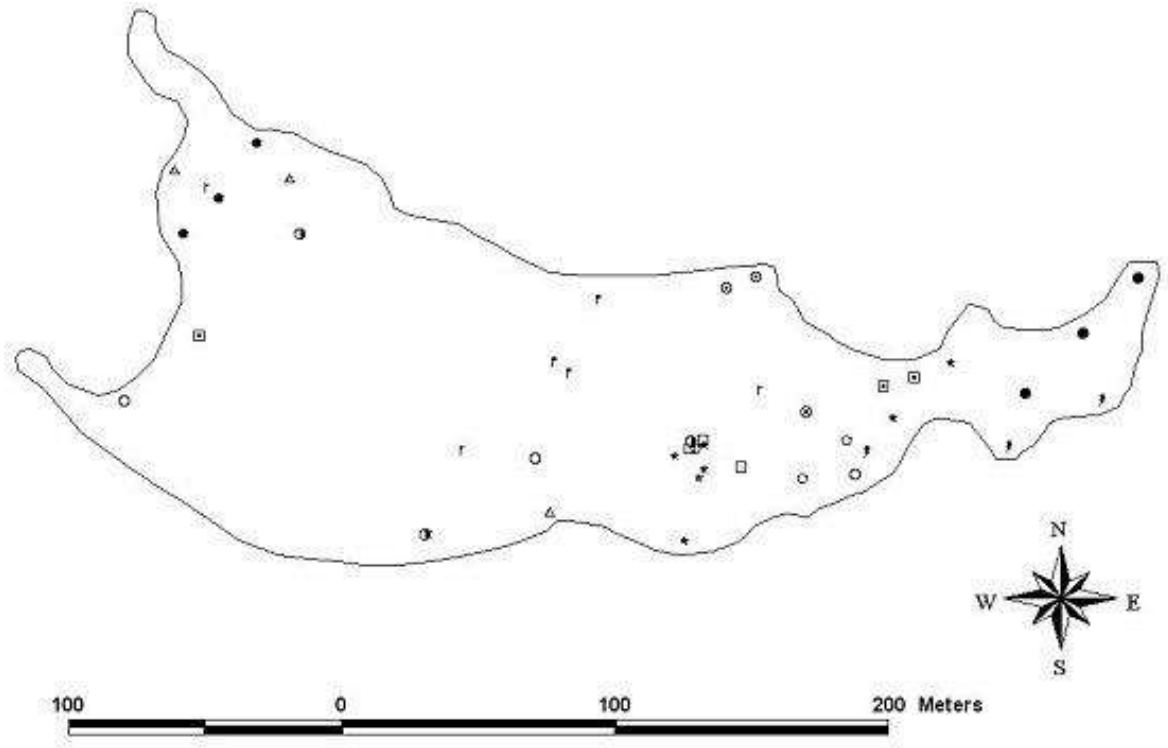

Figure 2. Movement patterns of Violet Copper (*L. helle)*, using data collected from individuals observed at least three times. Symbols indicate the position of each individual captured and same symbols show the movement positions of an individual.

individuals moved less than 200 m. The single largest movement between recaptures was 386 m for females and 163 m for males. Mean distances moved between recaptures were significantly different for both sexes (for male 44 ± 41 m, female 181 ± 74 m; ANOVA, F (1, 82) =92.63; p<0.001) (Table 3). In the case of multiple recaptures, if we connected the two marginal points covered by each individual, the average restricted movement was significantly different for both sexes (ANOVA; F (1.26) = 83.16; p<0.001). Most of the marked adults were recaptured from very near to their points of release (Figure 2).

Out of the 84 individuals recaptured at least once, six were recaptured maximum number of times within 0.9 ha area and 12 were recaptured at least three times within a 0.2 ha area in which they were marked. For example, the individuals marked by the symbol ( ) were recaptured two times after the first release, but the area covered by this individual was 0.19 ha.

Habitat characteristics

The observations on the movement patterns of *L. helle* were made during June 2004 at study sites which comprised of grassland with two different plant communities of herb meadow (e.g. *Iris sanguinea* and *Alopecurus arundinaceus* community) and *Carex*-rich wet grassland (boggy area). Shrub layer contained *Salix* and *Padus asiatica* shrubs (Dulamsuren, 2004). This site was dominated by such species like *I. sanguinea* , *Carex arnellii*, *Equisetum arvense*, *Galium* sp. The site also had such plant species which were blooming earlier in the spring, such as, *Anemone crinita*, *Ranunculus japonicus*,

Table 4. Percentage of visits of the Lycaena helle to different plant species in the study sites of West Khentey.

Plants	Female (%)	Male (%)	Total %
Anemone crinita	20	14	18
Polygonum viviparum	16	14	16
Callianthemum isophoides	13	8	12
Filipendula palmata	10	11	11
Ranunculus acer	8	13	9
Thalictrum sp.	6	6	6
Iris sanguinea	3	13	6
Carex	4	2	4
Spiraea salicifolia	4	2	3
Rosa acicularis	2	6	3
Galium boreale	4		3
Rumex acetosella	2	2	2
Spiraea media	1	5	2
Trollius asiaticus	2	2	2
Rumex acetosa	1		1
Galium verum	1		0.4
Phlomis tuberosa	1		0.4
Potentilla anserina	1		0.4
Rheum undulatum	1		0.4
Sanguisorba officinalis		2	0.4
Vicia unijuga		2	0.4

Trollius asiaticus , *Callianthemum isophoides* (Gantigmaa, 2005). The total number of observed visits of L. helle to flowers was 455 during the mark- release-recapture study. *L. helle* visited in total 21 plant species (Table 4). Our observations revealed that females and males visited as many as 19 and 15 plant species, respectively and also fed on the nectar of 7 plant species, most preferably two species with white flowers: *A. crinita* (18% of all visits), *C. isophoides* (12%) and *Thalictrum* sp. (6%) (Table 4). During the last part of the flight period, they also visited plants with yellow flowers (more frequently *R. japonicus*). Although, both the sexes of *L. helle* were observed to more frequently visit *P. viviparum* and *F. palmate*, both these plant species were less abundant in the study sites.

DISCUSSION

L. helle prefers wet mesophile grasslands, moist clearings in forest and along streams, springs and bogs with an abundance of its food plants (Van Swaay and Warren 1999). However in our study in West Khentey, we found this species predominantly in wet mesophile grasslands and herb meadows although it was also observed flying in the riparian woodland, birch forests of the valley and mixed forests of *L. sibirica* and *B. platyphylla*. Its occurrence in the mountain dry steppes and meadow steppes was relatively low. During our field studies, we made a close observation on the foraging behaviour of the adult butterflies and the plant species they visited. Although there is lack of sufficient knowledge about the foodplants of *L. helle* from Mongolia, *Polygonium bistorta* and *Polygonium viviparum* have been reported as larval foodplants in Europe (Van Swaay and Warren, 1999). We found the males to be more active than the females and they also showed a tendency to persist for a longer time period in a habitat patch as compared to the females. Our results also revealed a higher recapture rate for the male butterflies. Our results which also showed a higher number of individuals encountered in the wet grasslands and herb meadows clearly defined the strong habitat association of *L. helle* with open natural landscape.

However, in our study we found that the mean distances between the first and subsequent recaptures of *L. helle* was higher as compared to previous studies, in Central Europe (Fischer et al., 1999). When compared with the mean recapture distance of another species, scarce copper (*Lycaena virgaureae*) the mean distance between first and subsequent recapture values were found to be lower (Schneider et al., 2003; Gantigmaa, 2005). The mean distances between first and last re-captures were shorter than the mean average distances. These observations could be interpreted in defining the territorial behaviour of this species (Schurian and Fiedler, 1996; Fiedler, 1999). So while in open habitats, butterfly individuals could actually fly over large distances in search of food resources, in our study we found that in the

natural habitats of West Khentej where the plant diversity was high and there was also an abundance of food resources, the butterflies did not actually have to fly over large distances as unlike in fragmented landscapes (Schneider et al., 2003).

The vast nature reserves and wildernesses in the West Khentey forest steppe ecosystem supports a full complement of native vegetation (Dulamsuren, 2004) and butterfly fauna (Gantigmaa, 2005) in North Mongolia. The forest steppe ecosystem of West Khentey region includes a natural forest-swamp mosaic and has the most ideal conditions for supporting native species. The mosaic structure of this natural landscape also fulfills the habitat requirements of *L. helle*. In previous studies this species has been reported to be restricted to sheltered locations in the vicinity of scrubs and trees (Fiedler, 1999) instead of moist meadows (Van Swaay and Warren, 1999). The West Khentej region offers an unique opportunity to study the role of abiotic factors such as climate and soils, with disturbances generated by occurrence of wildfires in driving the patterns of biodiversity within an otherwise "no human impact natural system". The natural vegetation patterns and prevailing abiotic conditions forming a very dynamic habitat mosaic have created the most suitable environment for the coexistence of many species of butterflies along with other native fauna within this system. More in-depth investigations are necessary to access the influence of the abiotic factors on the vegetation structure which could be crucial in determining the overall butterfly species diversity and richness.

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