Butterfly communities in the natural landscape of West Khentej, northern Mongolia: diversity and conservation value

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1. INTRODUCTION

The butterflies are among the best known insects of the world and estimated 90% of the world's species have scientific names (Robbins, 1996). Although Robbins noted that there are about 17,500 species of true butterflies (plus skippers) known on earth, butterflies comprise only 10 per cent of the insect order Lepidoptera (New 1997b).

Recent environment conditions of butterfly communities in Europe are overall affected by rapid economic development of the twentieth century. For example, the farming landscape has undergone profound changes with recent losses of many hedges that were planted over the past two hundred years (Pollard et al.,1995).

In European conditions the main threats reported come from agricultural improvements which affect 90% of threatened species, building developments (affecting 83%), increasing use of herbicides and pesticides (affecting 80%), and abandonment of agricultural land and changing habitat management (65%). The widespread loss and reduction in size of breeding habitats is affecting 83% of threatened species (van Swaay & Warren, 1999).

A wide range of human activities results in degradation of biotopes and loss of suitable habitats. Afforestation, peat extraction and management to improve the quality of cattle grazing (such as drainage, burning and chemical treatment) are main factors in Central Europe (Kudrna, 1986). Loss of habitats such as unimproved grasslands and wetlands has been particularly dramatic and has led to major declines of Lepidoptera in every European country (Kudrna 1986; van Swaay and Warren, 1999; Pollard & Eversham, 1995; Dolek & Geyer, 1997; Balmer & Erhardt, 2000; Ricketts et al., 2001; Rodriguez, 1994).

Most previous studies on butterfly ecology have stressed the declining patch occupancy and the increasing threat to survival due to progressive habitat fragmentation. In addition, the extinction risk increased significantly with decreasing heterozygosity (Saccheri, et al., 1998) and extinction risk followed the widespread destruction of the habitat (Pullin, 1997). In the UK the loss of flower-rich lowland grassland exceeds 97%, and 50% of broad-leaved woodland and 40% heathland within the last 50 years. That landscape alteration results in declining of many butterfly species. A recent review has shown that five of Britain's 59 resident species are now extinct (Warren et al., 1997).

Other recent studies on butterfly ecology have shown that habitat loss and increasing isolation of the remaining habitat patches (habitat fragmentation) are main causes of population decline

in many groups of butterflies (Caughley, 1994; Saccheri et al., 1998; Hanski & Ovaskainen, 2000; Cowley et al., 2000; Schmitt & Hewitt, 2004; Kudrna, 1986; Thomas, 1995).
Many ecosystems of high conservation interest are man-made and dependent on traditional types of land-use (Dolek & Geyer, 1997; Balmer & Erhardt, 2000; Sutherland, 1998), including grassland biotopes, generally considered to have the highest conservation value, for example in Sweden (Schneider, 2003). These ecosystems are becoming increasingly rare in Central Europe (van Swaay & Warren, 1999).

Butterflies are good indicators of habitat quality as they respond rapidly to modification of vegetation. Many autors documented the influence of landscape patterns on butterfly community (Schneider, 2003; Natuhara et al., 1999; Saarinen, 2002; Dover & Davies, 1997; Schneider & Fry, 2001; Pullin, 1997; Rodriguez et al., 1994; Summerville et al., 2003; Summerville & Thomas, 2004). Sparks (1995) found an influence of the floral composition on butterfly diversity. Söderström et al. (2001) resulted 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 landscapes are the most important predictors that influence the population and community ecology of species (Hunter, 2002; Tews et al., 2004; Rodriguez, 1994; Pullin, 1997; Root, 1972; Ehrlich & Murphy, 1987; Dennis & Eales, 1997). Hill et al. (2001) showed that the habitat availability was an important determinant of expansion rates. Saarinen (2002) concluded that the occurrence of many butterfly species is determined by the floral composition of the field verges, in particular the abundance of larval host plants and adult nectar plants.

In opposite to such features in Europe maintains Mongolia, a country in the heart of central Asia, still intact ecosystems in all region. Mongolia is landlocked and a relatively unbroken area “between Siberia and China”, but on the same latitudes as parts of central Europe and northern United States. The Mongolian territory includes several natural zones like taiga forest, mountain forest steppe, steppe and desert. Mongolia "has a chance to avoid the mistakes of other countries by integrating nature conservation with sustainable development" (MNE, 1996).
But there are also some environmental problems in the country. In Mongolia, most damage in the steppe zone is caused by livestock grazing on grass cover, while in forests most damage is caused by the increase of fire frequency (Gunin et al., 1999). Industrial forest harvest in

Mongolia affects only small areas, but felling for local consumption is prevalent in some regions (Gunin et al., 1999).
Mongolia's forest lands occur mainly in the northern part of the country. About 5 per cent of the country belong to the forest zone including the southern edge of the largest continuous forest system on earth, the Siberian taiga (MNE, 1996).

Butterfly study in Mongolia.

At the beginning of 1960s the first fundamental survey on the insect fauna of Mongolian country has started. The joint Mongolian – Polish, Mongolian Hungarian and Soviet (Russian) – Mongolian Complex Biological Expeditions gathered several thousands of insect specimens across the whole territory of Mongolia. For instance, Russian and Mongolian scientists participated in the Joint Expedition annually with specialists in botany, zoology, climatology, geomorphology, soil sciences, and paleogeography and created for the first time systematic lists of Mongolian insect fauna during the years of the expedition' activity (Ulikpan 2003). The research conducted between 1963-1966 revealed 175 species of Lepidoptera belonging to 22 families (Monkhbayar, 1999).

The known Mongolian butterfly fauna comprises 253 species (Korshunov et al., 1995; Tuzov, 1997; 2000; Mühlenberg et al., 2003). However given the description of new species on the southern side of the Mongolian Altai (Churkin & Tuzov 2003) additional species are likely. However species lists of butterflies in southern Siberia are very scarce. Chikolovets (1994) recorded 87 species in the Chita region, adjacent to West Khentej. Butterfly fauna of West Khentej region comprises about 60 % of total Mongolian butterflies (Monkhbayar, 1999; Korshunov & Gorbunov, 1995; Tuzov, 1997; 2000). Appendix 1 provides the English and scientific names of all species in this region.
In southern Transbaikalia and north-eastern Mongolia**,** assemblages of butterfly species are tightly linked with plant communities (Dubatolov and Kosterin 1998). The most probable modern analogue of Middle Holocene broad-leaved forests is the southern taiga forest of East Transbaikalia, which support three species of elms (*Ulmus)* and Mongolian oak (*Quercus mongolica*) and which have a butterfly fauna noticeably enriched with nemoral species (Dubatolov and Kosterin 1998). The butterflies of western Khentej can be classified into four

biogeographic categories: the biggest part constitutes the palearctic group (Mühlenberg et al., 2000a).

The area of this study belongs to the forest steppe zone which is located in the transition area of the taiga and steppe. The West Khentej harbours a rich combination of natural communities with a diverse composition of species. The butterfly fauna of West Khentej region includes the species that are typical for taiga forest, woodland and grassland biotopes and steppes.

This study on West Khentej butterflies was the first investigation of species richness and relative abundance of butterfly species in northern Mongolia. There are few studies to date concerning biodiversity of large natural landscapes in eastern Palearctic. Nevertheless for many regions, especially in western Europe and North America, part of these baseline data are already available, but for many other parts of the world this information is lacking (New, 1998).

The main aim of this study was to investigate the butterfly community in different habitat types in the natural landscape of West Khentej. In opposite to the human dominated landscape in Europe the Khentej represents natural conditions not altered by human activities. By comparison with European conditions we could learn something about human impact on butterfly faunas.

The present study focuses mainly on butterfly diversity and habitat occupancy in the natural landscape of the West Khentej Mountain area in northern Mongolia. Field data are analysed at the community and species level. Community level measures include species richness, abundance, and similarity of samples among the different types of habitats.

The specific objectives of this study are:

- to characterise the butterfly fauna of West Khentej in terms of taxonomic composition and biogeography
- to describe the influence of landscape structure and vegetation on butterfly community by comparing habitat occupancy of West Khentej butterfly fauna in four different habitat types
- to assess the habitat factors that influence butterfly diversity in natural landscape by comparing different grassland habitats
- to assess the importance of the study region to the conservation of butterflies

2. STUDY AREA

Northern Mongolia's floral richness must be interpreted by its location in northern and central Asia, and at the national level by the rich floras of the mountain systems of Mongolian Altai, Khangai and Khentej. Considering the largest flowering plant families, the flora of Mongolia combines features of boreal and ancient Mediterranean floras, i.e., high status of *Rosaceae, Cyperaceae and Ranunclaceae* as pronounced boreal families and *Leguminoseae, Cruciferae* and *Chenopodiaceae* as more Mediterranean families (Gunin, et al., 1999).

Northern boreal forest, the "taiga" is one of the largest biomes on earth (Helle & Niemi, 1996). The northern margins of this boreal forests border the tundra or arctic vegetation and the southern edges meet temperate deciduous forests or in Mongolia go straight into steppe vegetation.

The general physical structure of North American and Eurasian boreal forest is very similar: the canopy is usually one layered and consists of only few dominant tree species; the shrub layer is usually sparse and the number of dominant conifer species is highest in Eastern Siberia and lowest in Northern Europe (Helle and Niemi, 1996). More than 70 % of the global boreal forest cover is in Eurasia, mainly in the Russian Federation, and represent the largest unbroken forest area of the globe, the remainder is in Canada and Alaska, and relatively small areas of boreal forests are found in the North East of China and in the Fennoscandia (Goldammer and Furyaev, 1996). In Mongolia plant community diversity and endemic types and subtypes of vegetation remain fairly high and it includes 140 endemic species, and even more subendemics (Gunin, et al., 1999). Southern areas of Siberian region are located on territory of Mongolia and it comprises the high mountainous areas of northern Mongolia, the basin of lake Khubsgul, Orkhon-Selenge, Khentej Mountain. The Khentej and Khubsgul belong to high mountain region and are covered with boreal taiga forests. This region is the most coldest region in Mongolia and almost northern half of Mongolia is occupied with continuous and isolated regions of permafrost (Gantsetseg & Sharkhuu, 2002).

The **Khan Khentej province** is situated in northern Mongolia (Fig. 1) and covers about 48,000 km^2, parts of which remain unexplored. It still contains relatively intact examples of steppe, forest and grasslands and the wild creatures and plants that inhabit them. The West Khentej is part of the Khan Khentej mountain range. The Khentej is located in northern Mongolia bordering Russia, and is still covered in large parts with primary boreal forest. The

pristine nature of this region is maintained because much of it is devoid of human settlements, and 3,000 km² Terelj National park of the 48,000 km² in the Khentej Mountains and 12,000 km² has been protected as Strictly Protected Area since 1992.

The West Khentej region is located in the upper "Eroo" River valley, and covers about 100 km^2 at about 1000 m a.s.l ($107^0 13^I$ - $107^0 36^I$ E, $49^0 12^I$ - $49^0 36^I$ N) (Fig. 1).

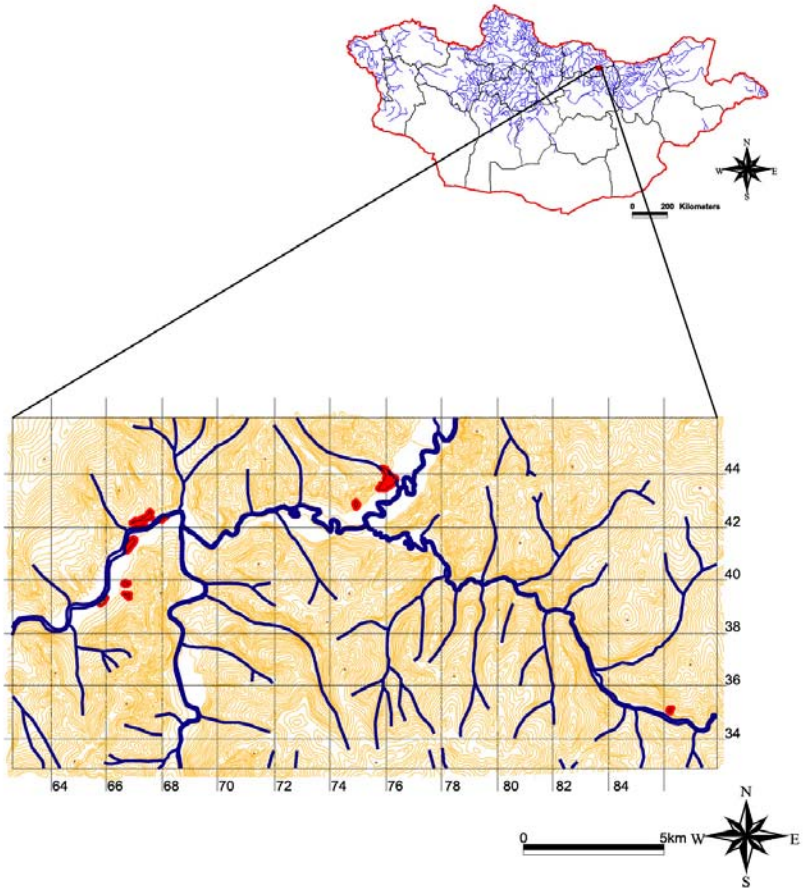

Figure 1. Location of the study area in Mongolia. The Khentej is the southern extension of the Siberian taiga system. This region consists of a high mountain belt, a forest belt, and forest-steppe and meadow steppe. The red points indicate the location of study plots in West Khentej.

Mean annual temperature in West Khentej is 0.7^0C. Mean maximum monthly temperatures range from -22.1^0C in January to 19^0C in July. Temperature extremes are 36.4^0C in June and --40.1^0C in January. Mean annual precipitation in the Khentej 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. The mean wind velocity is 1-3 m sec^{-1} and a gentle breeze is

observed throughout the year. Winds come mostly from the north, especially in spring and fall. In winter the direction changes slightly to winds coming from the northwest (Velsen-Zerweck 2002).

The Khentej Mountains rise up to about 2500 m.a.s.l. The West Khentej 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 (Velsen-Zerweck 2002). Ecologically this geographical zone is recently characterised by its high biodiversity of vascular plants (Dulansuren, 2004).

2.1 Climate

Given the significant influence of climatic conditions on the activity of adult butterflies (Pearson & Carroll 1998; Gutierrez & Menendez 1998; Kerr 2001; Choi 2003; Beaumont & Huehes 2002; Dover et al., 1997) data on ambient temperature, precipitation and humidity over the study period at the Bugant meteorological station were examined (Appendix 5). This station is nearest to the study area, and is located at the forest margin of the West Khentej.

The mean temperature in the extreme months is 36.4^{0}C in June and -40.1^{0}C in January (Velsen-Zerweck 2002). The atmospheric humidity ranges between c. 60 and 70% during the relatively rainy summer, and even in winter (when average temperatures fell below 0 ^{0}C), humidity ranges between c. 60 and 70% (Velsen-Zerweck 2002).

2.2 Vegetation types

The West Khentej belongs to the Euroasiatic-Boreal-Forest region, subregion of the East Siberian *Larix-Pinus silvestris* forest, province of Khentej mountain taiga (National Atlas of Mongolia 1990). The forest area in West Khentej region shows only on some patches climax coniferous forests, becuse fire causes mixed forest of variable successional stages, so that boreal coniferous forests are of high structural diversity and spatial heterogeneity, due to the natural disturbances (Gunin *et al.*, 1999; Goldammer & Furyaer 1996). In this region, boreal forests cover more than 75% of the area and less than 15% contains grassland communities (Batchuluun et al., 2003) (Figure 2).

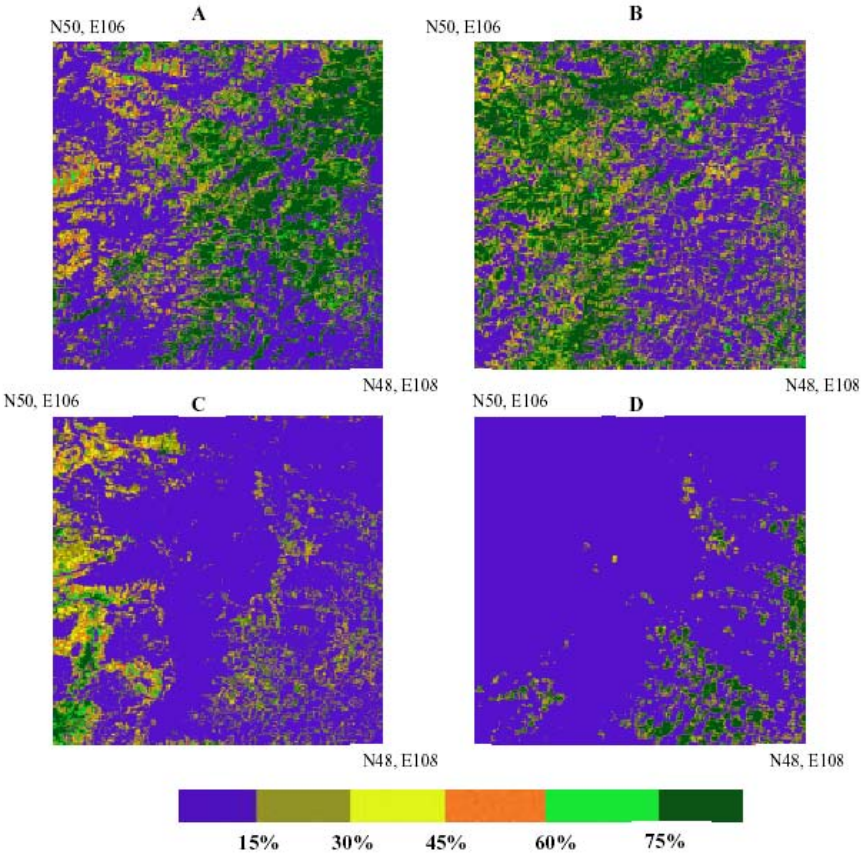

Figure 2. Fraction image of Selenge region derived from MODUS data acquired on 25 August 2000 for components A=pine, B=larch, C=grassland and D=cloud obtained by linear mixing model. Boreal coniferous forest and its transition to steppe in Northern Mongolia. The largest concentration of Siberian pine forest is recorded in central Khangai and Khentej.

River valley separate the hilly terrain characteristic of this region. This natural area 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* shrub and *Salix sp*., open riparian forest with *Larix sibirica and Betula platyphylla* with shrub layer, *Picea obovata* riparian forest, *Populus laurifolia* riparian forest) (Dulamsuren, 2004).

Mühlenberg et al. (2000a) described eight different types of vegetation in the West Khentej: mountain taiga, mountain forest, meadow steppe, mountain dry steppe, shrubland, riparian woodland, herb meadows and wet grasslands. **The mountain taiga** in Khentej ranges from about 1200 to 1600 m a.s.l., and extensive *Pinus sibirica* forest covers the northern, North-West and western slopes. The herbaceous layer is relatively poor in species numbers.

The **mountain forest** (about 800-1200 m a.s.l. in Khentej) consists of *Larix-Betula* forest on the northern and western slopes. *Betula platyphylla- Larix sibirica* secondary forests are rich in undergrowth vegetation: *Calamagrostis obtusata, Vaccinium vitis-idaea, Maianthemum*

bifolium, Fragaria orientalis, Viola uniflora, Artemisia sericea, Atragene sibirica, Bromus pumpellianus, Geranium pseudosibiricum, Aconitum septentrionale, Equisetum sylvaticum, Iris ruthenica, Cacalia hastata, Lathyrus humilis and *Vicia unijuga.* Typical in the shrub stratum are *Rosa acicularis, Spiraea flexuosa* and *Rhododendron dahuricum. Chamaeneron angustifolium* is frequent, occuring in particular in secondary forest after fire or clearcutting. Dry eastern slopes of mountains with relatively shallow soils (<30 cm) are covered with *Pinus silvestris* mixed with *Larix* and *Betula ssp.* In addition to the common plants of the conifer forest, heliophilous species of shrubland and steppe occur such as *Chrysanthemum zawadskii, Silene repens, Melica turczaninovina, Atragalus frigidus, Carex pediformis, Erigeron acer, Dracocephalum nutans, Polygonatum officinalis* and *Galium boreale.*

The vegetation cover of the **meadow steppe** (mesophilus grassland, plot FO3, FO4 in my study) includes heliophilous species of the eastern slopes, completed by *Aster alpinus, Campanula glomerata, Schizonepeta multifida, Koeleria macrantha, Poa attenuata, Stipa sibirica, Thisetum sibiricum, Antennaria dioica, Senecio campester, Scorzonera radiata* and *Lilium pumilum.* The **mountain dry steppe** (plot MDS1, 2, 3, 4) occurs on the southern slope of the mountains and is covered by *Spiraea aquilegifolia, Cotaneaster melanocarpa, Woodsia ilvensis, Thymus dahurica, Veronica incana, Agropyron cristatum, Allium anisopodium, Artemisia communata, Leontopodium leontopodioides and Festuca ovina.* In addition, *Orostachys spinosa, O. malacophylla, Aquilegia viridiflora, Patrinia sibirica, P. rupestris, Amblynotus rupestris, Eritrichium panciflorum* and *Potentilla acaulis* are found on rocky soils.

Shrubland strips are on the lower mountain stratum in the valley. Only few species form the dense shrubs: *Betula fructicosa, Betula fusca, Crataegus sanguinea* and *Salix ssp.* The **riparian woodland** is dominated by the trees *Populus laurifolia, Betula plathyphylla* and *Picea obovata.* The study plots FO1; FO3 are located in open area of this type of woodland. The understorey in the flood plains contains *Padus asiatica, Betula fusca, B. fructicosa, Crataegus sanguinea, Rosa acicularis, Dasiphora fructicosa, Ribes rubrum, Spiraea Salicifolia and Salix ssp.* The **herb meadows** (study plot HM1, 2, 3, 4) are found in the river valley terraces. These mesophilous meadows are covered by different herbaceous plants and include *Filipendula palmata, F. ulmaria, Heracleum dissectum, Achillea alpina, Geum alleppicum, Sanguisorba officinalis, Lilium dahuricum* and *Elymus dahuricus.* The **wet**

grassland is characterised by *Carex meyeriana, C. dichroa, C. enervis, C. caespitosa, C. schmidtii, Ligularia sibirica, Caltha palustris, Halenia corniculata* and *Comarum palustre.*

The **study area** is located in the western buffer zone of the Khan Khentej Strictly Protected Area (Fig.2). It is covered by forests, forest steppe, and grasslands (Foto 2).

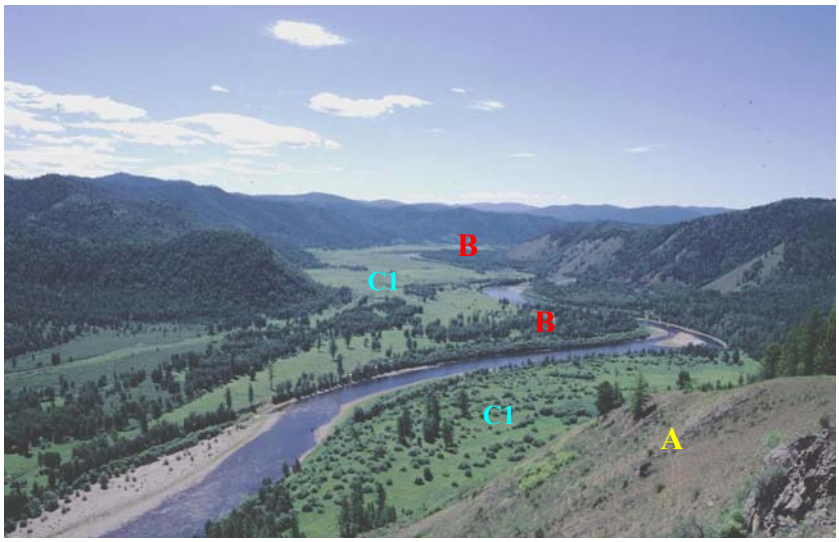

Foto 2. West Khentej. A: Mountain dry steppe on southern slopes; B-Open riparian forest with *Larix sibirica* and *Betula platyphylla.* C1-Grassland with shrubs, C2- Open grassland

Larch (*Larix sibirica)* and birch *(Betula platyphylla)* are dominant trees in West Khentej, but cold resistant taiga elements (*Pinus sibirica, Pinus obovata, Abies sibirica*) are common too. Northern hill slopes are typically covered with forest, whereas southern sun exposed slopes are treeless and covered with grassland vegetation. In valleys, swamp (due to underlying permafrost) is often covered with *Betula fusca* (Velsen-Zerweck 2002, Dulamsuren, 2004).
Typical habitats in West Khentej region are coniferous and deciduous forest with open areas of herbaceous plant meadows and meadow steppes on the terraces in the river valley, and at higher elevations there is a transition to xerophyte herbaceous communities on the southern slopes.
Riparian woodlands and open riparian forest with *Larix sibirica* and *Betula platyphylla* are found in the river valleys. Grasslands exist as hygrophytic vegetation on the river terraces and as xerophytic grassland habitats on the dry southern slopes (Foto 1).

In 1998 a research station in the Khonin Nuga valley was established by the Centre for Nature Conservation of the University of Goettingen, located in the buffer zone of the Strictly Protected Area of Khan Khentej ($49^0$05'260" N; $107^0$17'440" E). The study area is globally

important for biodiversity conservation, due to its large scale natural landscape (Mühlenberg & Samiya 2000).

Field data on the observations of butterflies were collected in different types of vegetation. The information gathered on each habitat type includes the year, the Mongolian uniform 107^0 grid, the counted or estimated number of individuals of species sampled, and the observation time. Because records on species richness and species incidences in quadrats significantly depend on the sampling effort (Dennis et al., 1999; Saarinen et al., 2003), the sample effort was kept constant. Saarinen (2003) described two distinct but interdependent aspects in the structure of butterfly populations**:** (1) population size, i.e. the total number of individuals in the study area and (2) spatial distribution of individuals. Both aspects were considered with samples of this study.

2.3 Study plots

The map of vegetation cover classes provides examples of the distribution of deciduous forest and grassland habitat in West Khentej (Khonin Nuga) region, each with noticeably different spatial structures (Figure 3). The main tree species in this region are larch (*Larix sibirica*) and pine (*Pinus sylvestris*). There are also *Betula platyphylla* and shrubs relatively common. This region has relatively little grassland cover. The grassland areas occur in West Khentej, with scattered areas of trees and on the terrace in the river valley (Batchuluun et al., 2003; Tsolmon, 2003).

Virgin forest-workcamper (2001-2003) described the major forest association of the West Khentej. The forest habitat, which is related to my study plots is represented by larch-birch forest on the river terrace. The upper layer of this forest is presented by single 30-40 m *Larix sibirica* trees. The second layer is formed by birch trees trees (*Betula platyphylla*). The major forest association of forest opening (FO) habitats is *Betula* - *Larix* with dominant species including white Birch *Betula platyphylla* (66%), Siberian Larch *Larix sibirica* (25.6%), Aspen *Populus spp*. (3.8%), Spruces *Picea obovata* (1.3%) and others (e.g. willows *Salix sp*. and bird cherry trees *Padus asiatica*). An extensive description of the forest covers of West Khentej region was given by Mühlenberg et al. (2001).

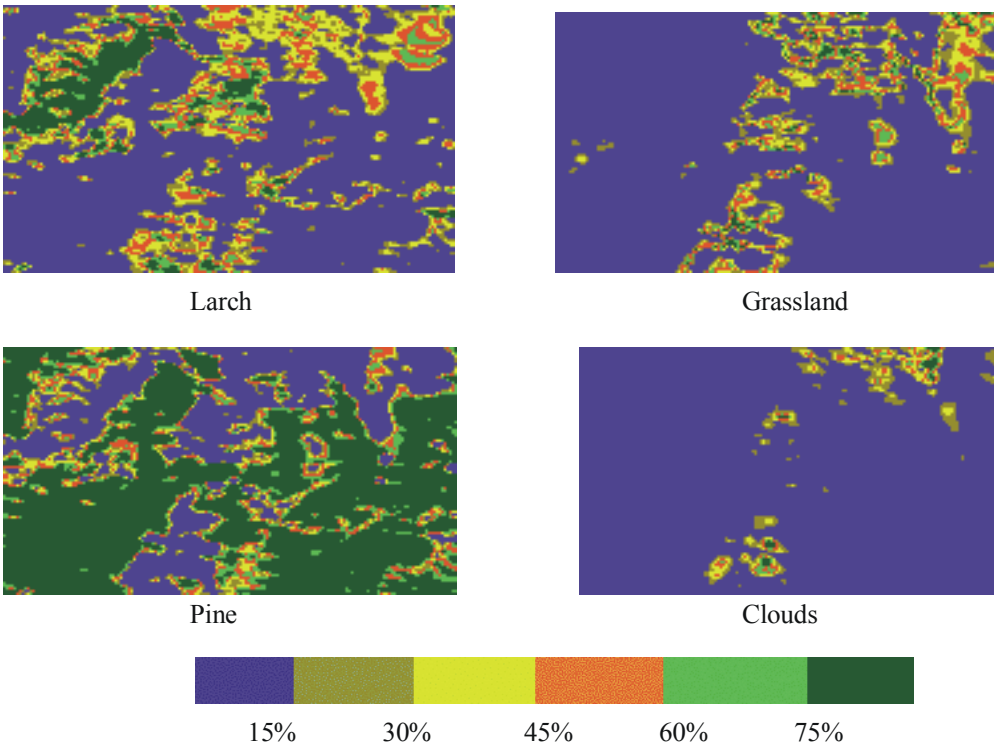

Figure 3. Vegetation cover of West Khan Khentej region ($107^0 13^I$ - $107^0 36^I$ E; $49^0 12^I$ - $49^0 36^I$ N). In this region, boreal coniferous forests cover more than 75% of the area and less than 15% contains grassland communities (Batchuluun et al., 2003; Tsolmon, 2003).

Field data were gathered over four years (2000-2003) during the warmer months of May until August. Three habitats were examined: mountain dry steppe (MDS), forest openings (FO) and herb meadow (HM) (Foto 3). Four plots from each of these habitats were chosen for butterfly community measures as replicates. Plots were separated from each other by distances of 0.5-26 km (Fig. 4). In the years 2000 and 2001 two plots from wet grassland biotope were surveyed in addition. Because herb meadow, mountain dry steppe and forest openings represent most of the community of butterfly species of West Khentej, wet grassland habitat type was excluded in the next two years (2002, 2003). All plots were different in size (Table 1), and ten of them were located on the terraces of river valleys, while the remaining two plots were on the southern slopes of elevated areas.

GPS (Global Positioning System) data were recorded around the perimeter of each plot. The map and area calculations were made using the Software programme ArcView.

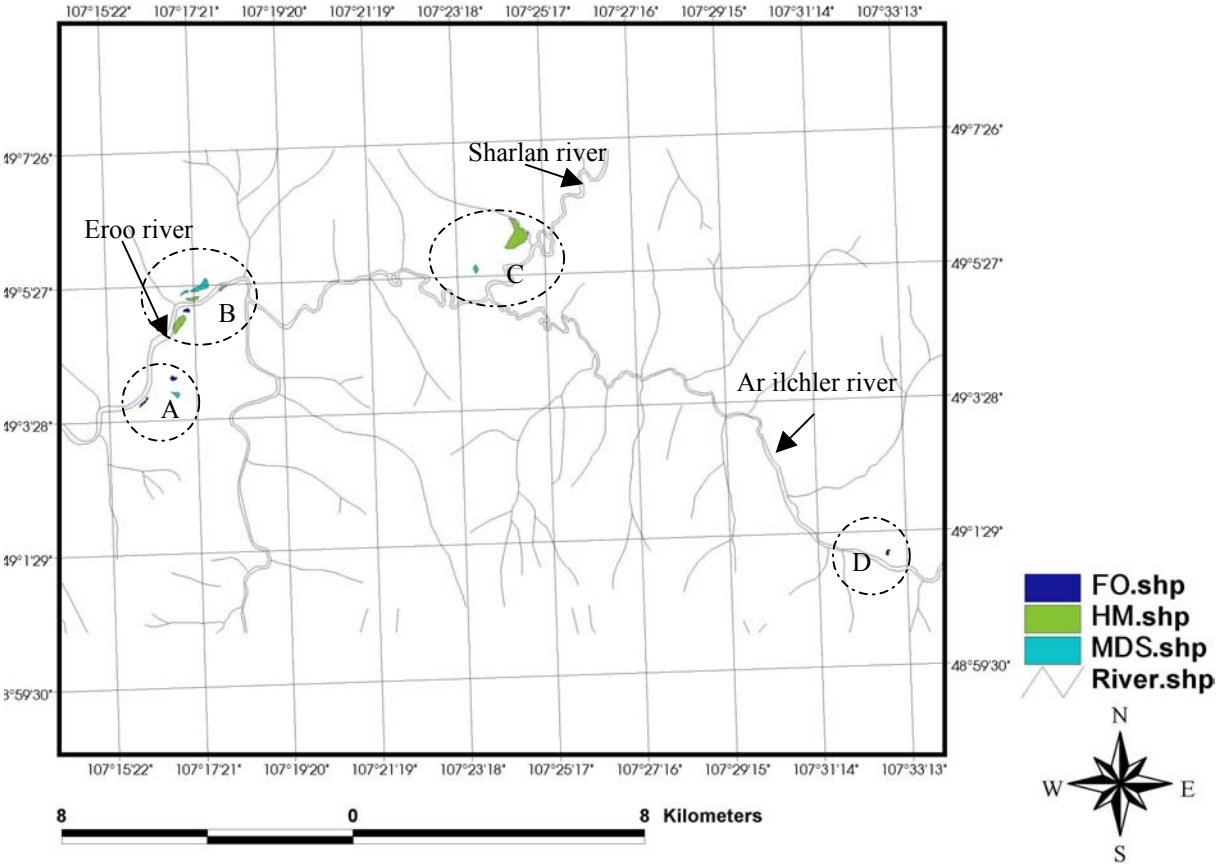

Figure 4. Study plots in West Khentej were divided among four river sections (A-D), plots were within 0.7-28 kmdistance to the Khonin Nuga Field Research Station

Habitat	Locations on the map (Figure 4)	Size of the study plot (ha)
Forest opening (FO1)	Figure 4 A	1.310
Forest opening (FO2)	Figure 4 A	1.472
Forest opening (FO3)	Figure 4 B	1.382
Forest opening (FO4)	Figure 4 D	0.964
Herb meadow (HM1)	Figure 4 B	1.065
Herb meadow (HM2)	Figure 4 B	7.889
Herb meadow (HM3)	Figure 4 B	2.355
Herb meadow (HM4)	Figure 4 C	24.062
Mountain Dry Steppe (MDS1)	Figure 4 C	1.727
Mountain Dry Steppe (MDS2)	Figure 4 A	2.940
Mountain Dry Steppe (MDS3)	Figure 4 B	0.974
Mountain Dry Steppe (MDS4)	Figure 4 B	7.072
Wet Grassland	-	3.100
Wet Grassland (mesophilous)	-	3.780

Table 1. Location of the study sites which are described on the map of the West Khentej region. The area measurement was calculated using the GPS (Global Positioning System) data.

Plots were divided among four river sections (A-D), stretching 28 km from west to east. The **Eroo river** section (Fig. 4A) consisted of three study plots, representing two habitats (forest opening and mountain dry steppe): **FO1** was situated in open riparian forest with *Larix sibirica*, *Betula platyphylla* and shrub layer. **FO2** was an open area with mesophilous grassland surrounded by *Larix sibirica-Betula* forest. **MDS2** (Fig. 4C) was located on the rather steep southern slope.

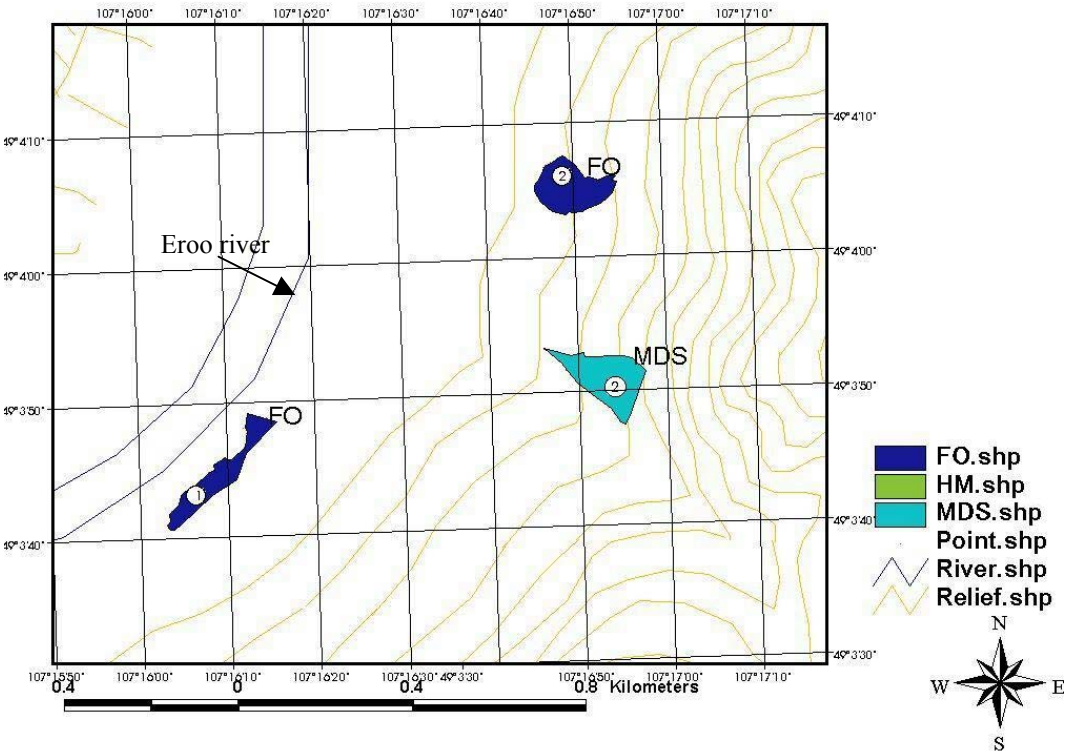

Figure 4A. Section A consists of 3 study plots representing 2 habitats, 4-5 km from research station; MDS2-.Mountain Dry Steppe 2; FO1-Forest Opening 1; FG2-Forest Opening 2.

The second section (Fig. 4B) along the Eroo River had six study plots, representing all three habitats, all situated within 5 km of the Research Station. The landscape in this river section was extremely mixed, including herb meadow, mesophilous grassland, and areas with shrubs (*Padus asiatica, Salix spp*) on the terrace of the Eroo river. The sole forest opening plot (**FO3**) is located in open riparian forest of mainly *Larix sibirica* and *Betula platyphylla*, with some *Populus tremula*, *Picea obovata and Salix platyphylla*. This plot also contained a shrub layer comprising *Padus asiatica* and *Crataegus sp.*

Of the three herb meadow plots, **HM2** was relatively large, whereas **HM1** was a small area surrounded by *Betula platyphylla*. **HM3** was bordered by the river to the south, to the west and east by *Salix* shrubs and to the north by MDS3 and MDS4. The two remaining plots in this river section were mountain dry steppes (**MDS3-4**) on eastern slope.

The third section, located along the Sharlan River (Fig. 4C) contained only two plots: **HM4** was a large open area on the terrace of the river, while **MDS1** was located on the southern slope of a mountain, adjacent to mesophilous wet grassland (WG mesophilous) (Fig. 4C).

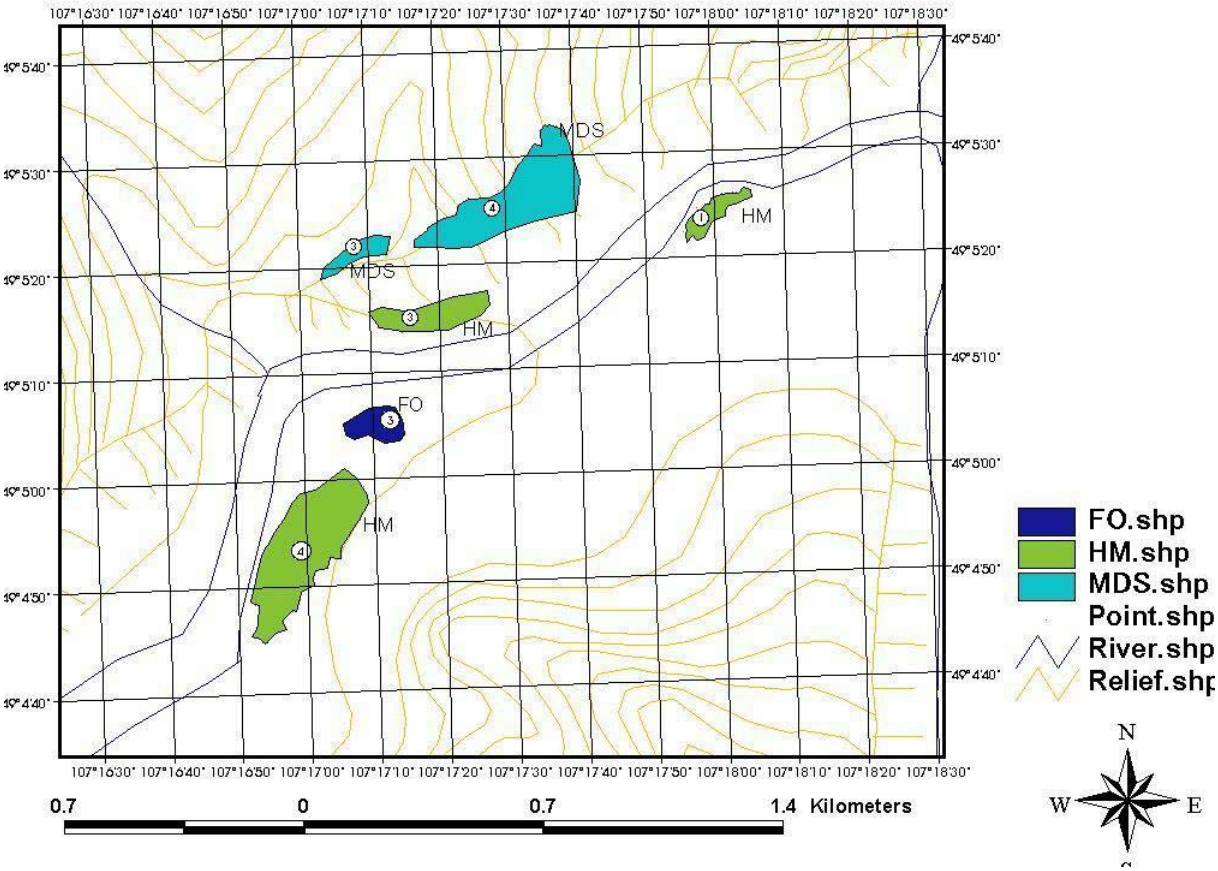

Figure 4B. Section B is the centre site of the study which has 6 study plots of 3 habitats; MDS3- Mountain Dry Steppe 3; MDS4- Mountain Dry Steppe 4; HM1- Herb Meadow 1;HM3- Herb Meadow 3; HM4- Herb Meadow 4; FO3- Forest Opening 3.

The fourth section (Fig. 4D) contained only one plot which was surrounded by *Betula* and *Larix* forest (FO4). The ground layer of this plot was mesophilous grassland (Foto 4).

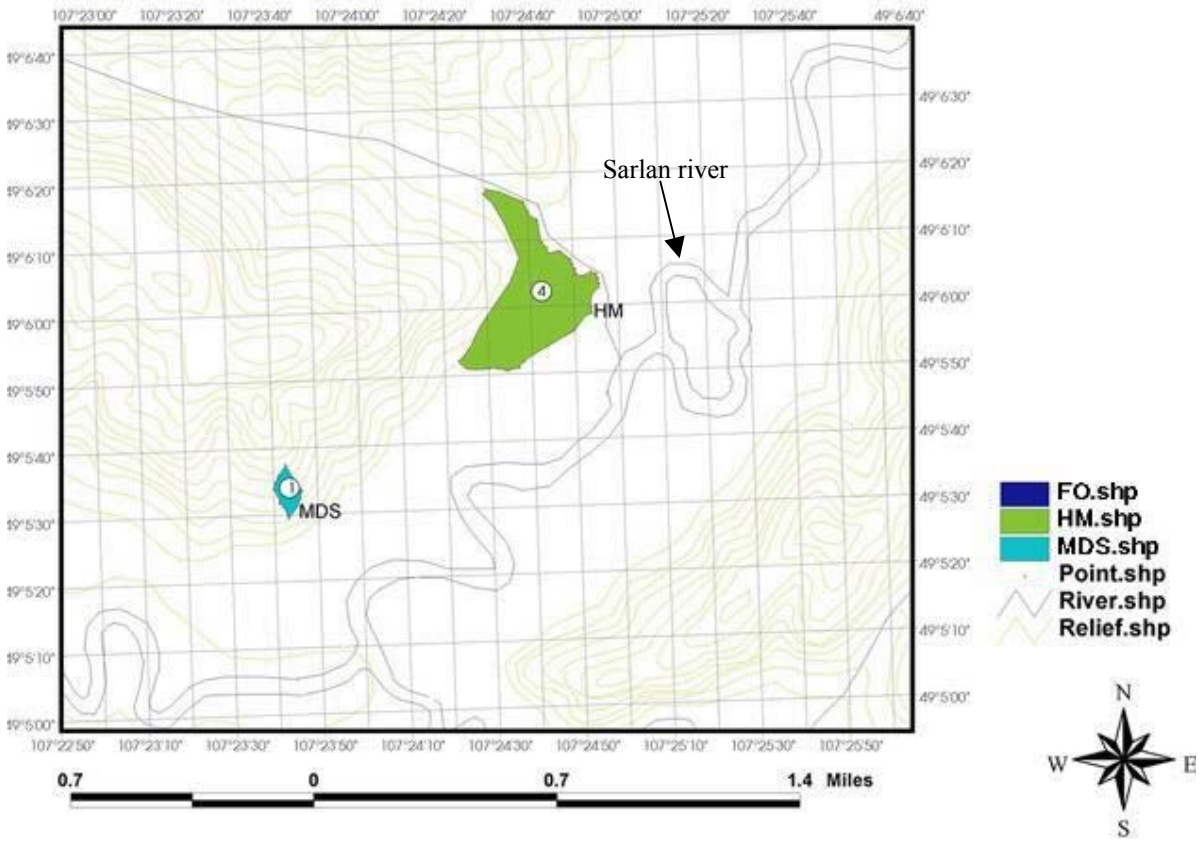

Figure 4C. Section C has 2 plots of different habitats which are situated about 13 km from the research station. Plot: MDS1- Mountain Dry Steppe 1;

Foto 3. Herb Meadow

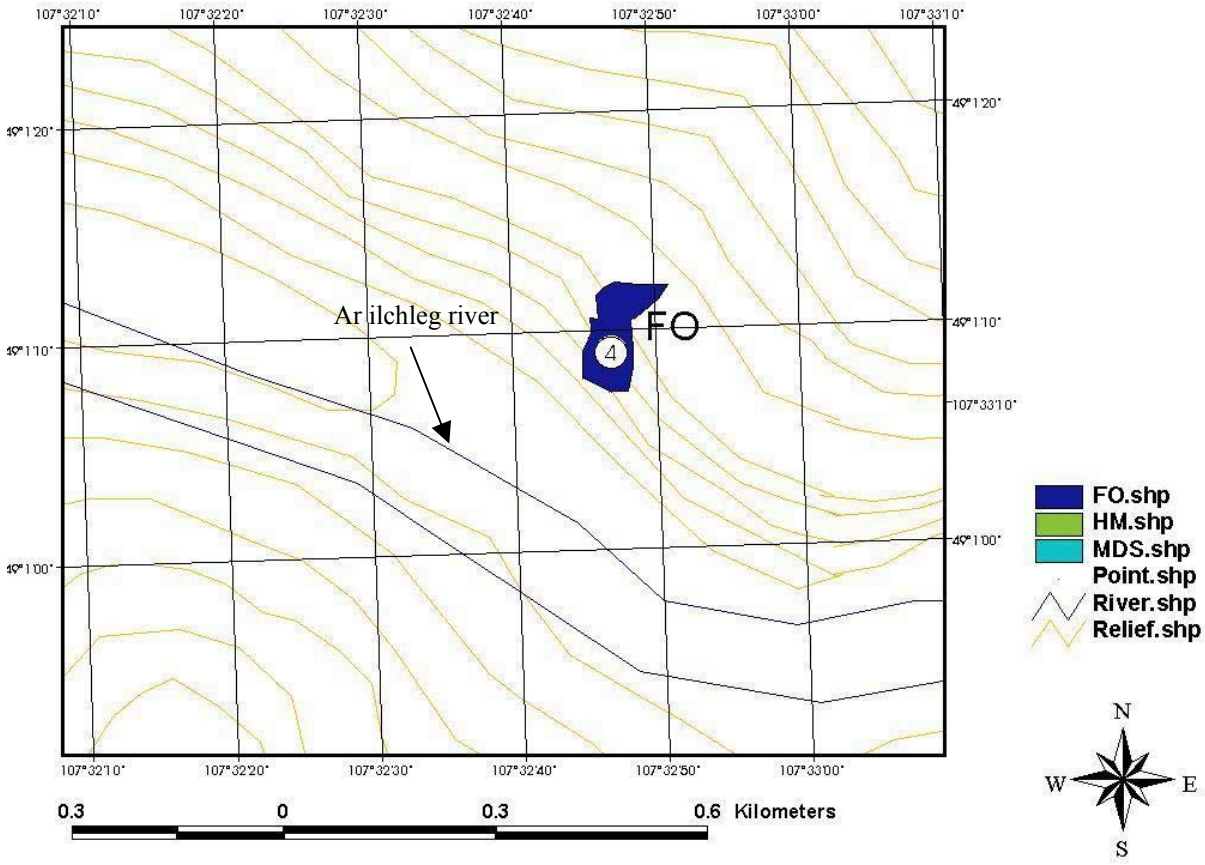

Figure 4D. Section D occurs 26 km from the centre of study which has a Forest Opening (FO4).

Foto 4. Forest Opening. Mesophilous grassland cover under canopy.

3. Methods

3.1 Standardised catch

Each of the 12 plots were sampled twice every month from May to August. The netting method was used for collecting butterflies during a standardised 1 hour sample. For each plots, the specimens obtained were killed in killing bottles containing chloroform wetted cotton balls and individually kept in a glassine envelope with all pertinent data written on the envelope. The total sampling effort over four years was 164 catch hours (Table 2).

Habitat	Years				Total
	2000	2001	2002	2003	
Forest 0pening (FO)	20		13	14	47
Herb meadow (HM)	7	8	17	17	49
Mountain dry steppe (MDS)	7	7	15	13	42
Wet grassland (WG)	13	13			26
Total sample size (hour)	47	28	45	44	164

Table 2. The total number of samples at the different habitat types. Herbaceous plant species were analysed in two habitat types.

Species density estimates were obtained using the butterfly transect method (Pollard, 1977). This involved counting the numbers of each specimen seen in each plot in suitable weather for butterfly activity. For comparisons between habitats, data were standardised for the 100 hour caught at each study plot (Appendix 2). Trends in the survey were evaluated per 100 catch hours. Species which encountered a total abundance exceeding 100 individuals were described as "dominant species".

3.2 Herbaceous plant analysis

To determine the floristic heterogeneity of plots and to distinguish between plots considering the vegetation and to correlate floristic characteristics with butterfly community structure, I recorded the species richness and abundance of vascular plants in 3-5 randomly-chosen sub-plots of 1m x 1 m in each plot of two habitat types (HM, MDS). Species composition was determined using the quadrat sampling method (Kent and Coker 1992). The purpose of using a quadrat was to enable comparable samples to be obtained from areas of consistent size. Therefore, quadrat sampling usually attempts to define plant community characteristics for an

area much larger than the actual area sampled. Usually, a rectangular quadrat frame, such as 1m x 1m quadrats would be suggested for short grassland. This method involved counting all individuals of each species within the sub-plot. Sampling was conducted in 2003, and data were collected by botanists Ouyntsetseg and Tungalag (Botanical Department, Mongolian State University). The relationship between the number of plant species and number of individuals in those species was examined using lognormal and logserie programmes.

3.3 Species identification

All specimens of butterflies captured during the study were transported to Germany, and identified at the Centre for Nature Conservation, Göttingen. Butterflies were determined to the species level using the references of D'Abrera (1990, 1992, and 1993), Settele et al. (1999), Tuzov (1997; 2000), Korschunov (2002) and Tshikolovets (2002*)*. Identifications were verified by Balint Zsolt, curator of butterflies at the Hungarian Natural History Museum in Budapest, Department of Zoology. Herbaceous plants were identified using Grubov (1982).

3.4 Food plants

Bernay and Chapman (1994) showed that a continuous spectrum exists between insect species that feed on one plant species only, and others that feed on a very wide range of plants from many different families. The host-plant specificity of butterflies of West Khentej were classified as: monophagous (feeding on one plant species only), oligophagous (butterflies feeding on a number of plants within one plant family), strongly oligophagous (insects feeding on a number of plants within one plant genus) or polyphagous. Polyphagous refers to insects feeding on a large number of plants from several families (Ebert et al., 1991). Polyphagous insects do not eat every plant they encounter (Bernay and Chapman, 1994), in my data, the term "polyphagous" included the butterflies that feed on plants from more than one family. Therefore, guilds of butterflies in respect to food plants were classified as tree feeders, herb feeders, grass feeders (in particular, plants from the grass family (Poaceae) and bracken-bush feeders.

3.5 Geographic distribution and habitat selection

The biogeographical distribution of each butterfly species recorded in West Khentej was classified into one of four biogeographic regions or subregions, based on Tuzov (1997, 2000) and D' Abrera (1990, 1992, 1993): (1) the Palearctic region, including Europe, North Africa, Asia Minor, the Himalayas and northern Asia; (2) the Holarctic, including the Palearctic and Nearctic (North America) regions; (3) Central Asia subregion: Tajikistan, Uzbekistan, Turkmenistan, Mongolia; and (4) East Asian subregion: East Siberia, Korea, Japan and eastern part of China.

3.6 Calculation of community parameters

The computer programme EstimateS 6 (version 6.ob 1a, Colwell, 2000) was applied to calculate butterfly diversity in each plot. The programme computes the following richness estimators and species diversity indices: observed number of species in sample (Sobs) and its standard deviation (Sobs_SD), observed number of individuals (Individuals) and its standard deviation (Individuals_SD), Fisher's alpha (alpha), Shannon and Simpson (1/D) diversity index (Magurran, 1988), Abundance-based Coverage Estimator of species richness (ACE), Incidence- based Coverage Estimator of species richness (ICE), and Chao1 richness estimator. Diversity indices assume that the probability of two successively sampled individuals belonging to the same species is dependent only on the relative abundance of species within the community (Magurran, 1988).

Fisher's alpha describes the diversity of species within a community or habitat and is obtained from the following equation (Magurran, 1988):

$$\alpha = \frac{N(1-x)}{x}$$

where x is estimated from the iterative solution of

$$S/N = [(1-x)] / x[-\ln(1-x)]$$

where N = the total numbers of individuals, S = total numbers of species. The only disadvantage of α is that the index is based purely on S (species richness) (Magurran, 1988). It does not take into account the relative abundance of the species. The index has a good discriminating ability, is less sensitive to the sample size and less affected by the abundance of the commonest species than either the Shannon or Simpson index.

The **Shannon diversity index** assumes that individuals of each species are randomly sampled from an effectively infinite population. It is calculated from the following equation:

$$H' = - \sum p_i \ln p_i$$

The quantity p_i is the proportion of individuals belonging to the *i*th species. Shannon's index takes into account the evenness of the abundances of species. It is also possible to calculate a separate measure of Evenness:

$$E = H' / H_{max} = H' / \ln S$$

As with H' this evenness measure assumes that all species in the community are accounted for in the sample, and H_{max} is the maximum diversity (when all species are equally abundant).

Simpson's index (D) is referred to a dominance measure because it is weighted towards the abundance of the commonest species.. It calculates the probability of any two individuals drawn at random from an infinitely large community belonging to different species as:

$$D = \sum \left(\frac{n_i(n_i-1)}{N(N-1)} \right)$$

where n_i = the proportion of individuals in the *i*th species. In order to calculate the index, the formula appropriate to a finite community is used:
where n_i = the number of individuals in the *i*th species and N = the total numbers of individuals. As D increases, diversity decreases and Simpson's index is therefore usually

expressed as 1- D or 1 / D. Simpson's index is heavily weighted towards the most abundant species in the sample while being less sensitive to species richness (Magurran, 1988).

Sobs reflects total number of species observed in all samples pooled (Colwell 2000) and is calculated as:

$S_{obs} = S_{rare} + S_{abund}$.

where S_{rare} = the number of rare species (each with 10 or fewer individuals when all samples are pooled) and S_{abund} = the numbers of abundant species (each with more than 10 individuals when all samples are pooled).

Coverage-based Richness Estimator: Abundance-based Coverage Estimator (ACE) is based on species with 10 or fewer individuals in the sample (Chao *et al*., 1993) but the corresponding Incidence-based Coverage Estimator (ICE) likewise, is based on species found in 10 or fewer units (Lee and Chao 1994).

ACE: Abundance-based Coverage Estimator. The sample coverage estimate based on abundance data is:

$$C_{ace} = 1 - \frac{F_i}{N_{rare}}$$

where $N_{rare} = \sum_{i=1}^{10} i F_i$

Thus, this sample coverage estimate is the proportion of all individuals in rare species that are not singletons. Then the ACE estimator of species richness is

$$S_{ace} = S_{abund} + \frac{S_{rare}}{C_{ace}} + \frac{F_1}{C_{ace}} \gamma^2_{ace}$$

where S_{rare} = the number of rare species (each with 10 or fewer individuals when all samples are pooled) and S_{abund} = the numbers of abundant species (each with more than 10 individuals when all samples are pooled), and γ^2_{ace} estimates the coefficient of variation of the F*i*'s, is

$$\gamma^2_{ace} = \max\left[\frac{S_{rare}}{C_{ace}}\frac{\sum_{i=1}^{10} i\,(i-1)F_i}{(N_{rare})(N_{rare}-1)} - 1\right]$$

where F_i= Number of species that have exactly i individuals when all samples are pooled (F_i is the frequency of singletons, F_2 the frequency of doubletons). The formula for ACE is undefined when all rare species are singletons ($F_1 = N_{rare}$, yielding C =0). In this case, EstimateS computes the bias-corrected form of Chao 1 instead on Anna Chao's advice (Colwell, 2000).

Chao 1 (Colwell, 2000): An abundance-based estimator of species richness. The full, bias-corrected formula is

$$S_{chao1} = S_{obs} + \frac{F^2_1}{2(F_2+1)} - \frac{F_1F_2}{2(F_2+1)^2}$$

The approximate formula is

$$S_{chao1} = S_{obs} + \frac{F^2_1}{2F_2}$$

where F_i= number of species that have exactly i individuals when all samples are pooled (F_1 is the frequency of singletons, F_2 the frequency of doubletons).

Species abundance distribution of samples was analysed using the programme **lognormal** and **logseries**. The species abundance distribution utilised all the information gathered in a community and is the most complete mathematical description of the data (Magurran, 1988). The logserie is estimated by terms

$$\alpha x, \quad \frac{\alpha x^2}{2}, \frac{\alpha x^3}{3}, \frac{\alpha x^4}{4}, \ldots$$

where αx = number of species in the total catch represented by one individual, $\alpha x^2/2$ = number of species represented by two individuals, and so on. The sum of the terms in the series is equal to $\alpha \log_e (1- x)$, which is the total number of species in the catch. The logarithmic series for a set of data is fixed by two variables, number of species in the sample and the number of individuals in the sample. The relationship between these is

$$S = \alpha \, \mathrm{Log}_e(1 + N/\alpha)$$

where S = total number of species in the sample, N = total number of individuals in the sample, α = index of diversity. The constant α is an expression of species diversity in the community (Krebs, 1998). The logarithmic series implies that the greatest number of species has minimal abundance and that the number of species represented by a single specimen is always maximal (Krebs, 1998). However the log normal model may be said to indicate a large, mature and varied natural community (Magurran, 1988). Log normal model is calculated as:

$$\lambda = S^* / \sigma$$

where S* = the total number of species in the community, σ = the root of variance. When the result of χ^2 calculation is lower than χ^2 in the table at 5% level, it means no significant difference between abundance pattern and the log normal distribution. It assumes that the data of those communities show a log normal distribution of species abundance. If logserie χ^2 calculation is lower that χ^2 in the table at 5%, it confirms logserie like distribution

In addition to the parameters available on EstimateS, I calculated the Morisita Horn and niche width.

Morisita Horn species similarity index is applied for the comparison of habitat differences. Morisita's similarity index suggested by Morisita, can also be used as a measure of niche overlap. Species similarity index (C_{MH} =Morisita Horn) is more sensitive to the abundance of the most abundant species. It is calculated from the following formula:

$$C_{MH} = \frac{2\sum (an_i\ bn_i)}{(da+db)\ aN*bN}$$

Where aN = total numbers of individuals in site A and an_i = numbers of individuals in the *i*th species in A.

$$da = \frac{\sum an_i^2}{aN_i^2}$$

Cluster analysis is carried out using the species dissimilarity index (Distance = 1- C_{MH}), single linkage cluster of Microsoft Stat.4.0

3.7 Similarity between habitats and niche width

Niche width is a measure of the breadth or diversity of resources used by an individual or species (Magurran 1988). I estimated the niche width of each butterfly species using adult habitat selection (i.e. the number of habitat types which adults occupy). The resource categories include different types of food eaten, or types of habitat (or parts of habitat) utilised. The usual approach is to use either the Shannon index or the Simpson index to calculate the width of the niche (Muehlenberg 1993).

The niche width of one species (NW*i*) can be calculated in two ways:

(1) According to the Simpson's formula:

$$NWi = \frac{1}{\sum_j p_{ij}^2} = \frac{Y_i^2}{\sum_j N_{ij}^2}$$

To standardise the values of NW, between 0 and 1, the formula is extended to:

$$\text{stand. } NWi = \frac{NW_i - 1}{r - 1}$$

where r = number of resource classes.

(2) According to the Shannon – formula:

$$\text{stand } NW_i' = \frac{-\sum_j p_{ij} \ln p_{ij}}{\ln r}$$

$$\text{where } p_{ij} = \frac{N_{ij}}{Y_i}$$

Y*i* = total number of individuals in the *i*th species which can be observed.
For standardisation the numbers of resource classes are taken into account.

In this case simpler is to express with antilogarithm.

$$\frac{\text{antilog. of } NW_i}{r}$$

NW_i is also limited between 0 and 1.0. The species with broad niche width close to the value of 1.0 may be considered as generalists, while species with narrow niche widths close to 0 may be considered as specialists (Mühlenberg, 1993).

I used butterfly distribution (distribution frequency of each species among all habitat types) as an indicator of the niche width in a habitat utilization pattern. For instance, butterflies with wide range of distribution are determined as habitat generalists (stand NW>0.5, species can be occur in different habitat types) and butterflies with narrow range of distribution (species require a particular habitat type) as habitat specialist. For instance, butterfly species with smaller standard niche width (<0.5) were determined as “specialists” species.

3.8 Ecology of selected species

Lycaena vigaureae L. is a very commen species in West Khentej. This butterfly is widely distributed in Europe, Middle Asia and Mongolia (Tolman & Lewington, 1998). However, it has become vulnerable in Germany (Bundesamt für Naturschutz (ed.), 1998) and is although

mentioned in the "Red Data Book" of European Butterflies (van Swaay & Warren, 1999: "lower risk, near threatened"). This category of threat status describes its decreasing abundance of more than 15% correlated with present abundance.

Foto 1. *Lycaena virgaureae* L. Male

The L*ycaena virgaureae*'s most characteristic habitats are forest-open area-corridors, forest meadow, opening cutted area, tree lines, forest edge and dry grassland (Settele et al., 1999), and tall herb communities, mesophile grassland, mixed woodland, broad-leaved deciduous forest and coniferous woodland (van Swaay & Warren 1999).

In West Khentej, this species occurs in all kinds of biotopes. For example, mesophile grasslands, dry slope, flower rich meadow, forest clearings and forest margins. It is univoltine with adults usually flying from mid June to late August. However, there is considerable variation between sites and emergence. In Asian part of Russia, it flies in late June to August (Tuzov, 2000; Settele *et al*. 1999), and in north-western Europe in one generation between July and August (Schneider, 2003).

3.9 Mobility of adults of selected species

Lycaena virgaureae was investigated from late July until end of August in 2004 at one open herb meadow habitat of West Khentej in northern Mongolia. Study site was surveyed everyday between 11.00 and 15.00 hours when it was sunny. During the survey two people walked around the site and netted all individuals when we saw. One person marked the individuals and released it. The exact GPS position of all individuals recorded during the mark-release-recapture studies was plotted on a map, in order to get measures of movement distances between captures (Fig. 5). The second person was made a record of sex, number of mark, and position of captures on "Data sheet".

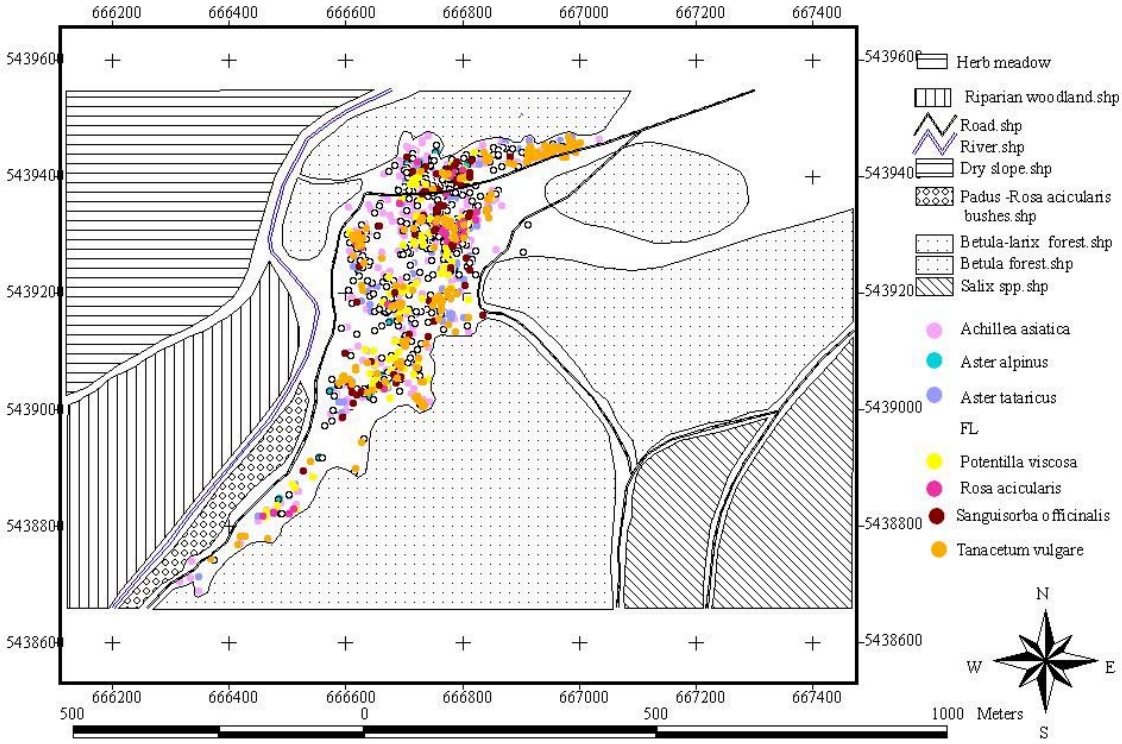

Fig. 5. The study site was located at 960m on herb meadow habitat in natural landscape of West Khentej forest steppe zone, northern Mongolia. The study site consisted of c. 10 ha area along the river Eroo. The site was chosen so that the meadow includes many of flowering plants with plenty of nectar species.

3.10 Adult population size of *Lycaena virgaureae*

Population size was estimated in 2004 for 24 days by a mark-release- recapture study. The study site was visited daily, between 11.00 and 15.00, from the end of July until the end of August except for days when it was raining. On several days the weather was windy and the observation could be shorter than normal way. Each adult caught was marked individually on the hind wing, using a fine permanent pen, and released immediately at the capture position. Daily population estimates were calculated using the Jolly-Seber method (Krebs, 1998). Male and female population size were calculated by plotting the daily estimates obtained from the Jolly methods.

4. RESULT

4.1 Climate condition

The mean maximum monthly temperature ranged between -22.7^{0}C in January and 21.4^{0}C in July (Figure 6). The averaged air temperature was unusually warm in November 2000.

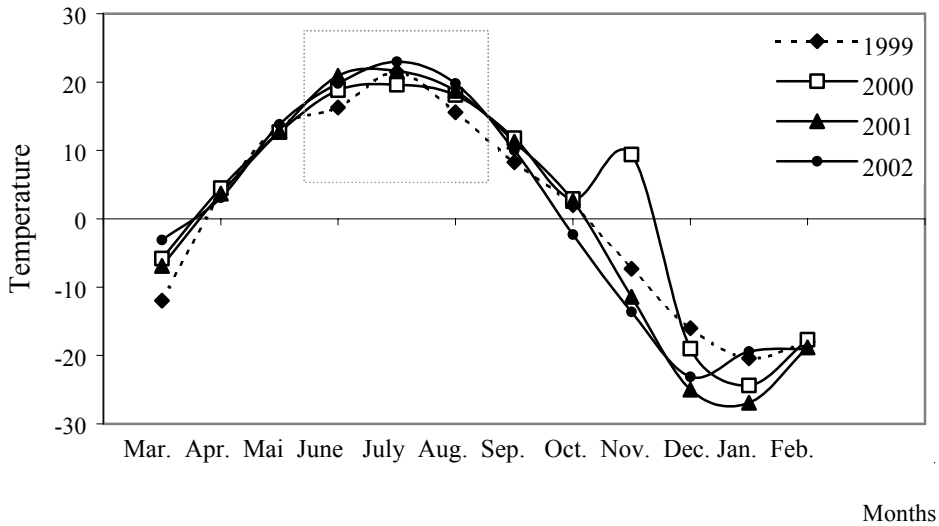

Figure 6. Average monthly temperature of Bugant meteorological station over the study period.

Extreme weather conditions occurred in July (2002) when the temperature was higher (2^{0}C), and in winter of December 2001, when it was 5^0 C cooler than the 10 years average (ANOVA, F (13, 0) =0, 00; p < 0,000).

Most rainfall was in July and August (Fig. 7). The annual rainfall in 2001 and 2002 was higher than the average for the previous 10 years. In 2002 the spring months (March, April, May) were unusually rainy (5 times > average (8.9 mm) in each month), the highest precipitation occurred in July and August and the lowest in February.

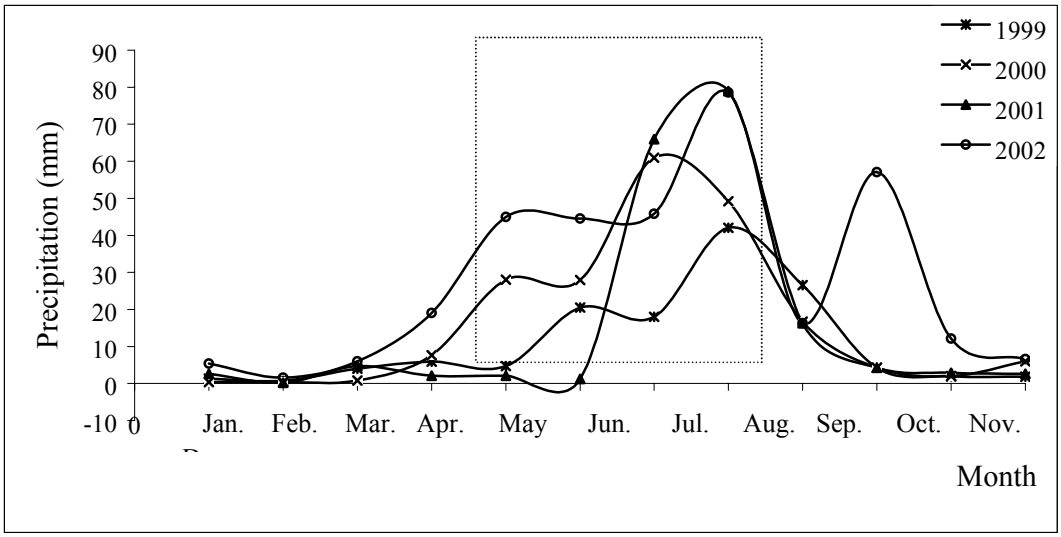

Figure 7. Mean monthly precipitation data from Bugant, 1999-2002.

These extremes of temperature and precipitation in 2002 should affect butterfly abundance in this region. Butterflies were more abundant in 2002 than in 2001.

A higher abundance of butterflies was correlated with this warmer summer of 2002 (Anova; $F(1, 46) = 4.59$; $p < 0.03$).

There was an overall significant variation in the abundance of butterflies between the four years.

The lowest atmospherical humidity (below 50%) is recorded in April and May when the maximum wind velocities (up to 28m/sec) also occur. The combination of these factors facilitates fires in the forest steppe during this season (Gunin et al, 1999).

4.2 Herbaceous plant community

The pooled data of herb meadow habitat type included 3762 individuals of 61 plant species. In the mountain dry steppe (MDS) I recorded in the plots 685 individuals of 29 species (Figure 8, Table in Appendix 2). Between both habitat types there is a clear difference in plant species numbers and individuals (Mann-Whitney *U*-test, $Z=2.31$, $p<0,05$).

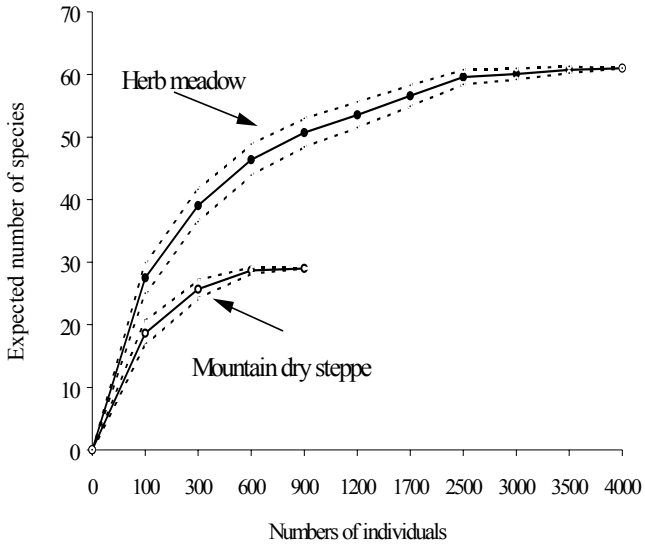

Fig. 8. Rarefaction curve for the vascular plant community of two habitats. Number of species in pooled samples of each habitat type were 61.0 and 29.0 in herb meadow and mountain dry steppe, respectively. The dotted lines indicate the standard deviation of species richness.

The difference between these habitats in their floristic composition is also shown by the analysis of similarity between species assemblages based on a cluster analysis using the Morisita Horn index (Figure 9). The dendrogram also shows that the two Herb Meadow plots were more similar to each other in their floristic composition than the two plots of Mountain Dry Steppe.

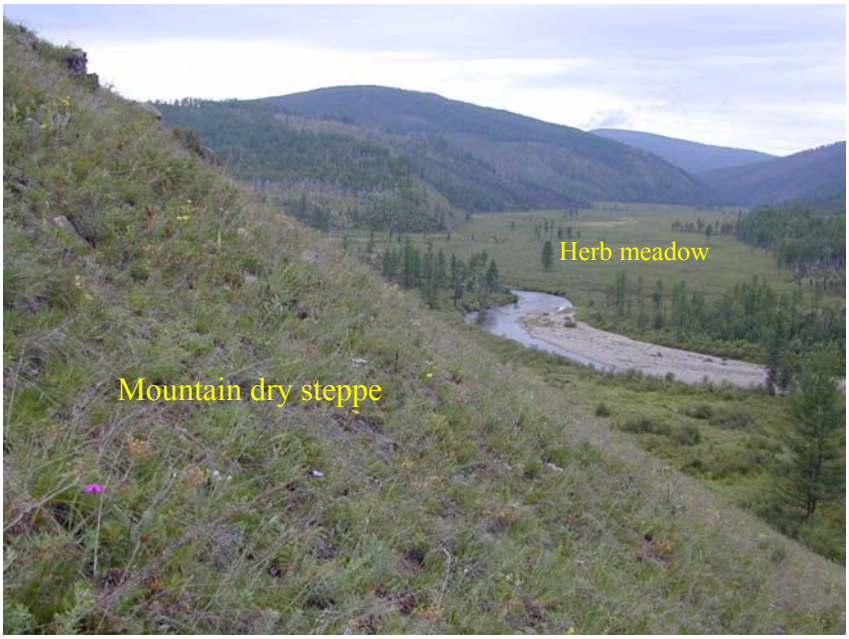

Foto 6. Natural vegetation type of herb meadow and mountain dry steppe

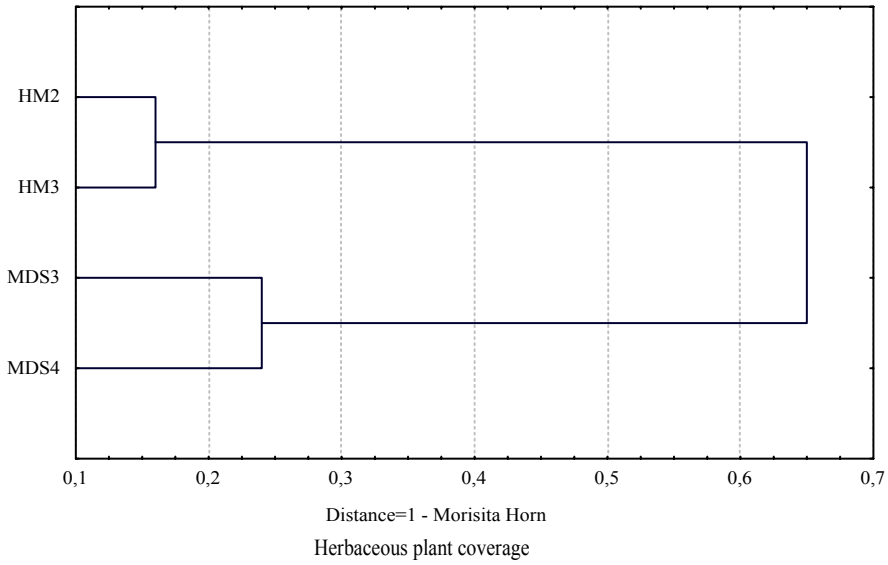

Figure 9. Single Linkage Cluster analysis using Morisita Horn similarity index for herbaceous plant communities of Herb Meadow (HM) and Mountain Dry Steppe (MDS) in West Khentej. Codes 2, 3, 4 signify study plots. Distance is calculated as (1-Morisita Horn similarity index).

Dominant plant species (> 4.0% of total plot plant coverage) comprised 7 species on herb meadows and 5 species on mountain dry steppe. Of all plant species 10 % were shared between the two habitats (Table 3; Appendix 3).

Site dominants on herb meadows were: *Carex arnellii*, *Bromus sibiricus*, *Artemisia tanacetifolia*, *Artemisia mongolica*, *Galium sp*., *Calium verum*, *Achillea asiatica,* on mountain dry steppe were: *Potentilla acaulis, Carex arnellii*, *Potentilla viscosa*, *Artemisia integrifolia*, *Koeleria macrantha*, *Pulsatilla sp*.,.

Mountain dry steppe (MDS) has a sparse vegetation cover dominated by *Potentilla - Carex*, often including *Potentilla acaulis, Potentilla viscosa, Artemisia sp. Koeleria macrantha, Poa, Thymus, Pulsatilla, Oxytropis sp,* and *Lilium pumilium*. In contrast, the **herb meadow** (HM) was predominantly a *Carex-Artemisia* 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* (Appendix 4). *Carex* spp are widely distributed in both habitat type.

MDS	%	HM	%	HM	%
Allium sp.	0,44	***Allium sp.***	0,11	*Iris sibirica*	1,44
Alyssum lenense	0,58	*Aconitum sp.*	0,11	*Lactuca sibirica*	0,03
Artemisia frigida	1,46	*Alchemilla gubanovii*	0,05	*Lilium sibirica*	0,08
Artemisia integrifolia	4,82	*Achillea asiatica*	4,47	*Linaria acutiloba*	0,05
Bepleurum bicaule	0,29	*Anemone crinita*	0,43	*Papaver nudicaule*	0,13
Bromus botryoides	0,15	*Artemisia dracunculus*	0,16	*Pedicularis sp*	0,08
Bromus sibiricis	0,29	***Artemisia integrifolia***	2,07	*Phlomis tuberosa*	0,21
Carex arnellii	16,9	*Artemisia mongolica*	4,86	*Poa sp.*	3,4
Cleistogenes squarrosa	2,19	*Artemisia tanacetifolia*	5,61	*Poa pratensis*	1,04
Crepis sibirica	1,46	*Aster alpinus*	0,03	*Polemonium racemosum*	0,13
Festuca lenensis	0,44	*Aster tataricus*	0,24	*Polygonatum odoratum*	0,19
Galium verum	1,02	***Bromus botryoides***	1,09	*Polygonium sibiricum*	2,05
Goniolimon speciosum	0,15	***Bromus sibiricis***	8,74	*Polygonium viviparum*	0,13
Greps sibirica	0,44	***Carex arnellii***	28,9	*Polygonum alpinum*	0,19
Koeleria macrantha	5,11	*Carex pediformis*	3,64	*Potentilla bifurca*	0,08
Lilium pumilum	1,02	*Carum carvi*	1,09	*Potentilla multifida*	0,27
Oxytropis myriophylla	2,04	*Cicuta virosa*	0,37	***Potentilla tanacetifolia***	1,14
Patrinia sibirica	0,88	*Dianthus versicolor*	1,36	*Ranunculus japonicus*	0,64
Poa sp.	1,17	*Elymus gmelinii*	0,08	*Rodiola rosea*	0,03
Polygala sibirica	0,29	*Equisetum arvense*	2,15	*Rosa acicularis*	0,16
Potentilla acaulis	40,4	*Equisetum pratensis*	1,04	*Rumex sp.*	0,03
Potentilla tanacetifolia	3,5	*Filipendula palmata*	0,48	*Sanguisorba officinalis*	2,21
Potentilla viscosa	5,84	*Galium boreale*	1,04	***Schizonepeta multifida***	0,08
Pulsatilla sp.	5,54	*Galium sp.*	4,09	*Scutellaria scordifolia*	1,41
Schizonepeta multifida	0,44	***Galium verum***	4,07	*Spiraea flexuosa*	1,89
Scorzonera radiata	0,73	*Geranium pratense*	1,7	*Spiraea media*	0,27
Taraxacum mongolicum	0,29	*Geum aleppicum*	0,08	*Thalictrum simplex*	0,61
Thymus dahuricus	2,04	*Hemerocalis minor*	0,13	*Thalictrum squarrosum*	0,85
		Hieraceum virosum	0,08	*Trifolium lupinaster*	0,29
				Valeriana officinalis	0,19
				Vicia amoena	2,23
				Vicia unijuga	0,21

Table 3. Dominant plant species (> 4.0% of total plot plants) in HM and MDS. Samples based on total of 4 subplots of 1m². Bold letters indicate that the species occurs in both habitat types.

4.2.1 Plant species richness

All indices, the observed number of species, the number of individuals, the estimated species richness (calculated as ACE estimator and Chao1), Fisher's alpha diversity and Simpson diversity were significant different in pooled data (4 m^2) (Mann-Whitney *U*-test, Z=2.31, p<0,05 in all cases) between the two habitat types (Table 4).

Habitat	Mean observed numbers of species	Mean numbers of individuals	Mean estimated total species richness	Abundance-based estimator of species richness	Mean Fisher's alpha diversity	Mean Shannon-Weaver's index	Mean Simpson diversity
HM	49 ± 1.88	2,269 ± 196.41	52.32 ± 1.04	55.25 ± 7.55	8.82 ± 0.54	2.75 ± 0.05	6.78 ± 0.73
MDS	29 ± 1.33	685 ± 77.91	29.96 ± 4.75	29.5 ± 1.03	6.14 ± 0.55	2.24 ± 0.05	4.88 ± 0.42

Table 4. Diversity parameters of herbaceous plant communities in Herb Meadow (HM) and Mountain Dry Steppe (MDS) in West Khentej, Mongolia.. Sample size (n) for both habitats is 4 x 1m² subplots. All parameters were calculated using EstimateS 6.01b (Colwell 2000).

Observed number of vascular plant species found in the herb meadow and mountain dry steppe were significantly different in each 1m^2 (ANOVA, F(1, 6)=10,50; p<0,02). Calculation based on data equally (4 x 1m^2) collected from each two habitat types (Fig 10).

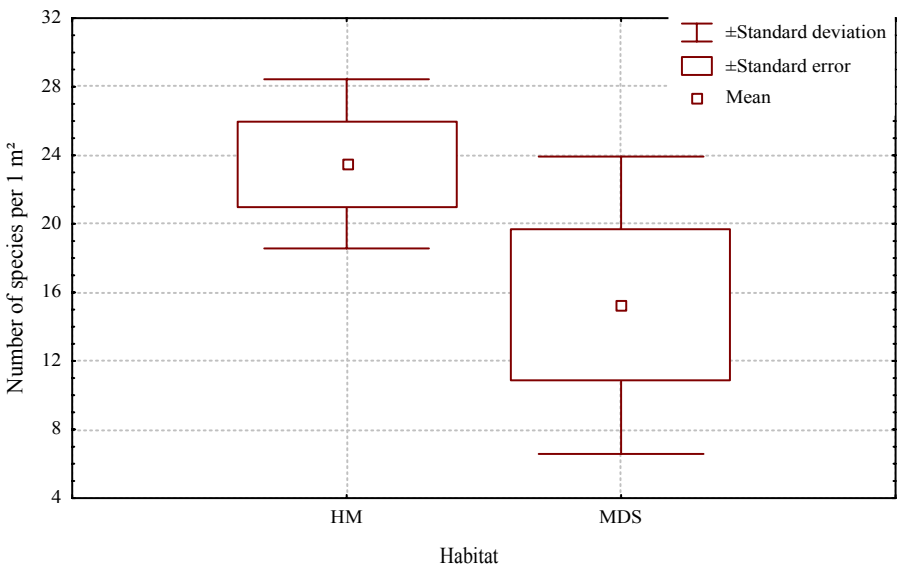

Figure 10. Observed number of vascular plant species found in herb meadow and mountain dry steppe in each sub-plots. HM=Herb Meadow, MDS= Mountain Dry Steppe. Sample size is 4 x 1m² for both habitats.

The abundance of plant species was significantly higher in the herb meadow than in mountain dry steppe (ANOVA, F (1, 6) =10, 50; p<0, 02). In the herb meadow habitat, only one species (*Carex arnellii*) had a significant higher coverage. Eight species (*Achilea asiatica, Artemisia mongolica, Artemisia tanacetifolia, Bromus sibiricus, Carex pediformis, Galium verum, Galium sp., Poa botryoides*) had a high coverage in each sub-plots. In the mountain dry steppe habitat, *Carex arnellii* had a higher coverage too, but *Potentilla acaulis* was most dominant. Plant coverage was more dense in herb meadow than in mountain dry steppe (Fig. 11).

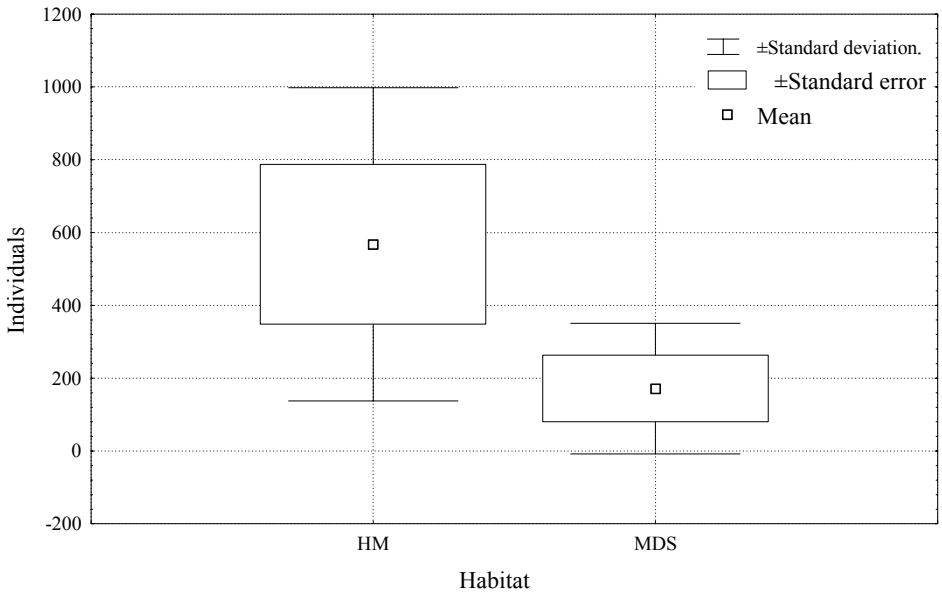

Figure 11. Mean number of vascular plant individuals sampled in herb meadow and mountain dry steppe. HM = Herb Meadow, MDS = Mountain Dry Steppe. The difference between the two samples was significant (Mann-Whitney *U*-test, Z=2.3, p=0.02).

4.2.2 Lognormal distribution of herbaceous plant species

The distribution of herbaceous plant species in the two habitats was both lognormal (HM- Lognormal χ^2=9,96<$P_{(0.05)}$=15.51; Logserie χ^2 =13,95<$P_{(0.01)}$= 20.09 ; MDS- Lognormal χ^2=5.82<$P_{(0.05)}$=12.59)(Fig. 12). Figure 12 shows again that the plant community composition within the two habitat types is not similar. The diversity curves of plant communities of West Khentej show that only few species were very abundant (e.g. two species represented by more than 100 individuals in the mountain dry steppe), some had a medium abundance, while most of them would be represented only by few individuals (e.g. about 30 species are represented by less than 10

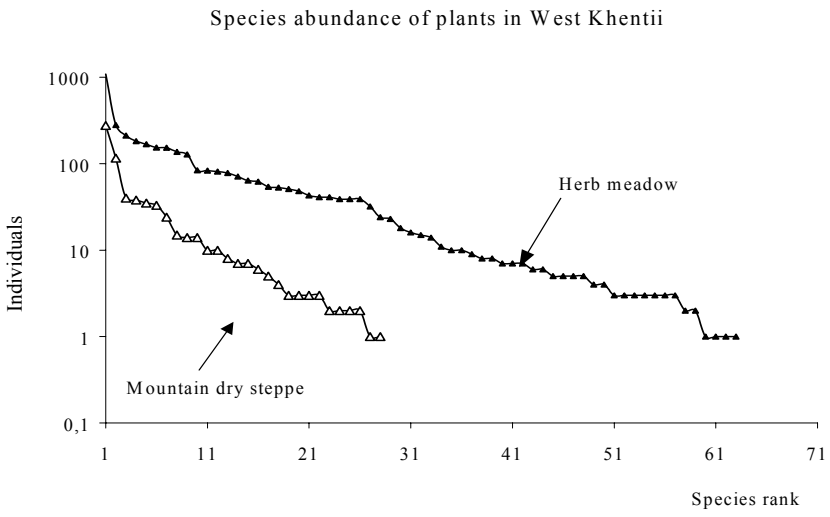

Figure 12. Rank abundance plot of vascular plants in two different habitats in West Khentej. Estimated total number of species in herb meadow (HM) =64.6; Estimated total number of species in mountain dry steppe = 29.2.

individuals in the herb meadow). The plant species richness of the herb meadow was almost twice as high than that of the mountain dry steppe habitat.

4.3 Butterfly fauna in West Khentej

15 species have been reported for the first time in the West Khentej region by this study (compare: Korshunov & Gorbunov 1995; 1976, 1977) (Table 5).

Two species of those butterflies seem to be non-resident (*Papilio xuthus, Vanessa cardui)*, they were captured outside the study plots. *Papilio xuthus* (Linnaeus, 1767) is an East-Asiatic species, proposed for protection in Chita Province. All the old records from Transbaikalia concerned capture or observation of single specimens (Chikolovets 1994).

Species name	Location
Albulina orbitulus de PRUNNER, 1798	West Khentii (Khonin Nuga)
Aricia allous HÜBNER, 1819	West Khentii (Khonin Nuga)
Aricia eumedon ESPER, 1780	West Khentii (Khonin Nuga)
Coenonympha glycerion BORKHAUSEN, 1788	West Khentii (Khonin Nuga)
Colias staudingeri ALPHERAKY, 1881	West Khentii (Khonin Nuga; Minj)
Hipparchia autonoe ESPER, 1784	West Khentii (Khonin Nuga)
Hyponephele pasimelas STAUDINGER, 1886	West Khentii:(Minj)
Lasiommata maera LINNAEUS, 1758	West Khentii (Khonin Nuga)
Melitaea arcesia minor ELWES,	West Khentii (Khonin Nuga)
Melitaea aurelia NICKERL, 1850	West Khentii (Khonin Nuga)
Melitaea centralasiae WNUSKOWSKY,	West Khentii (Khonin Nuga)
Melitaea plotina BREMER, 1861	West Khentii (Khonin Nuga)
Oeneis mongolica OBERTUHÜR,	West Khentii (Khonin Nuga)
Polyommatus aquilo wosnesenskii MENETRIES,	West Khentii (Minj)
Thecla betulae LINNAEUS, 1758	West Khentii (Khonin Nuga)

Table 5. List of species which were registered new for the West Khentej region.

The butterfly species represent six families: Hesperiidae, Papilionidae, Pieridae, Satyridae, Nymphalidae and Lycaenidae (Figure 13).

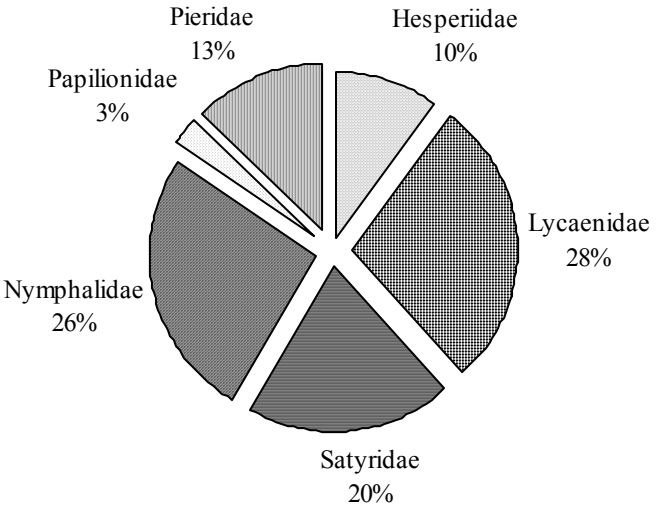

Figure 13. The butterfly fauna is represented by 6 families at the study area of West Khentej. The Lycaenidae and Nymphalidae constitute most of the total butterfly fauna (28% and 26%). These families include 42 and 39 species, respectively.

Lycaenidae and Nymphalidae are amount to approximately two-thirds (63%) of all individuals. Lycaenidae and Nymphalidae were the dominant families among Palearctic and Central Asian species, the two families together comprise 59% and 67%, respectively (Figure 13). Nymphalids also dominated the Holarctic species assemblage (52%), whereas the dominant family (45%) of the East Asian species belongs to the Satyridae. Lycaenids also dominate many other Palearctic countries, often followed by Nymphalidae (Tuzov, 1995, 2000; Korshunov & Gorbunov, 1995; D' Abrera, 1990; 1993; 1999). 35 dominant species (Table 6), occur in all four investigated habitat types in West Khentej, two species (*Maculinea teleius* and *Nymphalis polychloros*) of the dominants were recorded only in 3 out of 4 habitat types (Table 6).

Most abundant species in West Khentii region (by families)				
Papilionidae	Pieridae	Satyridae	Nymphalidae	Lycaenidae
Papilio machaon	*Aporia crataegy*	*Coenonympha glycerion*	*Neptis rivularis*	*Plebejus subsolanus*
	Leptidea morsei	*Minois dryas*	*Argynnis paphia*	*Everes argiades*
	Colias tyche	*Aphantopus hyperantus*	*Brenthis ino*	*Aricia eumedon*
		Oeneis sculda	*Melitaea didyma*	*Lycaena helle*
		Erebia neriene	*Nymphalis vau-album*	*Lycaena virgaureae*
		Coenonympha hero	*Inachis io*	*Plebejus idas*
		Boebera parmenio	*Argynnis aglaja*	*Agrodiaetus amandus,*
		Coenonympha oedippus	*Brenthis daphne*	*Maculinea teleius*
		Oenies urda	*Nymphalis polychloros*	*Glaucopsyche lycormas*
		Oeneis nanna	*Mellicta athalia*	*Cupido minimus*
			Mellicta britomartis	

Table 6. Species ranked with decreasing frequency in each family. Most dominant species (>100 indivivuals in standardised 100 catch hours) in West Khentej.

150 butterfly species (54% of the known Mongolian butterfly fauna at present) were recorded during the survey period. The most abundant species were *Aporia crataegy, Coenonympha glycerion, Nepthis rivularis, Plebejus subsolanus, Everes argiades, Argynnis paphia, Aricia eumedon, Minois dryas* , which amounted to about 30% of all individuals.

4.4 Community parameters of the butterfly fauna of West Khentej, northern Mongolia

At the community level species richness, abundances and similarity of samples along the different types of habitats were studied. A comparison is made between four habitat types using equal data from all four habitats.

4.4.1. Butterfly species richness

In West Khentej a total of 149 butterfly species have been recorded within 100 km² (Mühlenberg et al., 2000). Most of the species which have been recorded from West Khentej seem to belong to the Transbaikal faunistical group (Korshunov & Gorbunov, 1995). Monkhbayar (1999) recorded 70 species which belong to the 6 families of Rhopalocera in Central Khentej (Bogd Khan Mountain). Species density and distributions were not equal between the years 2000-2003 (Table 7).

Factors	FO	HM	MDS	WG	Anavo, (p)
Number of species	81.25+11.44	82.00+14.21	64.50+7.89	62.50+14.84	p<0.11
Number of individuals	13.15+2.90	26.115+9.17	13.538+2,60	9.803+2,643	p<0.01
Expected total species richness (ICE)	179.8+20.96	134.88+11.9	125.36+17.6	118.62+31.0	p<0.01
Expected total species richness (Chao1)	77.37+9.49	82.00+14.21	64.5+7.89	62.5+14.84	p<0.13
Fisher's alpha index	11.56+1.55	10.52+1.65	8.83+1.39	8.92+2.07	p<0.12
Simpson index	39.03+10.91	36.76+9.40	31.92+4.57	34.59+9.87	p<0.71

Table 7. Diversity parameters of butterfly species *i* sampled at four habitats in West Khentej. FO-forest opening, HM-herb meadow, MDS- mountain dry steppe, WG-wet grassland. Mean values calculated using the EstimateS program. Data are standardised per 100 catch hours for all habitat types.

The number of species found (species richness) increased with the number of individuals collected, and the two variables were significantly correlated (r_s=0.8125; p<0,000). (Fig. 14).

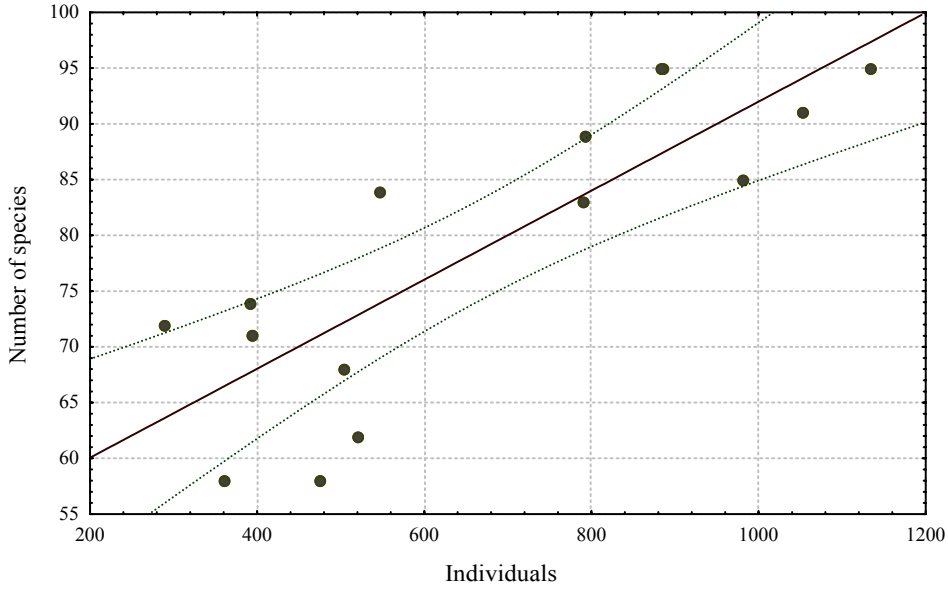

Figure 14. The relationship between species richness and total abundance of butterflies in West Khentej.

The observed number of butterfly species was not significantly different between the four habitat types (ANOVA, F(3.10)=2.59; p<0,1), but the expected number of species was significantly different (ANOVA; p<0.01). The highest mean number of butterfly species was found in the (HM)-Herb Meadow (mean number =82.00), followed by (FO)-Forest Opening (mean number = 81, 25) (Figure15). The natural features of this region could support the species richness in each habitat type (Lucau, 2004) (Foto 6).

Foto 6. A cluster of lycaenids in West Khentej. These cluster includes several species of Lycaenids (e.g. *Aricia eumedon, Polyommatus semiargus, Albulina orbitulus* and *Plebejus argyrognomon*)

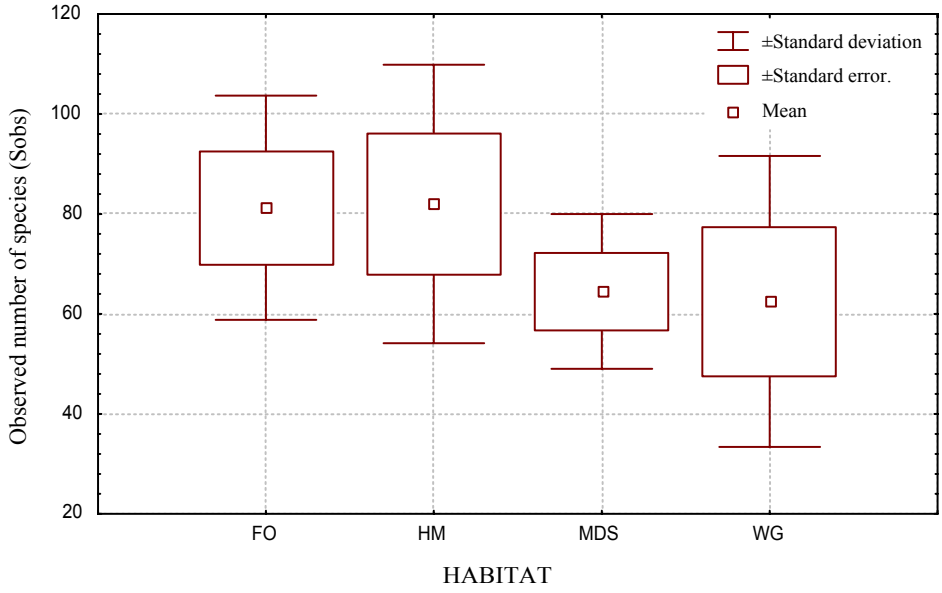

Figure 15. The observed number of butterfly species pooled data from 2 years in the forest opening (FO), the herb meadow (HM), the mountain dry steppe (MDS) and the wet grassland (WG). Data standardised per 100 catch hour.

The expected total species richness, calculated as ICE estimator was significantly different between the four habitat types in West Khentej (Anova, F (3, 10) =5.90; p<0.013 and F (3, 10) =7.44; p<0.006 respectively) (Fig.16). By this estimation the forest opening ranked highest in species richness

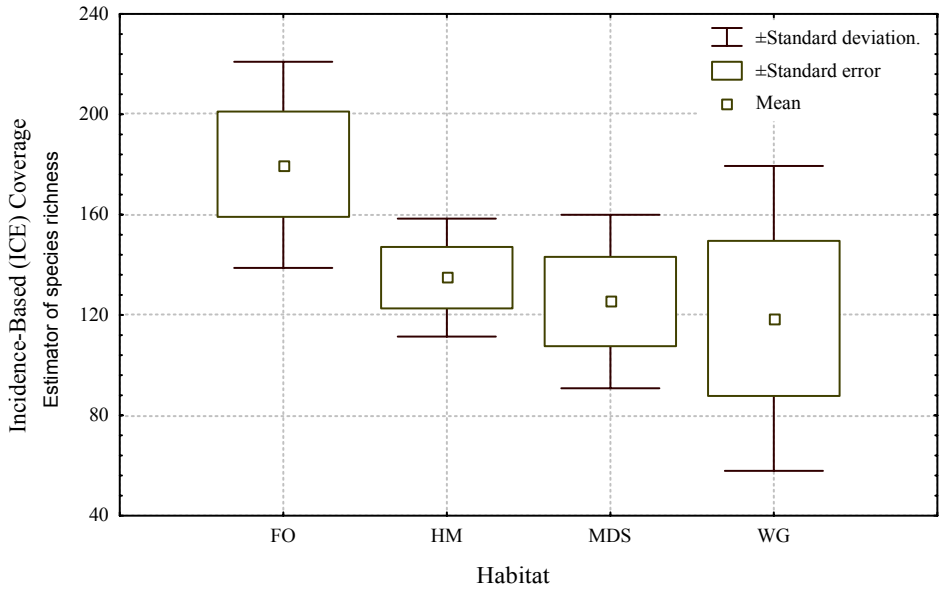

Figure 16. Incidence-based Coverage Estimator of species richness in four different habitat types. FO=forest opening, HM=herb meadow, MDS= mountain dry steppe, WG=wet grassland. Significant differences are confirmed by ANOVA.

4.4.2 Butterfly abundance

A total of 9993 individuals from 149 species were collected from the whole study area (100 km^2) during the entire sampling period. The number of the individuals captured in different habitats did not differ significantly between the habitat HM (herb meadow) and FO (forest opening) (ANOVA, $F(3,12) = 1.38$, $p<0.2$).

Butterfly abundance in HM (herb meadow) was almost twice the number of the mountain dry steppe (Figure 17).

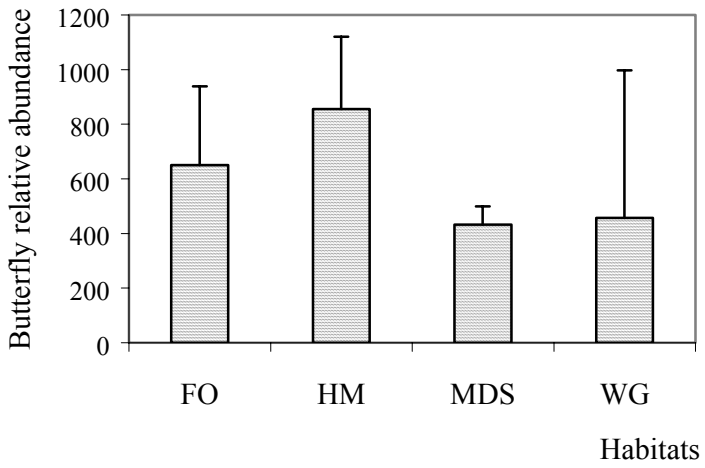

Figure 17. Mean number of individuals captured in 2000-2001 at different habitat types in West Khentej. FO= forest opening, HM= herb meadow, MDS= mountain dry steppe, WG= wet grassland. Differences between HM and MDS were significant F (1, 6) =9, 63 p<0.02). Data standardised for 100 catchhours.

Of the six families found in West Khentej, Nymphalidae and Lycaenidae occurred in the highest numbers, accounting for 29.2% and 27.5% of the total butterfly sample. These were followed in relative abundance by Satyridae (24.10%) and Pieridae (11.76%). Hesperiidae and Papilionidae constituted only 4.9% and 2.4%, respectively, of total abundance. The mean number of individuals per sample was significantly different among families (ANOVA, $F(5,18)=3,66$; $p<0.01$; $n=4.52$) (Figure 18).

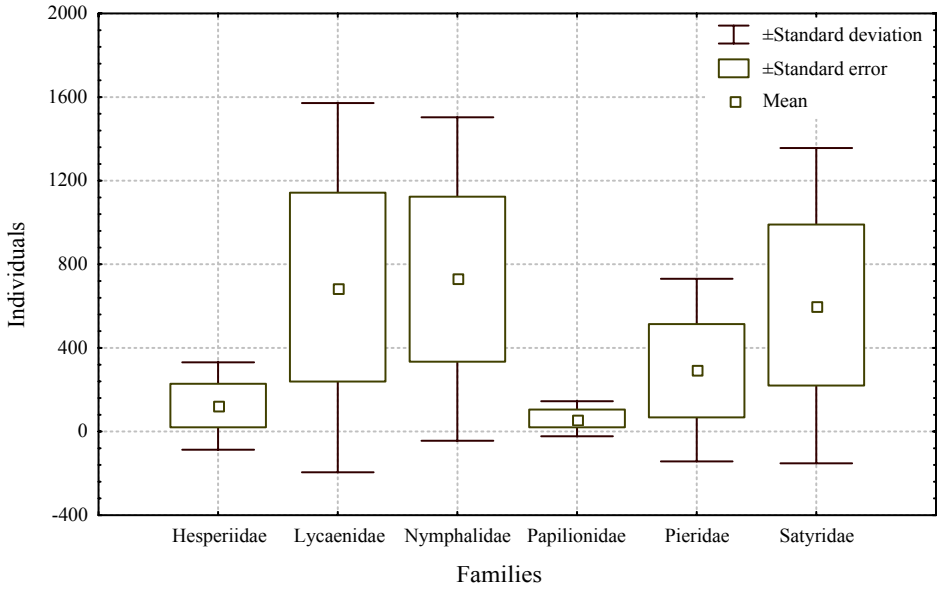

Figure 18. Mean numbers of individuals in 6 butterfly families. Data were pooled from four months each year and out of all habitat types (n = 12 samples) averaged over 3 years.

The populations fluctuated significantly between 2001 and 2002 (Anova; F (1, 46) =4.59; p<0.03; Fig.19)

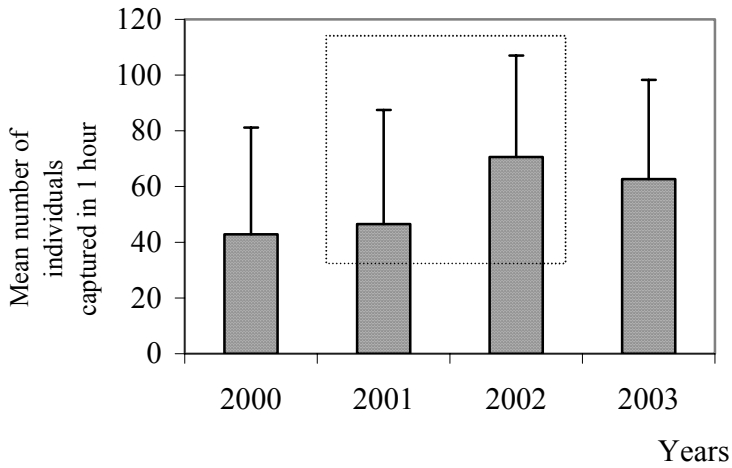

Fig. 19. Annual fluctuation of numbers of butterflies in West Khentej. Mean values were calculated with 3 samples in each year for comparison.

The analysis of the standardised catch of 114 species in 2000-2002, suggested an increasing trend for 10 species (7%) and a decreasing trend for 4 species (3%). In 2002, there was an exceptionally high abundance observed in some butterfly species (table 8). For *Aporia*

crataegy: for example, the number of individuals (frequency of occurrence) in one sample size was much higher in 2002 than in the previous two years (Foto7).

Species name	Number of individuals captured per 1 sample			Population trend *(only species with significant trend)*
	2000	2001	2002	
Aporia crataegi	3,28	4,22	11,35	increasing
Argynnis paphia	2,84	3,37	11,33	increasing
Aricia eumedon	2,08	2,66	6,7	increasing
Boeberia parmenio	3,6	3,6	6	increasing
Brenthis daphne	2,4	3	5,83	increasing
Carterocephalus silvicola	0	0	10,33	increasing
Coenonympha glycerion	4,73	5	11,54	increasing
Papilio machaon	1,16	2,62	5,41	increasing
Plebejus idas	3,36	3,62	7,8	increasing
Vacciniina optilete	3,25	2	9,5	increasing
Agrodiaetus amandus	3,57	5,6	2,42	decreasing
Everes argiades	4,03	4,88	3,72	decreasing
Polyommatus semiargus	2,8	20	2	decreasing
Mellicta centralasiae	1	5,33	2	decreasing

Table 8. Species list of population with increasing and decreasing trends in 2002.

Foto 7. *Aporia crataegy* is one of the commenest species in West Khentej, occurring in almost all habitat types. Outbreak of this species was observed in 2002.

There was a clear relationship between butterfly abundance and period of flight activity. The abundance of the four most common species (*Aporia crataegy, Argynnis paphia, Nymphalis*

vau-album, and *Minois dryas*) in West Khentej was significantly different at dates of first and peak appearance (Fig. 20). For example, the first emergence of *Aporia crataegy* is noted at early June, peak appearance in early July and it disappeared in late July.

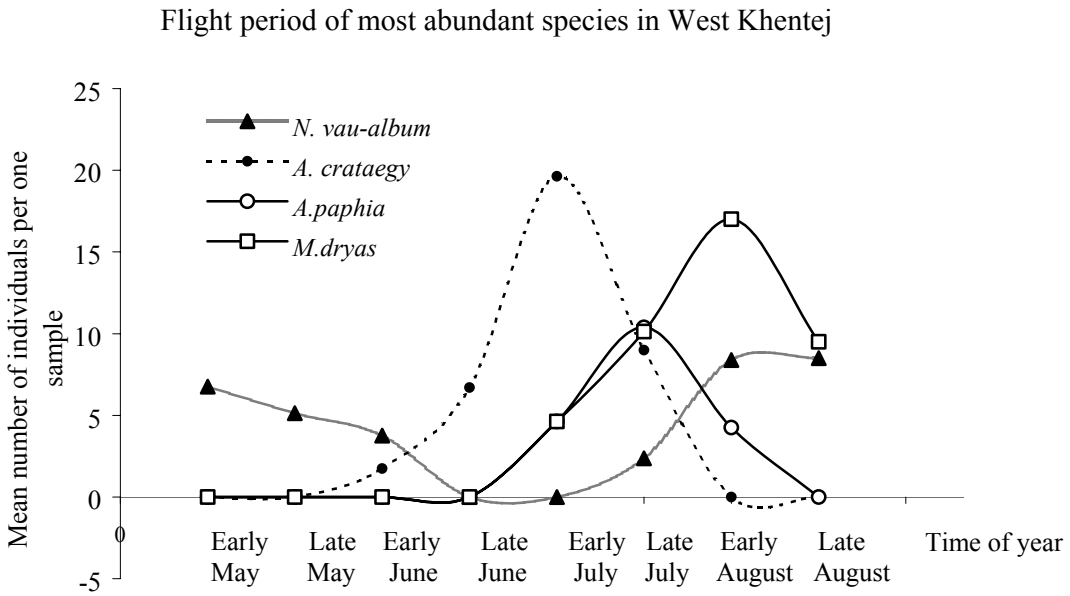

Figure 20. The graph shows the relative abundance of the most common four butterfly species at different stage of flight period in West Khentej. *Nymphalis vau-album* is overwintered adults and mate in the spring then re-emerge in July.

It should be pointed out that the abundance of butterfly species depends on the time of their flight activity.

4.4.3 Dominance - abundance pattern of the butterfly fauna

A total of 9993 individuals of 144 species were caught during the standard catch period. 12 species were represented in the catch by only a single specimen, and 34 common species constituted 67% of the total catch. One very common species (*Aporia crataegy*) was represented by 523 individuals in the catch. Log normal distribution of West Khentej butterfly was calculated in four different communities (Fig 21).

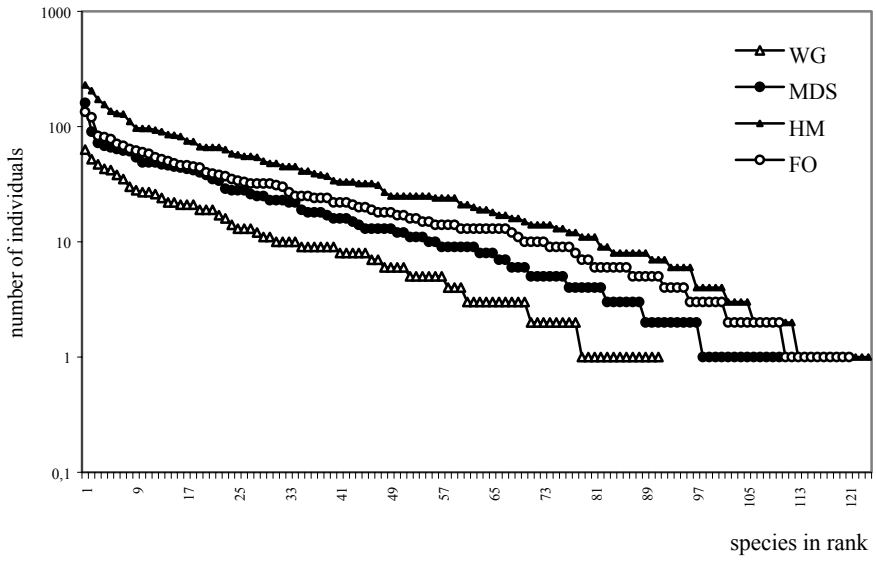

Figure 21. Butterfly community is fitted best by lognormal abundance distribution, indicating natural rich communities (Hubbell 2001). This graph shows the relationship between number of species and their number of individuals in butterfly communities in four types of habitat. WG-wet grassland, MDS-mountain dry Steppe, HM- herb meadow, FO- forest opening.

Goodness of fit tests of butterfly abundance distribution show an equal fit of lognormal χ models in West Khentej (Fig. 21). Butterfly species abundances follow a lognormal distribution (in all cases, see Table 9), but do not fit a logserie. The dominance-diversity curve of butterfly species is similar to the dominance-diversity distribution of tropical trees (Hubbel, 2001), fitted best by the logseries (metacommunity), indicating natural rich communities. The low population density of most species facilitates the coexistence of many species (e.g. Miyazaki et al., 2004).

Factors	FO	HM	MDS	WG
Total number of individuals	2,584	4,287	2,083	1,039
Total species	121	124	11	92
Logserie alpha	28.71	23.86	25.037	24.36
Logserie χ	0.98	0.99	0.98	0.97
Lognormal χ^2 calculation	χ^2<P(0.05)	χ^2<P(0.05)	χ^2<P(0.05)	χ^2<P(0.05)
Fit of the lognormal model	Yes	Yes	Yes	Yes
Fit of the logserie model	No	No	No	No

Table 9. Butterfly abundance distribution of West Khentej. FO= forest opening, HM=herb meadow, MDS= mountain dry steppe, WG=wet grassland.

To look for differences in habitat specialization, I examined the relative abundance of generalist (species with wide distribution range of different hatitat type, see chapter 5.4.3) and specialist (requiring a particular habitat type) species among habitat types. The specialist and generalist species did not differ significantly in abundance within habitat type (ANOVA: $F(6, 10) = 1.21$; $p < 0.344$).

I classified species with more than 100 individuals per 100 catch hours as dominant species for the particular habitat type (Table 10).

	Abundant species in each habitat type	
Habitat	Total number of dominant species	Total number of individuals
Forest opening	20	2.689
Herb meadow	34	6.174
Mountain dry steppe	21	2.833
Wet grassland	13	1.854

Table 10. This table shows the number of the abundant species among different habitat types in West Khentej. For detailed species list see Appendix 2.

Total number of individuals of those abundant species constitutes more than half (58%) of all butterflies caught in West Khentej.

4.4.4 Differences in butterfly communities between habitats

56% of total butterfly species were recorded in all habitat types of West Khentej region. As follows from Fig. 22, the majority part of butterfly fauna inhabiting various habitat types. Most of the dominant butterfly species, such as: *Aporia crataegy*, *Coenonympha glycerion, Neptis rivularis, Plebejus subsolanus, Everes argiades* are widespread over all habitat types. A total of eighty species were common in all surveyed habitat types in West Khentej. It may be correlated to their wide range of niche width. Although many palearctic butterfly species in Europe that are specialised in habitat and fragmented in several patches (Rodriguez et al., 1994; Baguette, 2003; Bergman, 2001; Pullin, 1997; Mennechez et al., Kussaari et al., 1996; Hanski and Ovaskainen, 2000; Saccheri et al., 1998; Hanski et al., 1994; Fisher et al., 1999) and threatened in Europe (Pullin 1995; Thomas, 1995; Kudrna 1986; van Swaay et al., 1997; Saarinen 2003; van Swaay and Warren, 1999) are still common in West Khentej, probably as ecosystems in the latter region are not yet fragmented.

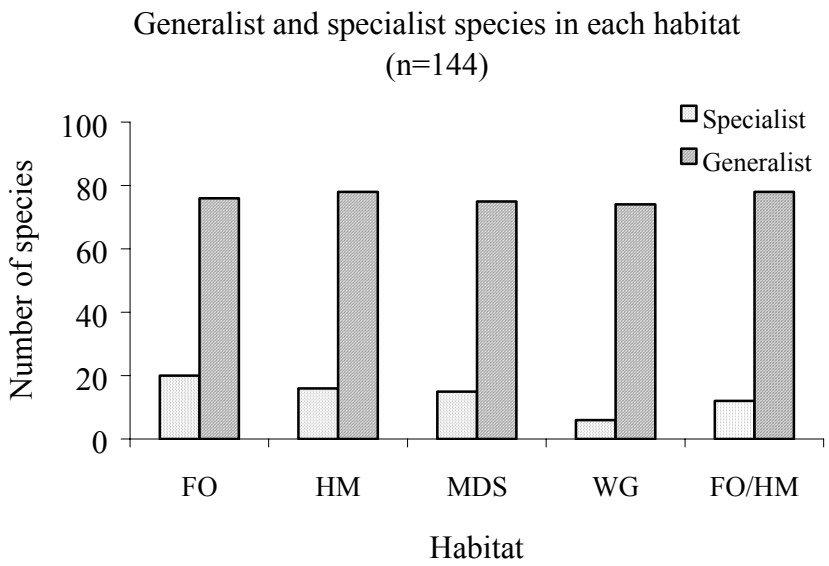

Figure 22. Number of specialist and generalist species at each habitat type in West Khentej. The majority of the generalist species are shared in all habitats, but the specialist species are habitat specific.

Many studies resulted that human disturbance and shade play an important role in the determination of community structure and composition (Kitahara et al., 2000; Kitahara 2004; Krauss et al., 2003; Natuhara et al.,1999; Schneider, 2003).

The rarefied species curve of butterflies from Khentej indicates weak differences between the four habitat types (Figure 23).

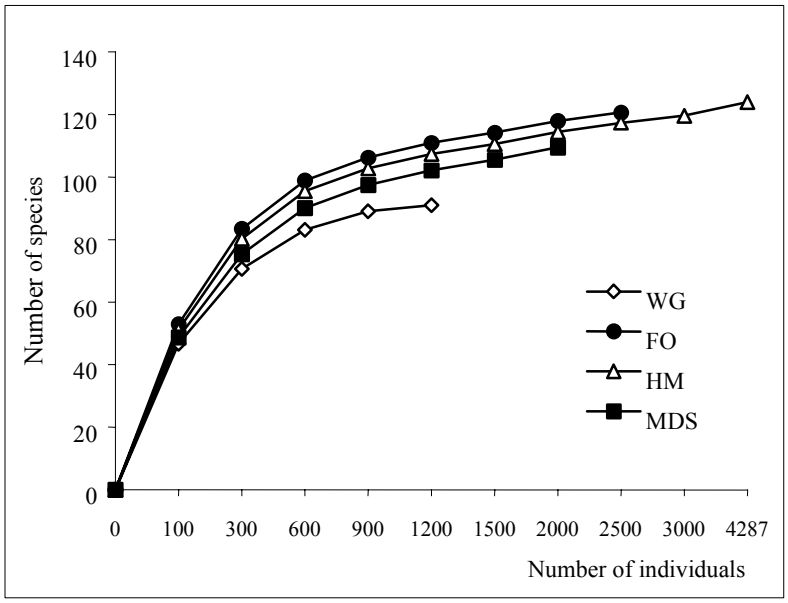

Figure 23. The rarefied number of species in each habitat type in West Khentej. WG= wet grassland, FO= forest opening, HM=herb meadow, MDS= mountain dry steppe. The highest mean rarefied expected number of species was found in the forest opening, followed by the herb meadow habitat (after, Krebs, 1989).

This is also shown by the analysis of similarity between species assemblages in different habitats based on a cluster analysis using the Morisita Horn index (Figure 22). The single linkage cluster shows that the habitats forest opening (FO) and herb meadow (HM) represents the highest similarity, and that the wet grassland (WG) grouped together with HM-FG cluster at the low dissimilarity of 0.16. The mountain dry steppe (MDS) is more isolated, but the distance between the habitats are very small (p<0.2 for dissimilarity index) (Figure 22).

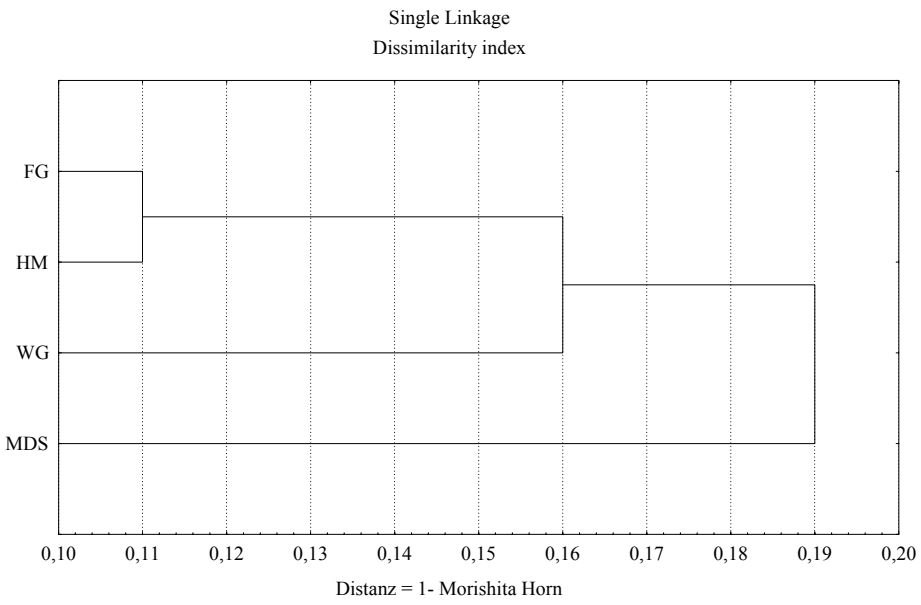

Figure 24. The cluster analysis using the Morisita Horn index and single linkage cluster method was performed for different habitat types for the pooled butterfly assambleges from 2000-2003. FO= forest opening, HM=herb meadow, WG= wet grassland, MDS= mountain dry steppe.

To check the butterfly habitat occupancy, I calculated the niche width of all bútterflies and classified them in 2 categories (specialist and generalist, see chapter 3.7). I found 79 “generalist” species (55% of total butterfly fauna), and 64 specialist species (44% of total butterfly fauna) in West Khentej. Then I checked the geographical distribution of generalist and specialist butterflies (Table 11).

Geographic range	Generalist	Specialist	Migrant	(*)	Total
Central-Asia	5	13		1	19
East Asia	9	11		2	22
Holarctic	11	8	1	1	21
Palearctic	54	32	1		87
Total	79	64	2	4	149

Table 11. The distribution of generalist and specialist species in geographical regions. *Vanessa cardui*, *Papilio xuthus* are described as migrant in West Khentej. *- species found outside the study plots.

Here, I found that among the species which have a restricted geographical distribution (e.g. Central Asian or East Asian), the specialists had a higher percentage than species with broad geographical distribution. Species with higher abundance belong more to the generalists (Fig. 25).

Some butterflies are specialist of herb meadow and wet grassland (e.g. *Colias palaeno*; Foto 8), some of them are specialists of mountain dry steppe. There are also dominant species which are specialised in one habitat type (e.g. *Lycaena helle*, *Euphydryas maturna, Mellicta athalia, Plebejus argyrognomon, Lopinga deidamia, Boloria angarensis, Polygonia interposita*) (Figure 23; Appendix 2). For example, *Euphydryas maturna* (Nymphalidae) flies in any habitats of wet and open grassland, forest opening, mountain dry steppe, but our data show that the adult distribution of *E. maturna* is determined by that of "suitable" forest opening (FO) and herb meadow (HM) habitats (e.g. it is common and widely distributed in *Betula spp., Salix spp.,* long-leaved speedwell (*Veronica longifolia),* honeysuckle species *(Lonicera* sp.) associated habitats.

Foto 8. Moorland Clouded Yellow (*Colias palaeno*) is a holarctic species, which ranges through the northern areas of North America, Europe, and Asia. This species is generally refers herb-rich meadows.

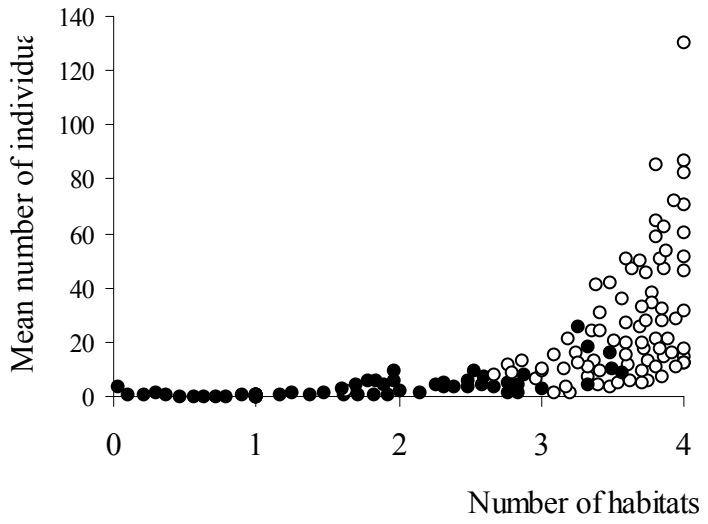

Figure 25. The distribution of generalist and specialist species of butterflies in West Khentej. The black circles indicate habitat specialists; the open circles show generalist species. Species with low stand. NW (<0.5) is classified as specialist and species with higher standNW (>0.5) is a "generalist".

The main result is that species with wider niche (measures of stand. niche width >than 0.5) seem to be highly correlated with the habitat occupancy of butterflies. For example, species with narrow niche breadth in terms of adult habitat occupancy, are presented only in one or two habitat types. Although, the result indicates that species with wider niche width can occur in all four habitat types.

Brown (1984) predicted niche-based explanations for the positive density distribution relationship and argued that generalist species should occur at high density and be widespread. With the data of adult occurrences, butterfly similarities between habitats were analysed by the Principal Component Analysis (PCA) and factor analysis. PCA is used in the survey to group species and factor analysis is used to detect the ecological variables. In the PCA of biotope occupancy, the first two factors contribute to 91% of the total variance. The first factor indicates the overall density of species. It has a high correlation with the density in all habitats, because the greatest proportion comes from the frequent species occurring in all landscape types (see Table 12).

Specialist species in each surveyed habitat type of West Khentej		
FO	**HM**	**MDS**
Ochlades sylvanus	*Aporia hipa hippa*	*Colias staudingeri*
Ochlodes venata	*Carterocephalus argyrostigma*	*Erebia ligea*
Oeneis mongolica	*Carterocephalus silvicola*	*Erebia niphonica*
Oeneis tarpeia	*Celastrina fedoseevi*	*Erynnis tages*
Pieris napi	*Colias erate*	*Everes fischeri*
Pieris rapae	*Colias palaeno*	*Hesperia comma*
Nymphalis polychloros	*Erebia medusa*	*Muschampia cribrellum obscurior*
Polyommatus eroitides	*Hemadara rurigena*	*Oeneis norno*
Pyrgus carthami	*Lethe diana diana*	*Thersamonolycaena splendens*
Rimisia miris miris	*Lycaena helle*	*Thersamonolycaena violacea*
Satyrus stheno	*Mellicta athalia*	*Triphysa phryne*
Techla betula crossa	*Patricius lucifer*	*Plebejus argyrognomon mongolica*
*Vanessa cardui**	*Pieris chlorodice*	*Pyrgus serratulae*
Boloria oscarus	*Polyommatus cyane*	
Colias alpherakii	*Vacciniina optilete*	**FO / HM**
Hipparchia autonoe		*Araschnia levana*
Hyponephele lycaon		*Aricia allous*
Lycaena hippothoe		*Boloria angarensis*
*Lasiommato maero**		*Boloria freija*
*Erebia jeniseiensis**		*Boloria titania*
WG		*Colias poliographus*
Hemadara rurigena		*Euphydryas maturna*
Cupido prosecusa		*Lopinga achine*
Melitaea cinxia		*Lopinga deidamia*
Polygonia interposita		*Maculinea arion*
Polyommatus eros		*Melitaea arcesia*
Polyommatus icadius		*Plebejus eversmanni*
		Limenitus populi

Table 12. Habitat specialist species in West Khentej. For results of the calculation of niche width, see Appendix 7. FO=forest opening, HM= herb meadow, MDS= mountain dry steppe, WG= wet grassland. FO/HM= (species had a similar preference for this two different habitat types ((FO/HM): FO=forest opening and HM=herb meadow).

The majority of species with their low and intermediate loading on the first axes are associated with all types of habitat. The second factor had a positive correlation to the density in WG (wet grassland, and negative correlation to that habitat in MDS (mountain dry steppe) (Fig. 26). Species with the highest loading on factor 2 are associated with wet grassland (see Table 13*),* and the variables with negative scores in the second axis are generally associated with mountain dry steppe species (e.g. *Everes fisheri, Erynnis tages, Triphysa phryne, Plebejus argyrognomon, Pyrgus serratulae, Thersamonolycaena violacea, Colias staudingeri*). There is little correspondence between the factor analysis and the habitat specialist classification which is determined by their niche width. The measures of niche

width are used here to identify specialist groups and split them into their most favourable biotope (Table 13).

	Factor 1	Factor 2
eigenvalue	3,1031204	0,5294103
% variance explained	77,57801	13,235258
% total variance explained	77,57801	90,813267
Factor loads		
FG	0,9353902	0,1043691
HM	0,9279941	-0,0626237
MDS	0,8124533	-0,5387713
WG	0,8407806	0,4736255

Table 13. The factor scores which were extracted from principle component analysis. FG= forest opening, HM= herb meadow, MDS= mountain dry steppe, WG= wet grassland. PCA calculated by software 99 Edition, Stat 5.5.

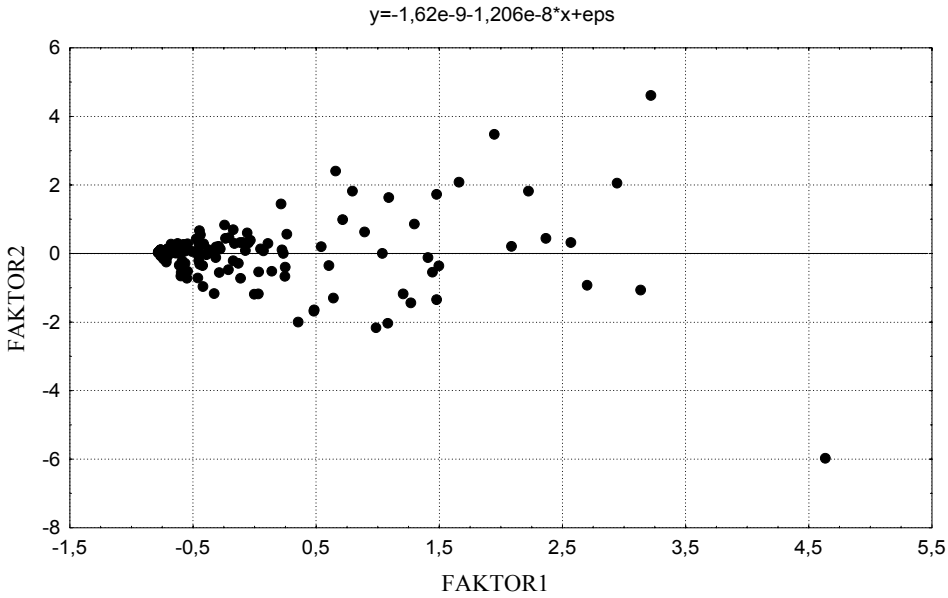

Figure 26. A principle component plot of 144 species of butterflies from West Khentej is based on two factors of variables. Species with higher scores in the second axis are mainly wet grassland species and species which have lower scores in the second axis are more associated with mountain dry steppe.

Specialist species classified by niche width are more than twenty out of sixty four species and have a high loading on factor two which place them at the second axes with species of alternative groups (group with higher scores and group with lower (negative scores) identified using principle component analysis.

25 species were found in one habitat type, 21 species in two, 24 species in three and 47 in four habitat types. The abundance of species differed significantly between species in these four categories of habitat fidelity (ANOVA; F (3,113) =23, 64; p<0.0000). Eleven species were represented by only one individual, whereas the most abundant species were found in all (4) habitat types (Figure 27*)*.

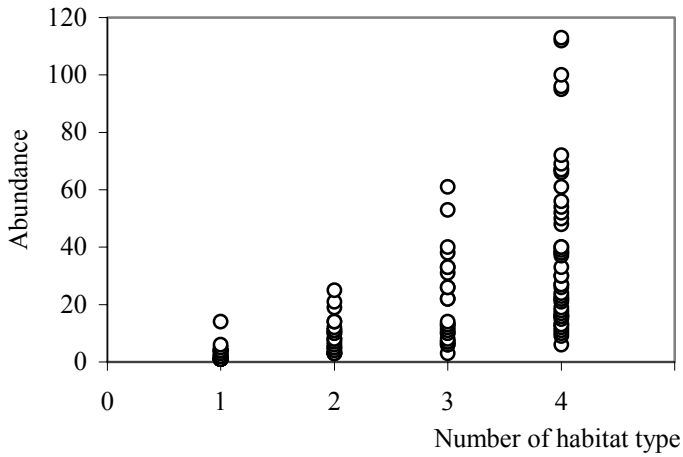

Figure27. Numbers of habitats occupied by 117 species of butterflies in West Khentej.

4.5 Geographical classification and habitat selection of the species

More than half (59%) of the butterfly species that inhabit West Khentej are Palearctic species (Figure 28). Each of the other three regional categories contributed a similar proportion of the remaining butterfly fauna (12-15%).

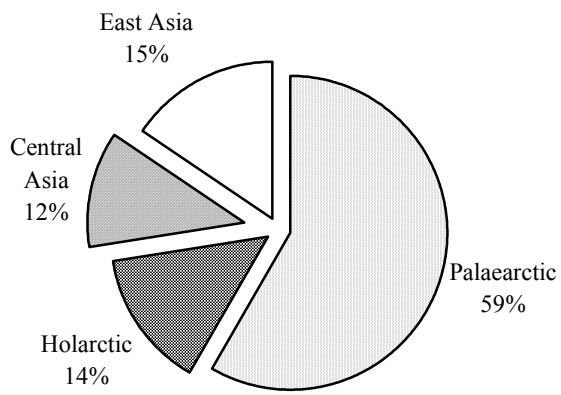

Figure 28. Biogeography of butterflies of West Khentej, Mongolia (n=149).

Furthermore, I examined the biogeographical distributions of butterfly species separately for four habitats types and found that there are no significant differences regarding the occupancy on proportions of biogeographical distribution of butterflies (Figure 29).

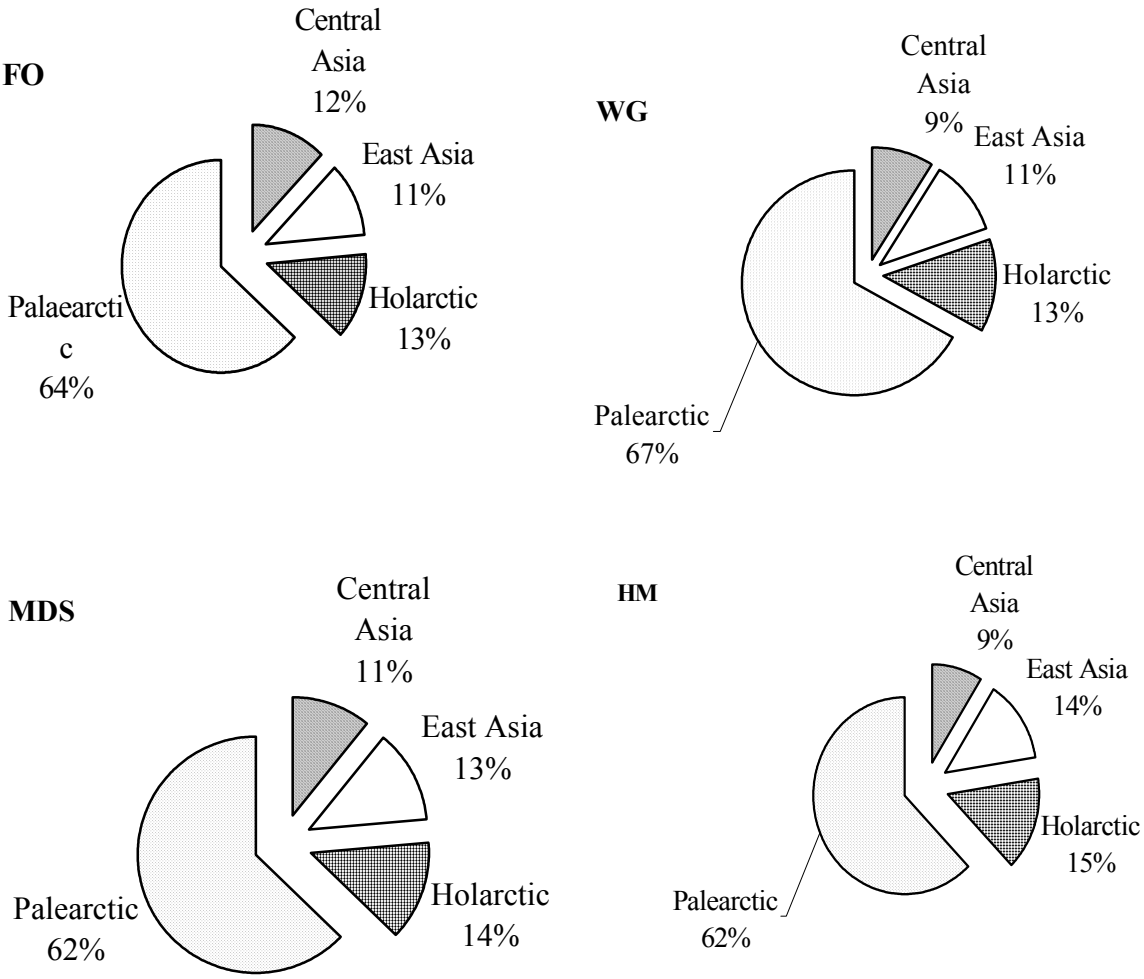

Figure 29. Biogeographical division of butterfly assemblages among the four habitats studied at West Khentej: This graph shows the proportion of the number of species recorded at four different habitat types in West Khentej. FO= Forest opening, WG= Wet grassland, MDS= Mountain dry steppe, HM= Herb meadow. For definition of biogeographical classification see chapter 4.5

For example, the proportion of palaearctic species constitutes approximately two-thirds (64%) of total species in each habitat type. These findings reassured that the species richness at different habitat types in West Khentej was very similar (see the chapter 4.4.4). It can be illustrated by the habitat selection of Maculinea species in West Khentej region.

For example, the **Scarce Large Blue**, *Maculinea teleius*, possesses a highly specialised ant-attendant univoline life-cycle (Thomas et al., 1989; Wynhoff, 1998): The young larvae first feeds on flowerheads of its host-plant *Sanguisorba officinalis* (Foto 8), but fall down to the ground after the fourth moult and need than to be found by certain ant of the genus *Myrmica*.

The right host-ant would take it into its underground-nest, where the butterfly-larvae stay over winter and feeds on the ant-brood. In late spring or early summer it crumbles out of the brood-chambers and pupates just beneath the ground. Two weeks later, from the end of June until the end of July, the Imago emerges (Foto 9). The phenology of a chosen flowerhead and vegetation characteristics are thought to be the most important variables for females react upon when depositing an egg (Wynhoff, 2001).

Foto 8. The young larvae of *Maculinea teleius* feeds on flowerhead of *Sanguisorba officinalis*. The flowering period of *S. officinalis* in West Khentej is from end of June untill end of August. *Sanguisorba officinalis* occurs in various habitat type of West Khentej region.

Foto 9. The Scarce Large Blue (*Maculinea teleius)* adults mating. Foto taken in West Khentej, July 5, 2003. The eggs are deposited in certain phenological stages of *Sanguisorba officinalis*.

Wheras in Europe this butterfly inhabitates rather moist areas, that went more and more extinct due to intensified agriculture and which are mostly isolated, in the Khonin-Nuga-region it occurs in a wide range of habitats. Predominantly first of all it has been found in herb meadows and wet grassland. But it also flies (and oviposites!) in the riparian woodland, in the

birchforests of the valley, even in Mixed Forests of *Larix sibirica* und *Betula platyphylla*, and finally, though not that often, in mountain dry steppes and meadow steppes. The obligate food-plant *Sanguisorba officinalis* can be found in any biotope that is not too dry and dark. So it is the host-ants, whose presence or absence limitates the occurence of the butterfly. So far three species of *Myrmica* have been identified as possible host-ants (Lucau, 2004). One of these can be found only in wet habitats, the remainig two occur in herb meadows as well as in the described forest areas. One prefers dead wood for its nest, the others use to live under the ground in the soil (Lucau, 2004).

Furthermore, I analysed the relationship between exclusive pairs of species within groups (generalist and specialist species in different habitat type) and their biogeographical affiliation (Figure 30).

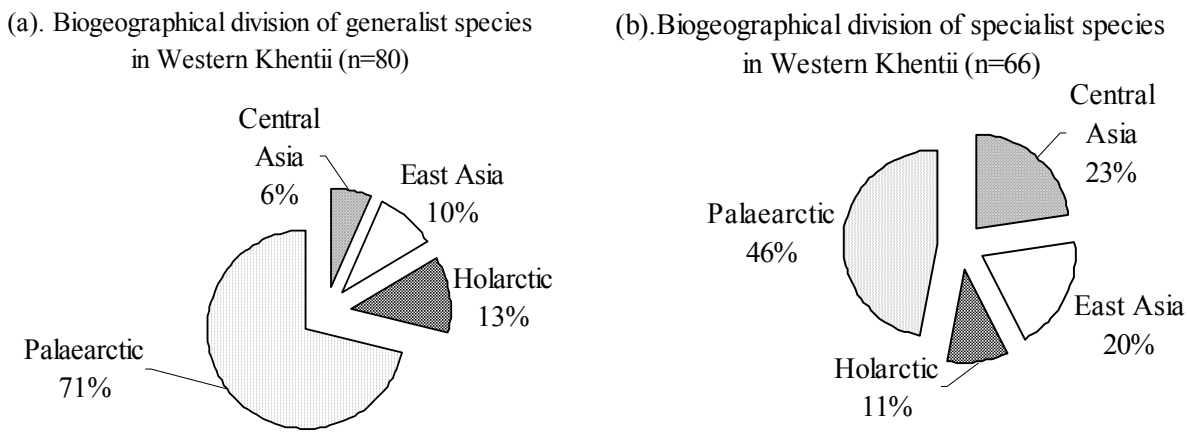

Figure 30. Beogeographical division of generalist and specialist species. The graph shows the geographical distribution of butterfly species which are discribed as generalists and specialists in West Khentej. (a) - biogeagraphic division of generalist species. (b)- biogeagraphic division of specialist species. For definition of generalist and specialist see chapter 4.7

In West Khentej the biogeographical categories of butterflies differed significantly between habitat specialists and habitat generalists (Fig. 30). Palearctic species constituted a higher proportion of habitat generalists than of habitat specialists (71% and 46% respectively, Figure

30**).** In contrast, habitat-specialised species showed a higher proportion of Central and East Asian species (Figure 30b).

Now we want to look for a significant preference of habitat selection in respect to biogeographical distribution. The patterns in generalist species for each habitat type are similar within the palaearctic species (Figure 30: a, c, e, g). Another hypothesis is that the habitat occupancy of specialist species which geographical restriction to Central and East Asia more occurs in grassland biotopes (Figure 30: f, h), but the specialist species with palaearctic and holarctic distribution peaked at forest opening and forest margin biotopes (Figure 30; b). Palaearctic species occupied more the forest opening (FO) (Figure 30: b). The specialist species with Central and East Asian distribution constitute more than 40 % for all type of grasslands (Figure 30: d, f, h).

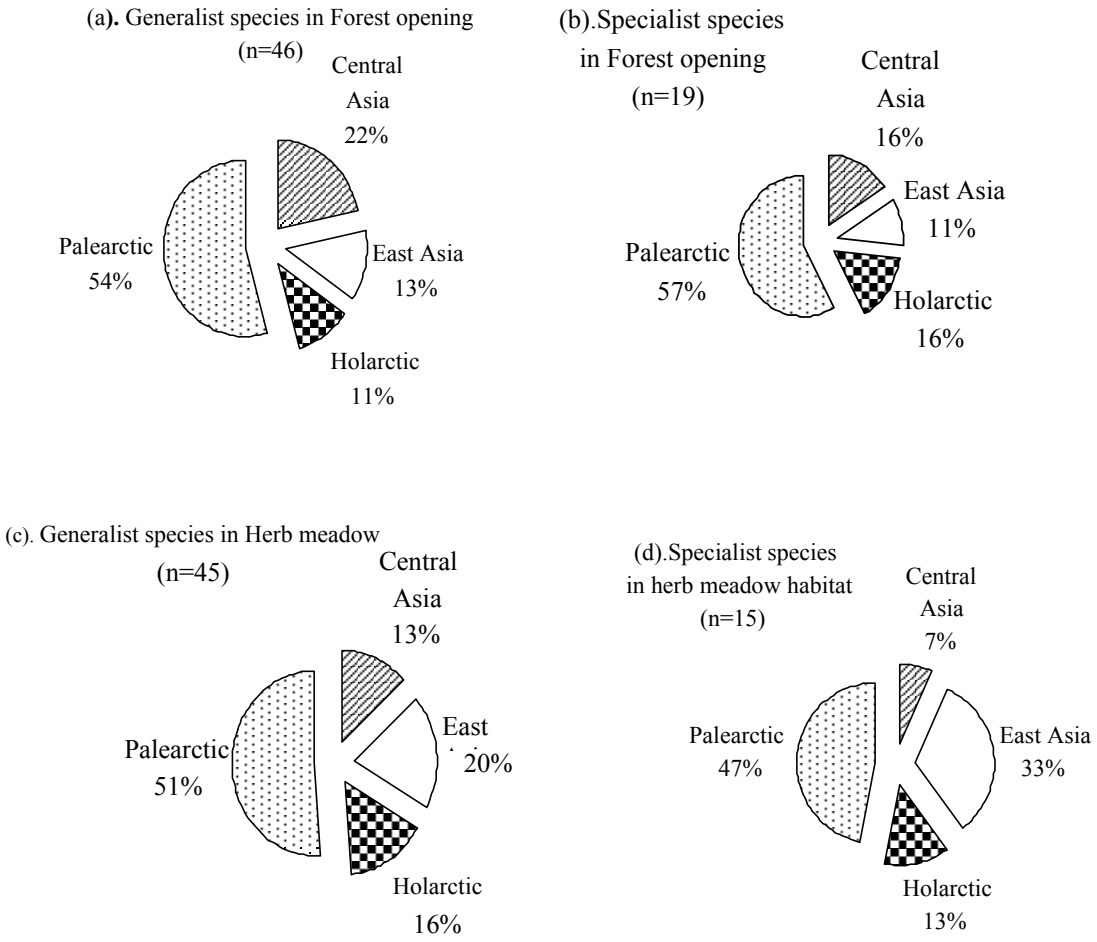

Figure 30. Habitat preference and biogeographical range is shown separately for generalist and specialist species. MDS= mountain dry steppe, WG= wet grassland. The graph shows the significant differences between habitat types (ANOVA; (F (3, 0) =0.0; p<0.00 in each cases) for the specialis group.

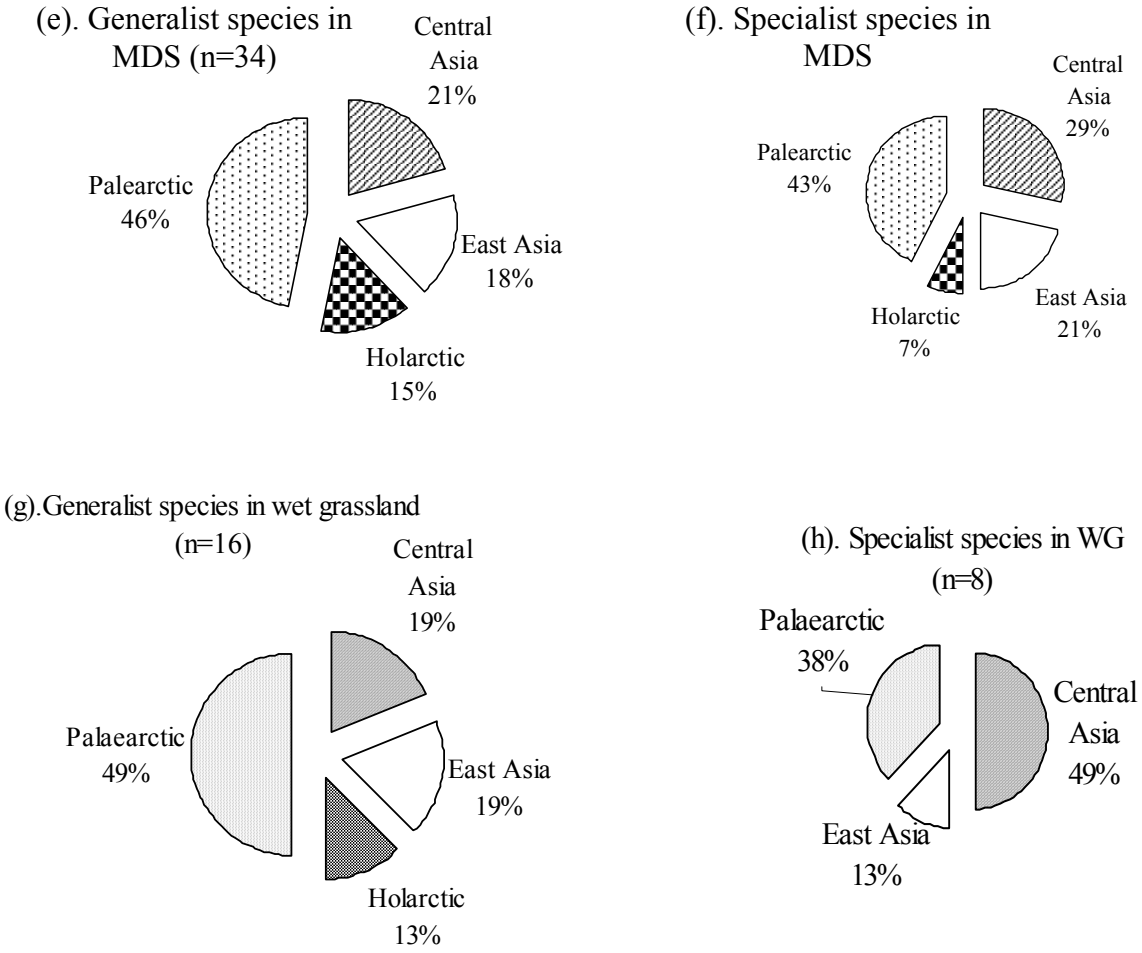

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Foto 10. The Scarce copper *Lycaena virgaureae*. The distribution of this species covers most of Central and Eastern Europe and Northern Europe up to polar circle, and Turkey to Mongolia

Therefore, I examined the butterfly habitat selection of Palearctic species (e.g. species inhabiting Britain, Germany and West Khentej (Mongolia)). The majority (72% of all joint species) of the West Khentej species which occur also in Germany and England were recorded in all habitat types (Fig. 31). For example, *Lycaena virgaureae* is occurs in every habitat type of West Khentej region (Foto 10).

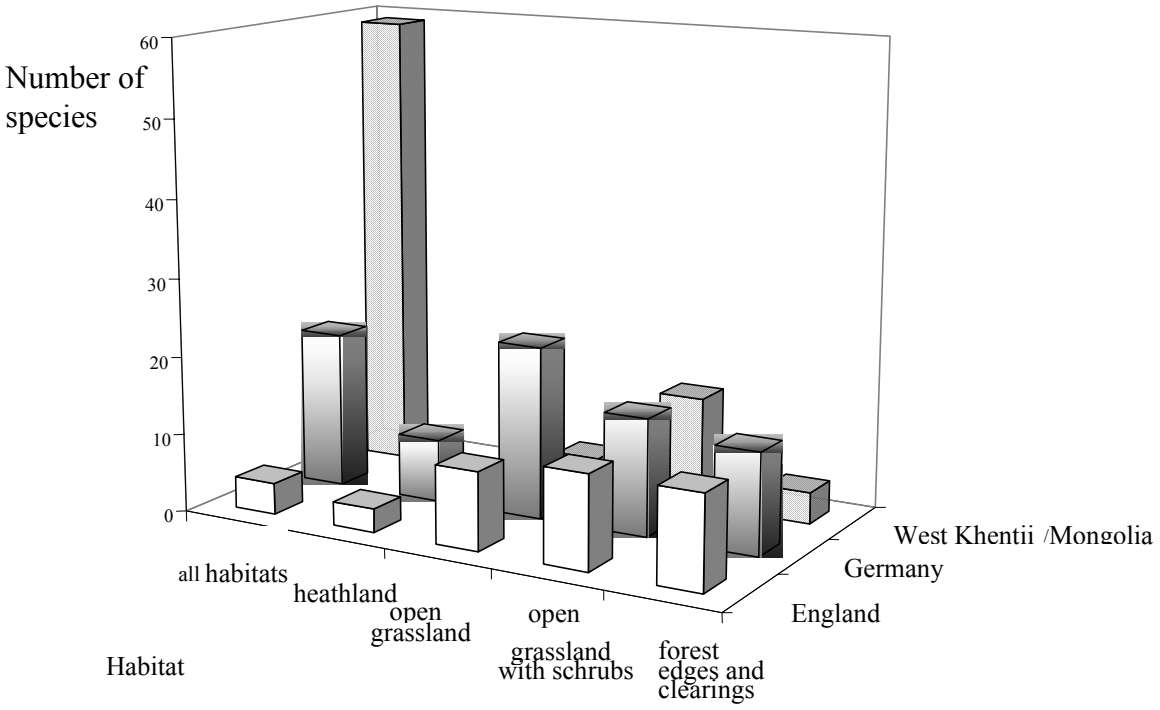

Figure 31. Habitat selection of butterfly species in different regions of palaearctic range. 81 species were chosen for this classification.

Most of German (31% of total shared species) species were associated with open grassland, followed by species which occupy different habitat types (all habitats). More than half (57%) of Brithish butterflies were connected with open calcacerous grassland and open grassland with scrubs and clearings.

4.6 Food plants

In an examination of hostplants, according to the informations from Korshunov (2002) and Tuzov (1997, 2000), there were 6 monophagous (for definition see methods chapter 4.4), 40 oligophagous (such as: *Agrodiaetus amandus, Anthocharis cardamines, Aricia agestis,*), 21 strongly oligophagous (e.g. *Aricia eumedon, Boloria selenis, B. angarensis, Triphysa phryne*) and 55 polyphagous species in West Khentej. Polyphagous species were dominant in West Khentej (they constitute about 40% of total butterfly species).

The distribution of those species (monophagous, strongly oligophagous, oligophagous, polyphagous) among four different habitat types is shown in Fig. 32. Polyphagous species constitute in each habitat type the biggest proportion.

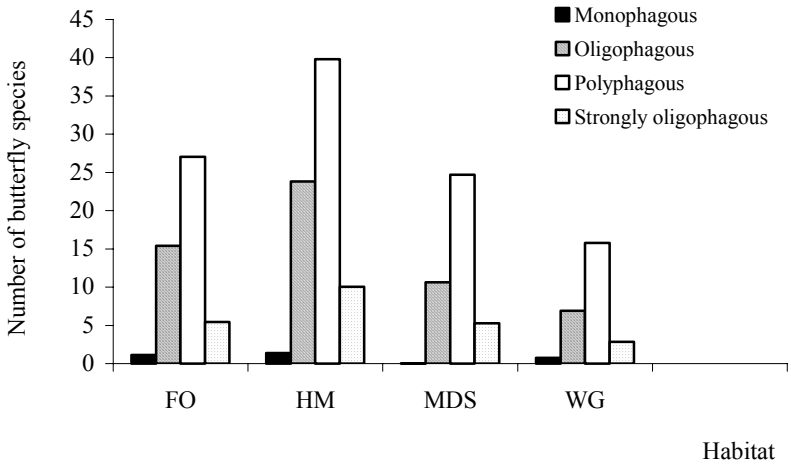

Figure 32. Feeding patterns of butterfly species among different habitat types. FO= forest opening, HM= herb meadow, MDS= mountain dry steppe, WG= wet grassland.

Statistic analysis of those species reveals that the distribution of monophagous and strongly oligophagous species are not significantly different among habitat types (ANOVA; $F(3,187)=0.45$; $p<0.7$; $F(3,187)=1.69$; $p<0.17$, respectively), but distribution of oligophagous and polyphagous species were significantly different (ANOVA; $F(3,187)=3.53$; $p<0.01$; $F(3,187)=4.49$; $p<0.004$, respectively) throughout habitat types (Table 14).

	Monophagous	Oligophagous	Polyphagous	Strongly oligophagous
Forest opening	1.12± 6.46	15.42± 21.49	27.04± 27.74	5.46± 11.96
Herb meadow	1.37± 8.99	23.83± 42.07	39.81± 44.31	10.05± 25.05
Mountain dry steppe	0.06± 0.31	10.65± 17.43	24.69± 29.10	5.26± 11.23
Wet grassland	0.76± 3.55	6.89± 10.03	15.78 ± 15.31	2.84± 6.51
Total	0.84± 6.00	14.87± 27.37	27.81± 32.83	6.18± 16.09
ANOVA/MANOVA	F(3, 187)=0.45 P<0.7	F(3, 187)=3.53 P<0.01	F(3, 187)=4.49 P<0.0045	F(3, 187)=1.69 P<0.17

Table 14. Number of species which are described as monophagous, strongly oligophagous, oligophagous and polyphagous in West Khentej.

I compared the specialisation on food plants with habitat niche width and distinguished species of monophagous generalist, monophagous specialist, oligophagous generalist, oligophagous specialist, strongly oligophagous generalist, strongly oligophagous specialist, polyphagous generalist and polyphagous specialist species which inhabit West Khentej (Table 15).

Host plant specifity	Generalist	Specialist
Monophagous	2	1
Oligophagous	21	15
Strongly oligophagous	12	7
Polyphagous	28	19
Total number	63	42

Table 15. Classification of host plant specifity with habitat breadth.

For instance, the species *Maculinea teleius* is a monophagous species (e.g. caterpillars feed only on the flowerbuds of *Sanguisorba officinalis*), but this butterfly is a generalist in its adult stages. In other words, *Maculinea teleius* can occur in almost every habitat type of West Khentej, because *Sanguisorba officinalis* occurs in wet grassland, herb meadow, and mesophilous grassland under canopy as well as in meadow steppe.

Lycaena helle fly as specialists for herb meadow and wet grassland, but they could be encountered also in forest opening and meadow steppe (see App.8). The food plants (e.g. *Rumex acetosa* and *Polygonum sp*) of this butterfly occur in wet grassland in West Khentej.

Lycaena virgaureae is strongly oligophagous and a very widespread habitat generalist in West Khentej. This species can be encountered in all four habitat types. *Rumex spp.* (e.g. *Rumex acetosella* and *R. acetosa*) is recorded as food plant of *Lycaena virgaureae* (Douwes, 1975; Schneider, 2003; Settele et al., 1999). But the *Rumex* species occur only in wet grassland

habitat (Foto 11). There is no correlation between food plant specifity and habitat utilisation of adults.

Foto 11. *Lycaena helle*, female. Flight period: from end of May to end of June

Triphysa phryne is another strongly oligophagous butterfly. However it was a habitat specialist butterfly in west Khentej. This species is nearly confined to mountain dry steppe. The larva feeds on *Stipa krylovii*. The distribution of this plant species is restricted to the mountain dry steppe habitat of West Khentej.

One example of the polyphagous generalist species is *Erebia neriene*. Food plants of this species are *Poa pratense, Festuca rubra, Calamagrostis sp.,* other *Poaceae* and *Carex* (Korshunov & Gorbunov 1995). This butterfly species is distributed all around the West Khentej. For example, *Poa* and *Carex* species are everywhere among the different habitat types, the species of *Calamagrostis* genus occur in forests.

In West Khentej region, the Nymphalidae family includes 29 polyphagous species (23% of all butterflies and 49% of total polyphagous species). Most of the oligophagous and strongly oligophagous species belong to Lycaenidae (Fig.33).

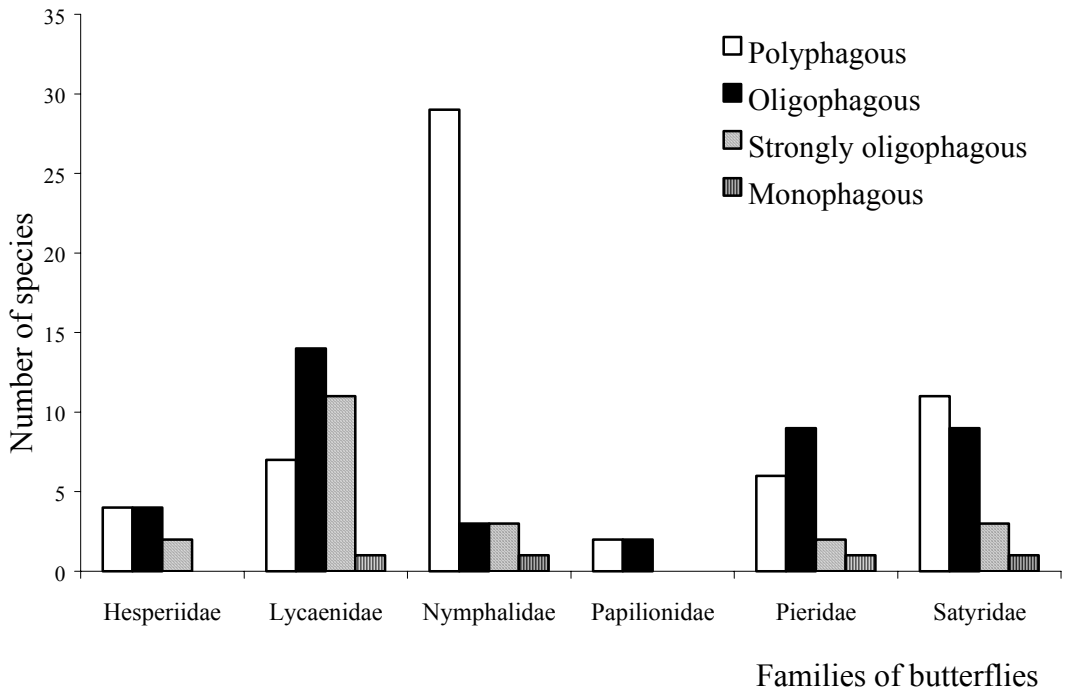

Figure 33. Feeding behaviour of butterfly families in West Khentej: Polyphagous species peak at the Nymphalidae family.

All polyphagous Nymphalidae show palaearctic distribution such as *Aglais urticae, Argynnis paphia, Euphydryas maturna, Nymphalis antiopa, Nymphalis polychloros*.

The majority (25 species) of oligophagous and strongly oligophagous Lycaenidae show also a wide range of distribution (Palaearctic), only 4 species have a Central Asian distribution such as *Plebejus eversmanni, Glaucopsyche lycormas, Polyommatus eroitides,* and *Polyommatus icadius*. Oligophagous and strongly oligophagous species with East Asian distribution include 2 species of Satyridae, Pieridae and Hesperiidae each, and only 1 Nymphalidae species. Monophagous palaearctic species include *Maculinea teleius* and *Mellicta plotina*. Monophahous species with East Asian distribution include only one species of Satyridae (App. 11). Butterfly species with a taxonomically wide range of food plants (generalist) tend to be more widely distributed than butterflies that use only one species or genus of host plant (Cowley *et al*. 2001), see for Khentej species in Fig. 34.

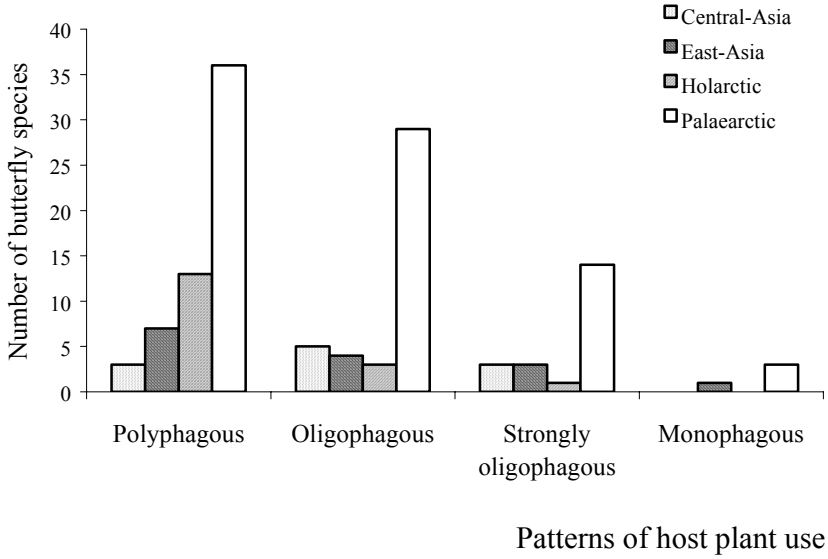

Figure 34. Biogeographical classification of butterfly feeding behaviour.

The majority (70% of total butterfly fauna of Khentej) in the study area are herb/grass feeders, 7% of the total were feeders on trees and bracken/bushes (Table 16).

Host plant group	Number of butterfliy species in the guild
Herbs	77
Tree	5
bracken/shrub	6
Grass	23
Total number	111

Table 16. Host plant type of West Khentej butterflies.

Out of the abundant species 63% are herb feeders, 17% grass feeders and 11% feed on wooden plants (see chapt. 5.3).

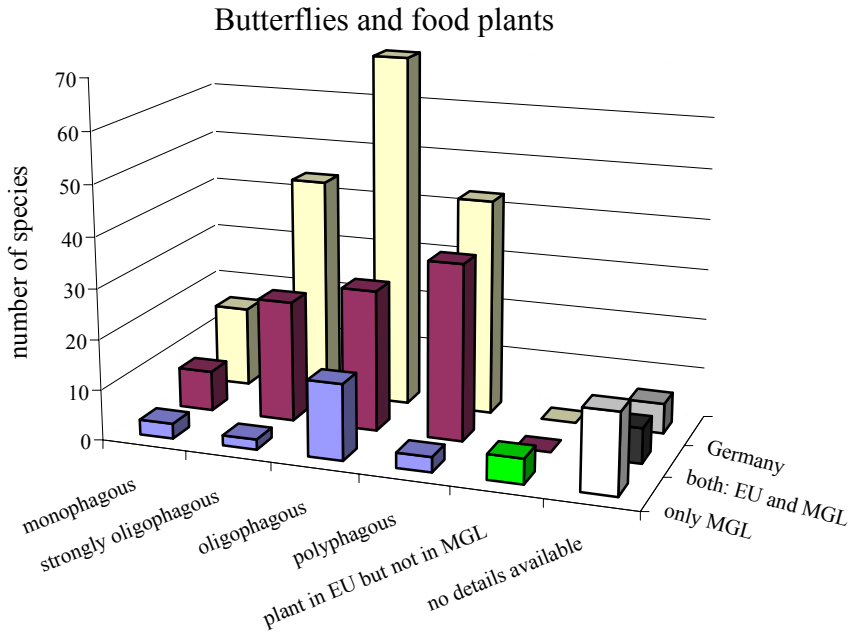

Figure 35. Butterfly species with larger geographic ranges are more likely to be polyphagous than restricted range species

Butterfly species with larger geographic ranges are more likely to be polyphagous than restricted range species**.** Being able to identify regional plants may be helpful in locating populations of butterflies in nature (Dubatolov & Kosterin, 2000). They acted that the distribution of broad-leaved forests could be determine the characteristic of insect fauna. For example, numerous species which develop only on particular broad-leaved trees can be found in Europe and East Asia, such as: *Parnassius mnemosyne* L., *Parnassius stubbendorffii* Mén. (Papilionidae); *Pyrgus maculatus* Brem. & Grey (Hesperiidae), *Ahlbergia frivaldszkyi* Led. (Lycaenidae), in which the main part of the range lies within the zone of broad-leaved or coniferous/broad-leaved forests (Dubatolov & Kosterin, 2000).

4.7 Population dynamics of selected species

The analyses of the butterfly distribution of 144 species from the survey period 2000-2003, suggested for few species an increasing trend and for few other species a decreasing trend, but most of the species showed relatively constant population size. For a detailed analysis I have chosen some Palearctic butterfly species that are threatened in Europe to compare with the known trend of the species in Europe.

Species with increasing populations were *Aporia crataegy, Nepthis rivularis,* and *Aricia eumoden* which are very abundant and widespread throughout the West Khentej. *Papilio machaon* in West Khentej is recorded in all habitat types and a common species without noticeable biotope preference (Chikolovets 1994). It declined in 2003. *Everes argiades* declined in two years consecutivly, it inhabits various meadows and openings (Fig. 35).

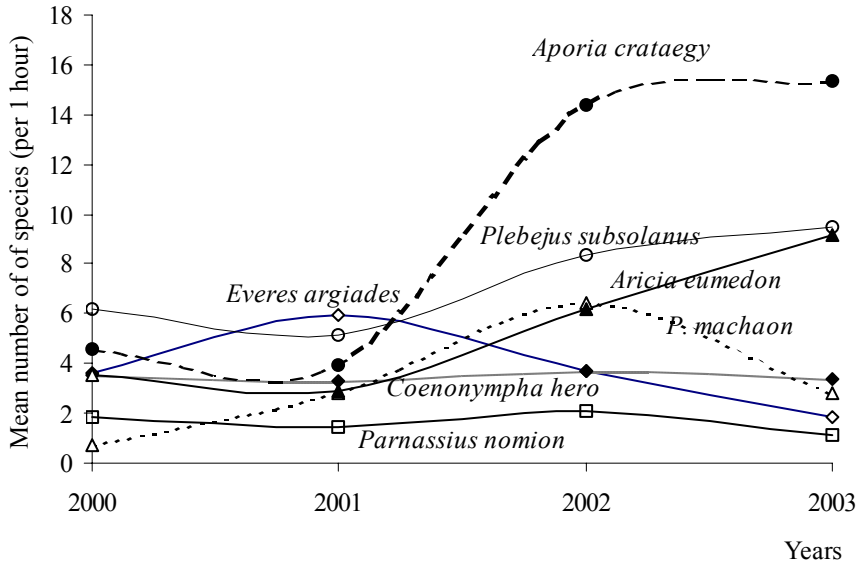

Figure 36. Population dynamics of some selected species. Mean number of individuals calculated as individuals captured per 1 hour. Population fluctuations of the majority of species were relatively constant in West Khentej.

The population density of most species indicated a constant population size, for example: *Coenonympha hero, Coenonympha oedippus, Lycaena helle, Cupido minimus, Euphydryas maturna,* which are all listed as threatened in Europe (Table 17).

Species name	F(FG1,2)	p-value	increasing (+) or decreasing (-) trend
Neptis rivularis	3,43	0,02*	(+)
Plebejus subsolanus	0,52	0,66	relatively constant
Everes argiades	2,83	0.05#	(-)
Aricia eumedon	4,19	0,01*	(+)
Lycaena helle	2,16	0,1	relatively constant
Coenonympha hero	0,03	0,99	relatively constant
Boebera parmenio	4,4	0,009*	(+)
Coenonympha oedippus	0,83	0,48	relatively constant
Papilio machaon	11,22	0.00#	(-)
Cupido minimus	0,48	0,69	relatively constant
P. semiargus	0,77	0,51	relatively constant
Euphydryas maturna	0,79	0,5	relatively constant
Parnassius nomion	0,52	0,66	relatively constant
Mellicta phoebe	1,27	0,29	relatively constant
Aporia crataegy	3,45	0,02*	(+)
Argynnis paphia	5,99	0,007*	(+)
Aphantopus hyperantus	2,46	0,09	relatively constant

Table 17. Statistics of population development analysis. * significant increasing, #significant decreasing population trend.

The population density of *Coenonympha oedippus* (a species listed as extinct in Red Data Book of Germany) was similar (Fig. 37) between years 2000 and 2003 (comparison of mean average individual number: ANOVA, F = 0.83, df = 3, P< 0.48).

Foto 12. False ringe (*Coenonympha oedippus*), species of high conservation interest, extinct extinct in Germany, critically endangered in Europe.

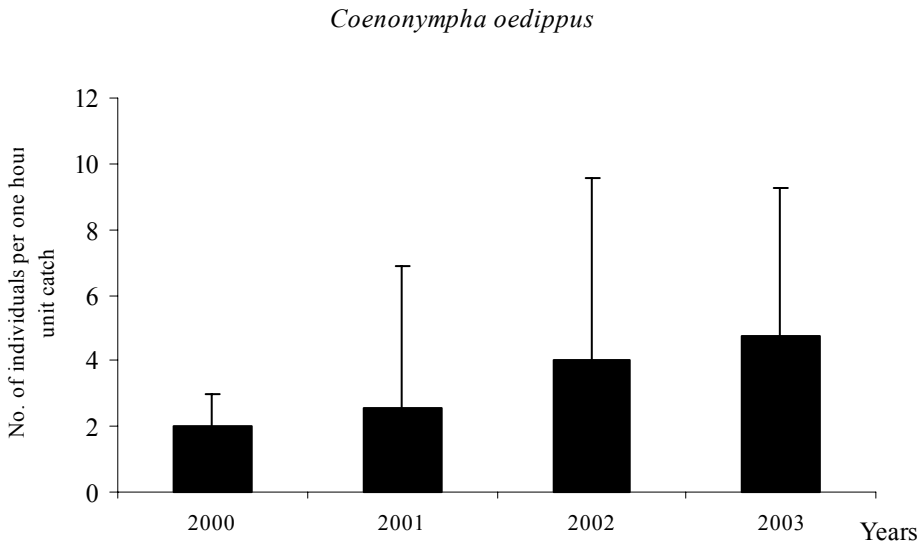

Figure 37. This figure shows one example of species with a nearly stable population (frequency of individuals per unit sample) between 2000 and 2003.

Other species of constant population as *Aphantopus hyperantus* (Satyridae), *Inachis io, Plebejus subsolanus, Everes argiades, Lycaena helle, Coenonympha hero, Coenonympha oedippus, Cupido minimus, Polyommatus semiargus, Euphydryas maturna, Parnassius nomion, Mellicta phoebe, Aglais urtica,* did not differ significantly between the years of 2000 till 2003 (Table 17*)*. Nevertheless, several species (*Everes argiades*, *Papilio machaon*) show a declining trend. On the other hand, some species have an increasing trend of the population (e.g., *Neptis rivularis, Aricia eumedon, Boebera parmeno, Aporia crataegy, Argynnis paphia*).

4.8 Mobility of adults of selected species

The scarce copper (*Lycaena virgaureae* L.; Foto 13*)* was predominantly studied in natural landscapes with more continuous habitats in herb meadow grassland areas. A total of 1345 butterflies (758 females, 587 males) were marked during the 1 month recapture study. 19 % of all marked individuals were recaptured within 4 weeks. 26% of males and 13% of females were recaptured at least once (Table 18). The maximum time interval between mark and recapture was 24 days for males and 22 days for females.

Foto 13. *Lycaena virgaureae* L. It is quite common in Eastern Europe in mountain ranges from 900 up to 2000m. These pictures were taken in West Khentej. Male has an orange upper side, the female is more yellowish with dark brown drawings. The under side is orange-brown with big black spots on the upper wings and some white spots on the lower wings.

Capture category	Male		Female		Total
	n	%	n	%	
Recaptured once	115	77	84	84	199
-twice	24	16	13	13	37
-three times	10	7	3	3	13
-four times	1	1	0	0	1
Total recaptured	150	26	100	13	250
Disappeared	437	75	658	87	1095
Total marked	587		758		1345

Table 18. The recapture records of *Lycaena virgaureae* in herb meadow habitat of West Khentej. The survey was carried out between 25 July and 25 August 2004.

For the period of 24 days the mean distance moved by females in herb meadow was greater than the distance covered by males. The mean distances moved by *Lycaena virgaureae* was smaller for both sexes than reported in other studies (Schneider, 2003). Emigration and immigration from the study population were not examined in detail. Most of marked adults were recaptured from nearby previous place (Fig 38).

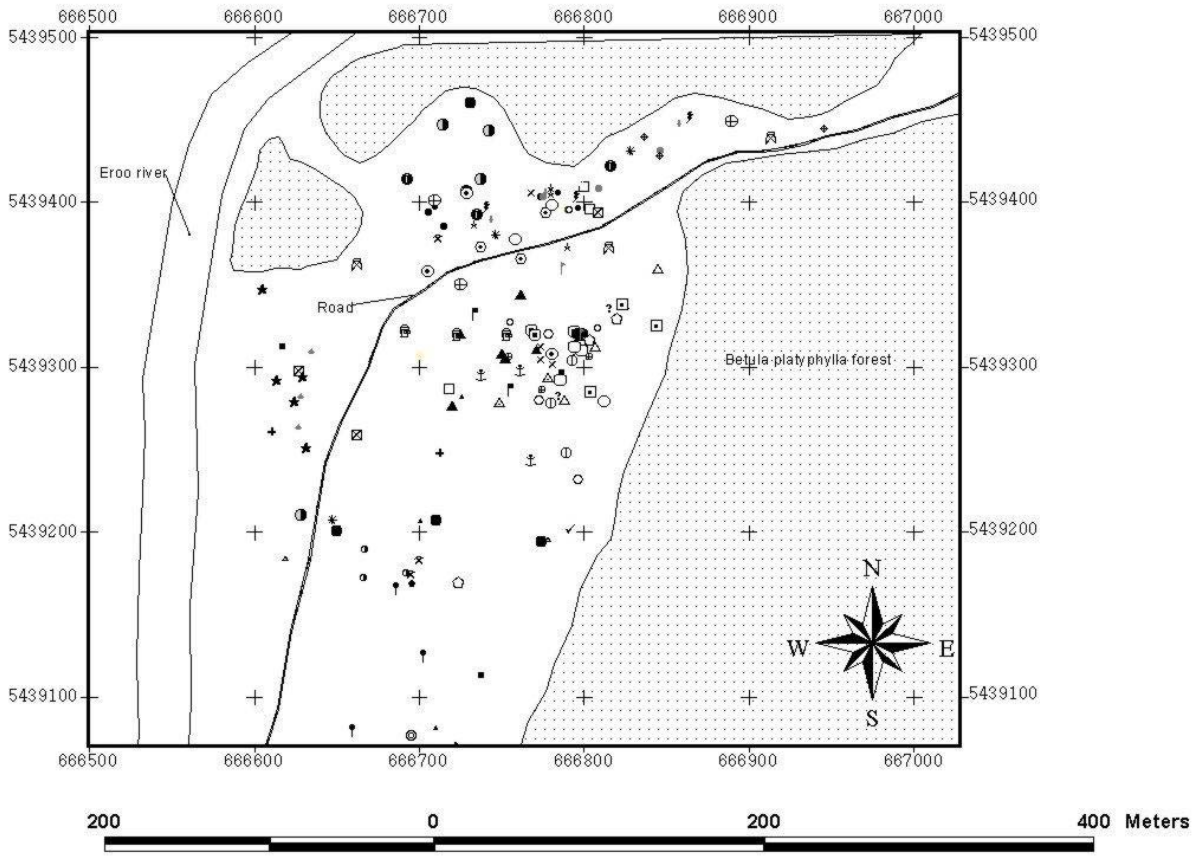

Figure 38. Map of the distribution of *Lycaena virgaureae* in one habitat type. Butterflies were recorded in open herb meadow. Symbols represent the position of each individual captured, same symbols indicate movement positions of an individual.

Figure 38 shows for *Lycaena virgaureae* that the majority of individuals remained within fairly small areas in the open landscape although no borders or barriers limited the movement. For example, the individual marked by the symbol (★) recaptured four times after the first release, but the total distance covered by this individual was only 56 metres.

The distances moved between 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 19).

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

Table 19. The mean distance moved by *Lycaena virgaureae*.

The mean distance moved at different time intervals between recaptures is plotted in Fig 39. For the time intervals between recaptures, mean distances moved by females was greater than by males. This figure shows that females move at a constant rate whereas males increase their distance in time between recaptures (for males 91 ± 75 m at short interval compared with 190 ± 140 m at longer interval (recaptured after more than 10 days); ANOVA, $F(1.38) = 9.12$; $p<0.004$). The mean distance moved by female was not significantly different (ANOVA, $F(1.38)=2.74$; $p<0.1$) between time intervals. The greatest distance between recaptures were 705 m for females and 633 m for males. Marked individuals moved freely throughout the mark-recapture circuit, but females had moved farer than males when recaptured within different time intervals (Fig. 39). However, recapture results show great differences between mean distances moved by males and females (Table 19).

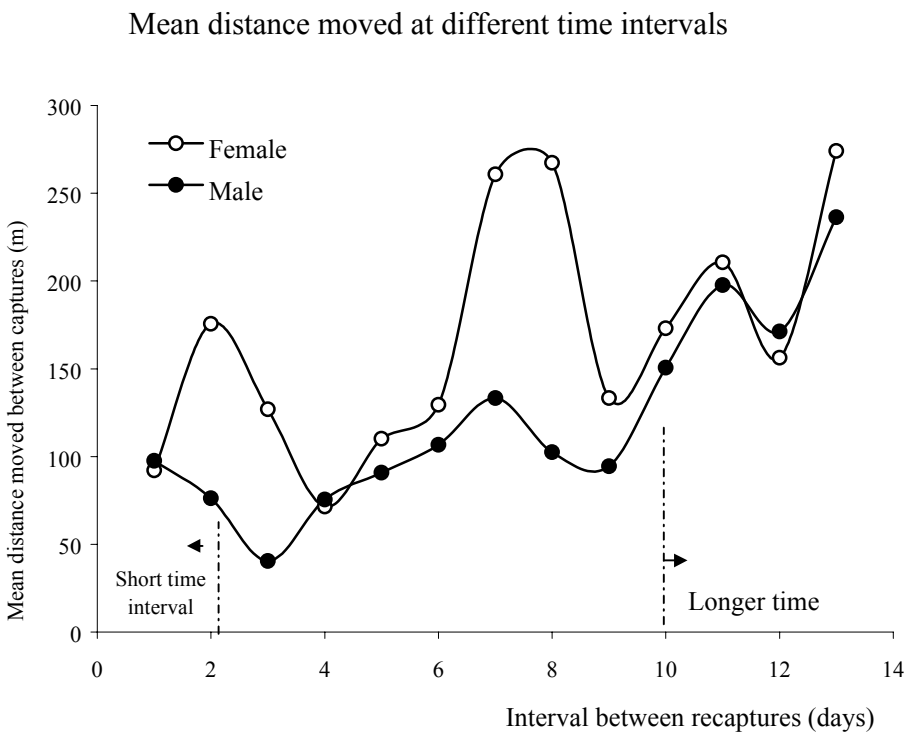

Fig. 39. Mean distances moved at different time intervals between recaptures for *Lycaena virgaureae* adults.

51% of the linear distances moved by *Lycaena virgaureae* were more than 100 meters, 29% less than 50 meters. The mean distances between first and last recapture was not significantly different (Fig. 40) for both sexes (149 ± 133 m for females; 104 ± 71 m for males; ANOVA, (F1.28)= 1.30; p< 0.26). However, the mean moved distances by L*ycaena virgaureae* was significantly different among the recaptured times. The maximum range is calculated for individuals captured three or more times (for males 174 ± 117 and 388 ± 287 for females).

The total distance covered by the lycaenids was significant higher than the distance between first and last recapture (ANOVA, F(1.98)=12.20; p<0.0007). That means *Lycaena virgaureae* remains in its habitat within a restricted area.

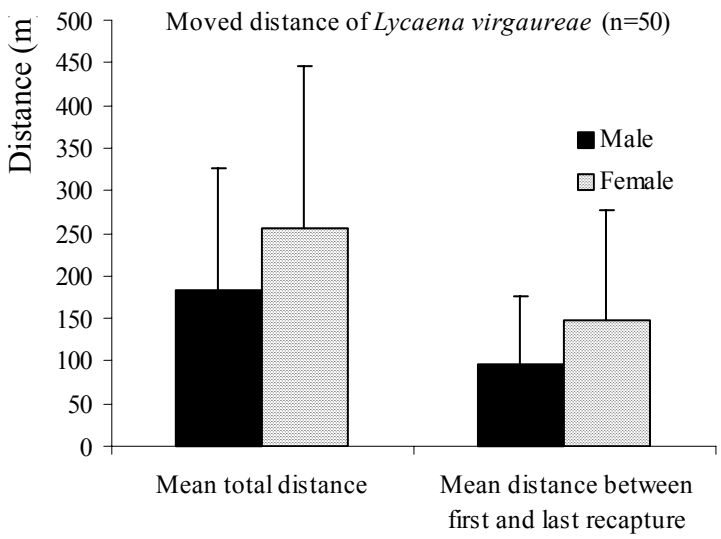

Fig 40. Mean distances at different movement parameter. Mean distances between first and last recapture was shorter than mean total distances and not significantly different for both sexes.

4.9 Adult population size of *Lycaena virgaureae*

The scarce copper *Lycaena virgaureae* L. is an univoltine butterfly with adults flying between middle of Juny and late of August (Tuzov, 2000; Settele et al., 1999; Schneider, 2003). During the flight period, study site was visited as often as possible, weather permitting. The data can be used to estimate the sex ratio. The analyses was performed by grouping dates together and dividing the survey period into three discrete section, approximately equal time interval (9-10 days). The adult counts of *Lycaena virgaureae* indicates that males emerged first and were captured more frequently than females (Table 20).

Phases of flight period	Number of individuals				p-value
	Male	SD	Female	SD	
first appearance (25 July-02 Aug.)	90,67	9,71	16,00	13,53	0.001*
peak flight activity (06 Aug.-16 Aug.)	58,33	14,19	67,33	21,03	0.57
end of flight period (17 Aug.-25 Aug.)	10,00	3,61	56,00	20,66	0.01*
p-value	0,0002*		0,03*		

Table 20. The sex ratio of Lycaena virgaureae at different attributes of flight period. Average number of *Lycaena virgaureae* caught in three attributes of flight period censused on each time interval.

Population size of the scarce copper was estimated using the capture-recapture data. Butterflies were surveyed from the beginning of the flight period until the end of flight period.

Male can reach large numbers before a single adult female is seen. The estimated population size was not significantly different between sexes (ANOVA, $F(1.46)=3.24$; $p<0.07$) over the whole surveyed flight period, but males appear earlier and females stay longer in the habitat (Fig 41).

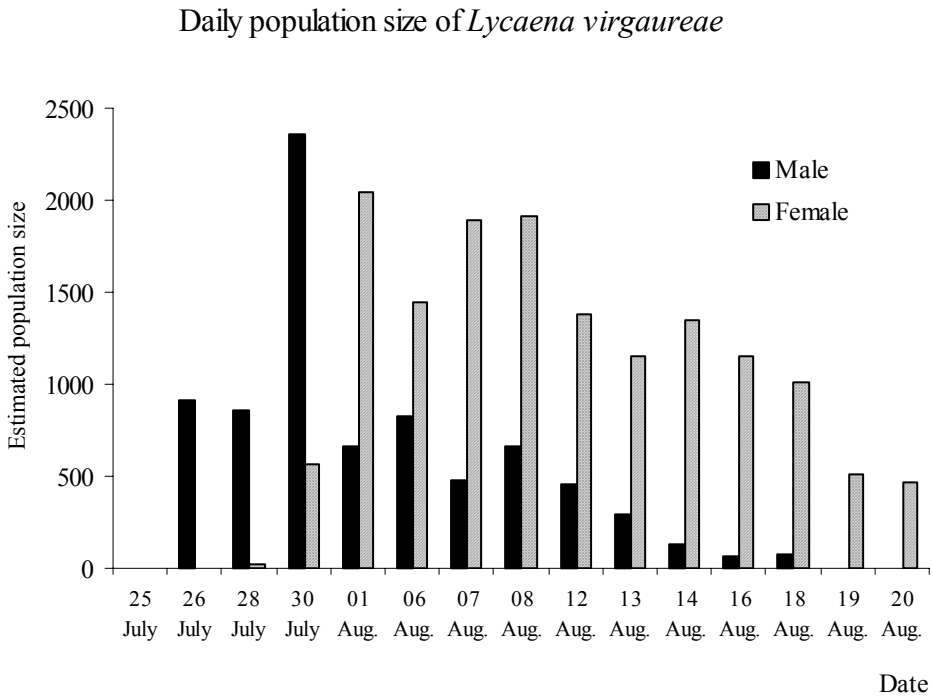

Fig. 41. Estimated population size of *Lycaena virgaurae* recorded between 25 July and 25 August. Daily change in the number of adult population estimated by the Jolly-Seber method.

The estimates of male and female populations suggest a slight preponderance of females, but statistic examination showed no significant differences from a 1:1 ratio. The estimated total population on the study site was 2880 (recapture calculation by the). The scarce copper flies in West Khentej in one generation between middle of July and August and its highest abundance was around the beginning of August (Fig 41). The total numbers of individuals which were recorded between 02-08 Aug. are approximately 30% of all captured individuals.

There were several significant relationships between the abundance of *Lycaena virgaureae* and the nectar plants (Fig. 42). The female population size was positively correlated with abundance of *Achillea asiatica* and *Aster tataricus* (Spearman rank, $r_s=0.58$; $p<0.01$). The data showed a significant relationship between male abundance and *Potentilla fragarioides* (Spearman rank, $r_s=0.51$; $p<0.05$).

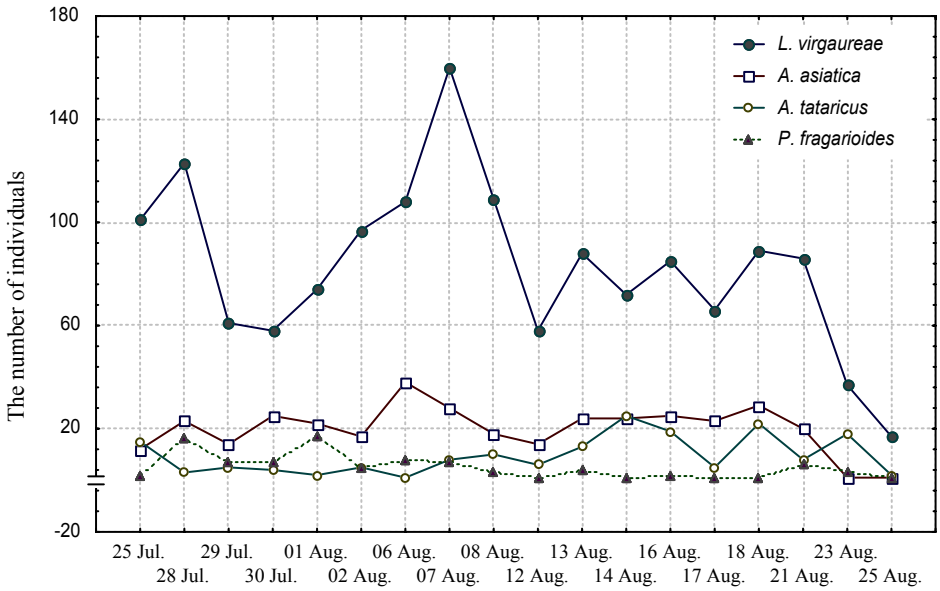

Fig. 42. Total numbers of individuals of *Lycaena virgaureae* and nectar plants recorded per plot censused on each date. Number of individuals peaked between the days 02-08 Aug. 2004. These selected plants are used as nectar source for *Lycaena virgaureae*. The flowering period of *Achillea asiatica* was between June and August. The greater percentage of flowers during the study was obtained from end of July to end of August. The peak abundance of *Potentilla fragarioides* occurs in July (Qin et al., 2003). *Aster tataricus* starts flowering in late summer (Mühlenberg et al., 2000b).

The results obtained for *Lycaena virgaureae* indicate that at different times of the flight period, different resources are more important (Auckland *et al*., 2004). This was presumably because of the flowering phenology of nectar plants. The peak abundance of *Potentilla fragarioides* occurs in July (Qin et al., 2003). During the survey period of *Lycaena virgaureae*, the number of males was dominant at end of July and most males were observed visiting *Achillea asiatica, Potentilla fragarioides* and *Aster tataricus.* 46% (n=761) of all butterflies were captured from the feeding plants. The most popular source of nectar was *Achillea asiatica* (25% of total captured butterfly was using this plant). The majority of the males (59% compared with 49 % for female) were flying or perched on vegetation at the moment of encounter, it has been shown that males tend to fly more frequently than females (Brakefield, 1982a; Pullin, 1997; Fisher *et al*., 1999).

4.10 Conservation value of the Khentej for butterflies.

It is the first time that the butterfly community of this region has been investigated with standard methods. Although quantitave data on the occurence and abundance of Mongolian butterfly species have not been available for the country, only 6 butterfly species (*Parnassius apollo, Parnassius eversmanni, Parnassius stubbendorfi, Parnassius phoebus, Parnassius*

tenedius, Papilio machaon) are listed in the Mongolian Red Data Book from whole country (Shiirevdamba 1997). We can compose the palaearctic species of Mongolia with their conservation status in Germany or Europe. *Coenonympha oedippus* is listed as "extinct" in the Red Data Book of Germany and it is already mentioned on Appendix II of the Bern Convention at present (van Swaay and Warren 1999) and considered threatened in Europe under the threat status "critically endangered" (Bundesamt für Naturschutz, 1998) (Fig. 43; Appendix 10).

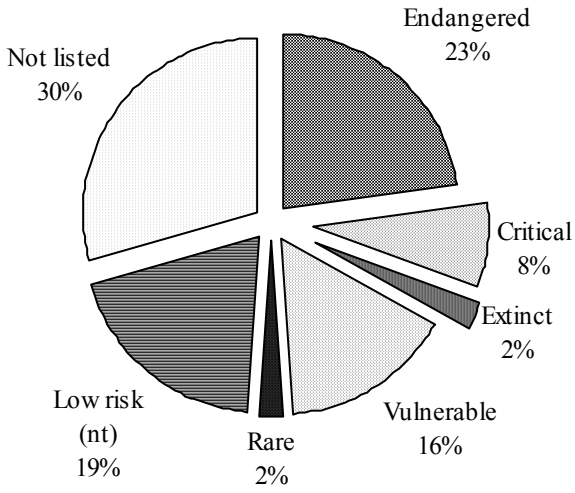

Figure 43. Proportion of palearctic species from Mongolia within each threat status for Germany (n=62). Low risk (nt)-near threatened) = conservation dependent species.

Many species which are ranked as "extinct", "critically endangered" or "endangered" in Europe (e.g: *Leptidea morsei, Nymphalis vau-album, Euphydryas intermedia, Triphysa phryne, Coenonympha glycerion, Lycaena helle, Coenonympha hero*, *Cupido minimus*, *Nymphalis polychloros*) are recorded in West Khentej as abundant species (Appendix 10).

DISCUSSION

5.1 Climate

There are many evidences of effects from climate on butterfly populations (Camille et al., 1999; Choi, 2003; David, 1998; Poy and Sparks, 2000; Dunn and Winkler, 1999; Walter et

al., 2002; Warren et al., 2001; Dennis, 1993). In this study no experiments concerning climate factors were carried out, but some extreme events coincidented with either increase or decrease of some species. However, there are some personal observations on lepidoptera species in West Khentej. For example, A large gypsy moth outbreak occurred during the last three years in West Khentej. Eggs hatch in late May into tiny black, hairy caterpillars (Foto 14).

Foto 14. Newly hatched caterpillars of *Lymantria dispar* (L.). Foto was shot in end of May in West Khentej. Huge outbreaks of *Lymantria dispar* occurred in Byryatiya (neighbouring country of West Khentej) in earlier years.

Newly hatched caterpillars climb into tree canopies and begin feeding. The greatest feeding damage is done by older caterpillars during the first two weeks of July. Egg masses are deposited during mid to late July. When the larvae densities reach very high levels, trees may become completely defoliated (Foto 15) and that happens in natural landscape without human disturbance. Kharul et al. (2003) said that the catastrophic outbreaks of Siberian silkmoth are induced by a combination of favorable weather conditions (e.g. optimal temperature and low levels of precipitation).

Foto 15. The *Salix sp*. is eaten by catepillars of *Lymantria dispar* (L.).

Several autors (e.g. Kharuk et al., 2003; Raimondo et al., 2004) pointed to the synchrony of environmental factors, such as weather deviations, and butterfly' survival or reproduction. We could observe mass production of *Aporia crataegy* and *Argynnis paphia* (Foto 16).

Foto 16. Mass production of *Argynnis paphia* recorded in the study region between 2001-2003.

Argynnis paphia is a very common species in this region. Butterfly abundance data showed a certain effect on the population of *Argynnis paphia* (chapter 4.4). The abundance of *Argynnis paphia, Aporia crataegy, Neptis rivularis* became significantly higher between 2001-2003.

Similar results, with high abundance of fritillaries (e.g. *Argynnis paphia*) were recorded at the same time period in the northern taiga zone of the western Russian Plain (Bolotov, 2004). The population fluctuation may be related to the insreasing summer temperature (Pollard, 1988; Bolotov, 2004; Bryant et al., 2002).

Causes of natural changes in butterfly number, commonly manifested as a temporary decline or increase, include weather, natural enemies, other animals (such as the variability and abundance of particular ant species for Lycaenidae) (New 1997; Dennis, 2004) and vegetational or habitat change (van Swaay & Warren, 1999; Rodriguez et al., 1994; Bergman, 2001; Saarinen and Jantunen; 2004; Dolek & Greyer, 1997; Swihart et al., 2003; Inoue, 2003; Bergman et al., 2004). Although Mongolia shows many extremes in climate, the continental climate with its warm summer provides good conditions for reproduction (Saarinen, 2002).
New (1997) described some factors leading to decline in butterfly populations and gave examples of effects of adverse weather such as droughts or late frosts (that could also kill young foliage needed as food), which impose direct mortality. Hill and Fox (2003) noted that approximately 20% of British butterflies have increased their ranges during recent climate warming. However, most of British butterfly species have declined due to the negative effects of habitat loss (e.g. causes of climate warming commonly manifested as a habitat loss) (Hill & Fox, 2003). Butterfly Monitoring Scheme data show many short-term effects of climate on population increase of several species in the last 25 years (www.butterfly-conservation.org.).
In West Khentej, the species *Argynnis adippe, Argynnis aglaja, A. niobe, A. paphia* seem to prefer dry spring and hot summer. The first emergence of those butterfly species were recorded end of June and they fly until end of August in West Khentej. The *A. adippe* - larvae hatch in March (at end of April in West Khentej) and become fully grown by the end of May or beginning of June (Barnett & Warren 1995). The authors pointed that the duration of the prepupal period depends on the temperature. Pollard (1988) found a positive association of the spring-flying butterflies (e.g. *Erynnis tages* and *Pyrgus malvae*) with temperature. He discussed the effect of warmth on egg-laying and early larva survival rate, both increasing with temperature. He mentioned that many species (e.g. *Erynnis tages, Polyommatus icarus, Aricia agestis, G.rhamni, Maniola jurtina, Coenonympha pamphilus*) may increase in abundance if summer temperatures increase. Mongolia has an extreme continental climate characterized by sharp seasonal fluctuations with long, cold winters and short summers, in August most precipitation falls. In 2002, there were a lot of weather extremes in West Khentej. Summer months were very hot and the winter period was very cold (much colder

than previous years). The May was unusually rainy. The extreme precipitation in May 2002 in the study region could influence the population of butterflies that "hibernate" over winter as adults. The population dynamic of an insect population depend on mortality at various stages of the life cycle (Dennis, 1992). There are a number of butterflies that "hibernate" in winter as adults (e.g. *Nymphalis vau-album, Nymphalis antiopa, Nymphalis polychloros, Polygonia c-album, Aglais urticae)*(Dennis, 1992; Setelle, et al., 1999, Korshunov & Gorbunov, 1995). These nymphalids are recorded mainly in early spring when they emerge from hibernation and feed on birch sap, mate, and lay eggs when it starts to warm up (Tuzov, 2000). For instance, *Nymphalis antiopa* needs a warm and dry spring (van Swaay, 1995). In West Khentej, I found many indications for adult hibernations of some species, e.g. for *Nymphalis vau-album, Nymphalis polychloros, Nymphalis antiopa, Aglais urticae*. They all emerge in early spring between April and May. First emergences of butterflies were recorded in middle of April in West Khentej and reproduction in May. All of those species such as *Nymphalis antiopa, Nymphalis vau-album*, showed a decreasing trend in summer 2002 (Appendix 15). Population fluctuations in *Nymphalis antiopa, Nymphalis vau-album* and *Aglais urticae* species might be linked to this factor - extreme precipitation in May. In this way this extreme extended either the egg laying or larval growth period and affect reproduction, survival, or development of these butterflies (Murphy et al., 1990; Mattoni et al., 1997). Fluctuations of butterfly species are related to preceding spring temperature (Dennis, 1992; Pollard, 1988), the timing of rainfall (Pollard, 1988; Roy et al., 2001) and adult emergence (Gutierrez & Menendez, 1998; Bryant et al., 2002; Stefanescu et al., 2003), and senescence of food plants (Hellmann, 2002; Pollard, 1988). Several authors (e.g. Murphy et al., 1990) found that the timing and duration of rainfall during the growing season are the best predictors of developmental phenology and adult emergence. The response of species to climate change can differ in different species (Pollard 1988; Dennis, 1993). Pollard said that species like *Lasiommata megera, Pararge aegeria* and *Aphantopus hyperantus* may not benefit from increased temperatures, but may decline in numbers, unless rainfall also increases. Bourn & Warren (2000) pointed to other effects on the mobility, e.g. *Cupido minimus* may show greater mobility and dispersal in hotter years. They noted also, that *Cupido minimus* populations fluctuate very much from year to year, probably in relation to variation in flowering of the foodplant. Climate change and predicted increase in the frequency of droughts could change the distribution of suitable habitats and could lead to declines in that species (Bourn & Warren 2000).

Murphy (1990) gave examples that extreme weather causes the decline or local extinction of butterfly populations and may be especially significant for small, isolated populations.

Global warming is one of the environmental factors now recognised as a driving force for change in the geographical range of butterfly species, and its effect on the survival of individuals (Dennis 1993; Pollard 1988; Hodar et al., 2002; Mattoni et al., 1997; Bolotov, 2004). Many of the current studies, aiming at predicting future distribution, assume that the current distribution of species are both correlated with and in equilibrium with the current climate (Sparks 1995).

Pollard (1988) showed a clear relationship between increased numbers of butterflies and warm, dry summers in England. Ehrlich (1972) documented that droughts in California and Europe have caused widespread declines in butterflies: and as one example, a late season snowstorm in Colorada extinguished a subalpine population of the lycaenid *G. lydamus* by distroying inflorescences of the larval foodplant, on which females oviposit. However, it may well be possible we have also to consider indirect effects, e.g. the climate influences the habitat condition of the butterfly, which in turn causes the changes in the abundance of the butterfly (van Swaay 1995; Ehrlich & Murphy, 1987; Murphy et al., 1990; Rodriguez et al., 1994; Raimondo et al., 2004). Climate change is one of the principle environmental challenges of the 21st century and it is already affecting the conservation of some ecosystems and species (http://www.iucn.org) including butterflies. Population dynamics and geographical distributions of butterflies are dependent on the climate. For example, complete life cycle of an butterfly species undergo through four different life stages (e.g. egg, larvae, pupa, adult) and all these stages are related to temperature (Warren, 1995). As average European temperatures increase, more butterflies are being found at higher latitudes and as well most British butterflies shift to the northern limit of their ranges in Britain (Hill & Fox, 2003).

In summary, there are many evidences of dependence of butterfly species on weather conditions, and we can attribute some examples of butterfly fluctuations to climate condition too.

5.2 Herbaceous vegetation cover

To examine the butterfly distribution among the study sites in West Khentej, the herbaceous plant community from two different habitat types (see the chapter 4.2) were chosen as one of the environmental variables. In the natural landscape of West Khentej, the herbaceous

vegetation cover was significantly different at two different habitat types (Fig. 9: Cluster diagram of herbaceous plant cover of West Khentej). Range of the differences was between 16%-23% (see 4.2).

The correlation between butterfly species richness and plant species richness of West Khentej indicated no significant (r_s=0.6; p>0.05) relationship between those communities (Figure 44), however, a weak positive correlation was found. Kremen (1992) summarised that butterfly species richness was significantly related to average floral richness.

The butterfly species richness among the neighbouring plots (HM3, MDS3 and MDS4) (see the Figure 4b. in chapter 2.2; Foto 17) was eighty eight species with 66% of shared species. Connectivity between habitats is thought to be an important factor for maintaining butterfly diversity and abundance (Steffan-Dewenter & Tscharntke, 1997). However, the topographically isolated habitat (e.g. HM3) sustained most (88 of the 144 species) of the species. On the other hand, the natural grassland (HM2; Foto 17) with a low variety of plant associations contains fewer species (62 of the 144 species) than the more heterogeneous landscape (HM3). This might be explained by its habitat quality or habitat type. Collinge et al. (2003) found highly significant effects of grassland type on butterfly species richness. The area (HM3; Foto 17) contains unique habitat types (e.g. area with a high variety of plant associations). The high variety of plant associations of this habitat could be related to its habitat heterogeneity (e.g. habitat differs by shortage of soil moisture or trees, open water and fields).

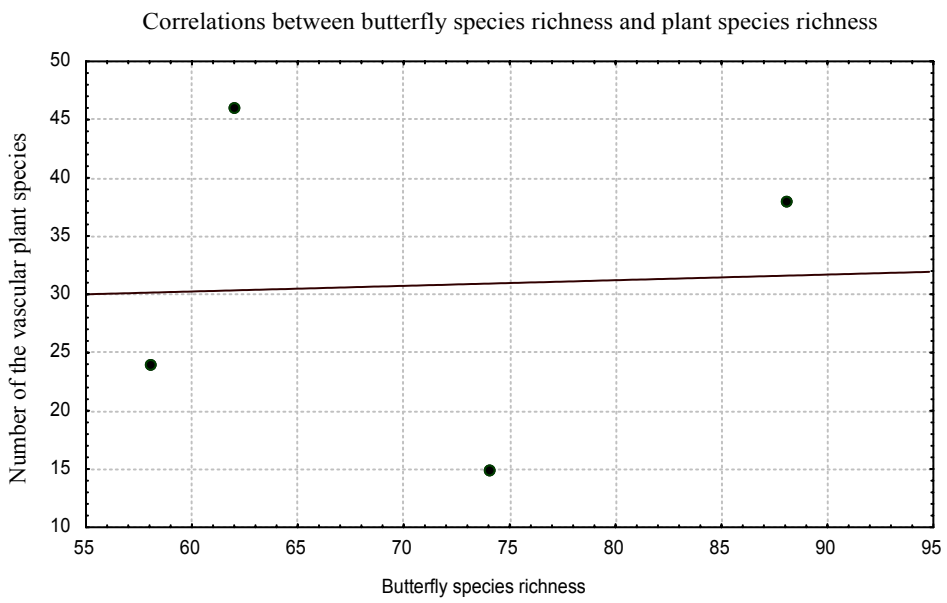

Figure44. Data calculated using the Spearman's rank correlation analyses (statgraphics 5.5) between the butterfly abundance and number of individuals in plant communities. There is a very weak trend of a positive correlation.

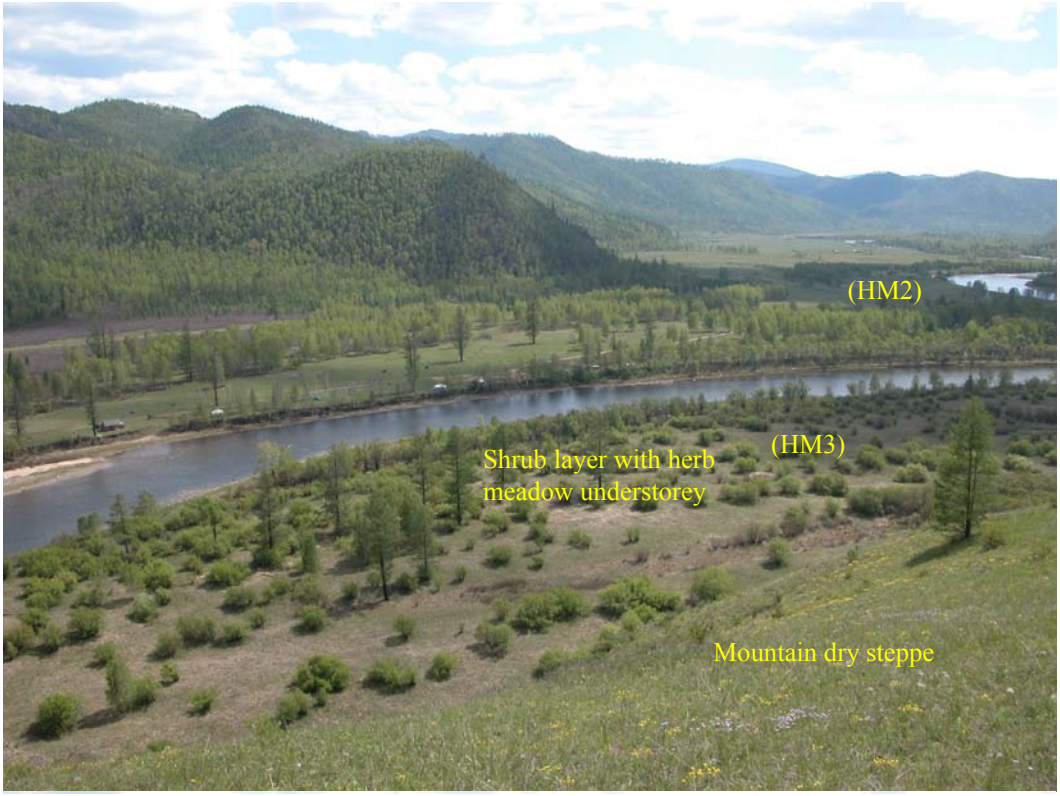

Foto 17. Natural habitats are heterogeneous with shrubs and herb meadow on the terrace in the river valley. The size of this habitat is less than 15 ha, but it includes grassland with two different plant communities of herb meadow (e.g. *Iris sanguinea* and *Alopecurus arundinaceus comminity*) and *Carex*-rich wet grassland. Shrub layer contains *Salix* and *Padus asiatica* shrubs.

These natural habitats are heterogeneous with shrubs and herb meadow on the terrace in the river valley, and with mountain dry steppe on southern slopes. This vegetation is naturally open (Dulamsuren, 2004). The flora and fauna of this region contains species found in the forests and steppes at a greater geographical scale. Mountain dry steppe (MDS) has a sparse vegetation cover dominated by *Potentilla* - *Carex*, often including *Potentilla acaulis, Potentilla viscosa, Artemisia sp. Koeleria macrantha, Poa, Thymus, Pulsatilla, Oxytropis sp,* and *Lilium pumilium*. In contrast, the herb meadow (HM) was predominantly a *Carex-Artemisia* 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* (Appendix 3). *Carex* spp are widely distributed throughout both habitats and are utilised as foodplants by many species of butterflies, including *Aphantopus hyperantus, Coenonympha oedippus, Erebia ligea, Erebia neriene, Erebia niphonica, Lopinga achine, Minois dryas, Oeneis norna, Coenonumpha hero, Thriphysa phryne, Hesperia comma*.

High richness of the butterfly community in herb meadow (HM) may be explained by the habitat heterogeneity (Nally et al., 2003; Krauss et al., 2003; Rosenzweig, 1995; Collinge et al.,2003). The vegetation type of habitats plays a great role in the four stages of the butterfly life cycle (e.g. Penz & Araujo, 1990) and therefore butterflies are strongly associated with vegetation change. They often depend on one or few species of larval hostplants.

5.3 Butterfly diversity in West Khentej

The relatively high number of species in West Khentej could be promoted by (1) geographical location, (2) large contiguous areas without anthropogenic disturbance, and (3) habitat heterogeneity (Mühlenberg et al., 2000). The West Khentej 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 (Velsen-Zerweck 2002). The habitat heterogeneity is one of the important factors that influence the population and community ecology of a species (Hunter, 2002; Tews et al., 2004; Rodriguez, 1994; Pullin, 1997; Root, 1972; Ehrlich & Murphy, 1987; Dennis & Eales, 1997; Horhal et al., 2004). Ecologically this geographical zone is characterised by its high biodiversity of vascular plants (Dulamsuren 2004). These natural features of this region could support the species richness which is found in those adjacent natural zones (Wichmann, 2002; Dulamsuren, 2004; Mühlenberg et al., 2004, Lucau, 2004).

Several studies examined the relationship between ecological variables and species richness at different spatial scales (Cowley et al., 2001; Natuhara et al., 1999; Kolasa, 1998; Hortal et al., 2004; Sanders, 2002; Mac Nally, 2003; Dennis et al., 2000; Fleishman et al., 1998; Kerr, 2001; Sanders, 2003; Shreeve et al., 2001). MacNalley (2003) pointed out that species richness increases with increasing topographic heterogeneity corresponding to diverse plant communities in terms of both composition and structure. Many authors found positive effects of mosaic landscape on butterfly richness (Natuhara *et al.*, 1999; Schneider *et al.*, 2001; Kremen 1992), influence of landscape structure and landscape context (Schneider 2003; Krauss *et al.*, 2003). Our survey indicated an increase in species richness with increasing number of individuals. Species richness in West Khentej region may be attributed to landscape mosaic (spatial heterogeneity of habitats), overlapping of habitats along gradients and the naturalness of the region (Mühlenberg et al., 2000a).

The dominance-diversity curve of butterfly species is similar to the dominance-diversity distribution of tropical trees (Hubbel, 2001), fitted best by the logseries (metacommunity), indicating natural rich communities.

In conclusion, our data lend additional support to the notion that low human impact (e.g. natural habitat), large habitats and the connectivity between the habitats increase the species richness and abundance (Rosenzweig, 1995; Krauss et al., 2003a; Steffan-Dewenters, 2003).

Butterfly community in West Khentej was no more clearly differentiated by habitat occupancy. We found that butterfly density (number of individuals per unit effort) did not differ significantly (Anova, $F(3.12)=1.38$; $p<0.2$) among habitats. In addition, the result shows that many species (52% of the total species and 58% of total individuals of most abundant species) can occur in all types of different habitat. Kerr et al. (2001) found that patterns of community similarity are strongly related to patterns of habitat composition. Many authors (e.g. Warren & Gaston, 1997) show that abundant species tend to be widespread, occupying many sites, and species with low abundance tend to be more restricted in their distribution.

The significant differences of butterfly density between the two habitat types (herb meadow (HM) and mountain dry steppe (MDS) (Anova/Manova; $F(1,6)=9.63$ $p<0.02$) can be explained by the influence of habitat variables. There is some evidence (Sergio, et al., 2004) that the population abundance was positively related to the availability (e.g. food resource and habitat suitability) of habitat. But habitat suitability could not predict the occurrence of species (Rodriguez et al., 1994).

Some studies gave examples that environmental factors influence the structure of butterfly community (Kitahara 2004; Tscharntke et al., 2002; Ulrich & Buszko 2003; Balmer & Erhardt 2000, Dennis & Eales 1997; Kitahara & Watanabe 2003; Ries & Debinski 2001; Sutherland 1998; Dover et al., 1997; Krauss et al., 2003; Schneider & Fry 2001, 2003; Hortal et al., 2004). For example, Steffan-Dewenter & Tscharntke (2000) found that density of butterflies on the calcacerous grassland was increasing with plant species diversity. Our result can be explained by this findings, because plant species diversity on herb meadow habitat was higher than on mountain dry steppe (see the chapter 4.2.2).

5.4 Butterfly fauna in West Khentej and biogeography

We compared the faunal composition with other countries of the palaearctic region (Table 20a). The family Satyridae includes more species in the Russian region (especially in East Asian). The fauna of Transbaicalia, especially of its eastern parts, includes a lot of species, the main ranges of which lies in East Asia, in the Palaearchaearctic Subprovince of the Palaearctic (Dubatolov, 1999).

Families	Germany (%) n=179	Russia (%) n=241	Great Britain (%) n=59	Finland (%) n=105	West Khentii (%) n=150
Hesperiidae	13	10	13	9	10
Papilionidae	3	2	2	3	3
Pieridae	10	10	13	11	13
Lycaenidae	26	25	27	25	28
Nymphalidae	24	25	27	34	26
Satyridae	24	26	18	18	20

Table 20a. The butterfly species composition by families which are distributed in some countries of Palaearctic region. The Lycaenidae family is dominant in most countries (except Finland) and followed by Nymphalidae (except Russia). The family Satyridae includes more species in Russian butterfly fauna.

The West Khentej harbors a rich combination of natural communities. The West Khentej region includes species which are known from the taiga forest, woodland and grassland biotopes and steppes. The butterflies use a wide range of habitats, but a very large proportion of species breeds in grassland habitats. For instance, threatened butterflies from Europe (Mongolian species of European Conservation Concern - 71 species); use as the top 5 habitats grassland biotopes: the most important in Europe are dry, calcareous grasslands and steppes followed closely by mesophile grasslands and alpine and subalpine grasslands (van Swaay and Warren 1999).

Butterflies have very specific habitat requirements (Pullin, 1997; Fischer et al., 1999; Anthes et al., 2003 van Swaay & Warren, 1999 Rodriguez et al., 1994 Thomas 1991; Christian et al., 2001). In West Khentej, many species (46,6% of total Mongolian species of European Conservation Concern) occur in the forested landcape, which includes grassy woodland openings and margins of surrounding meadows, wet open forest such as open riparian forest with *Larix sibirica* and *Betula platyphylla* (Fig. 45).

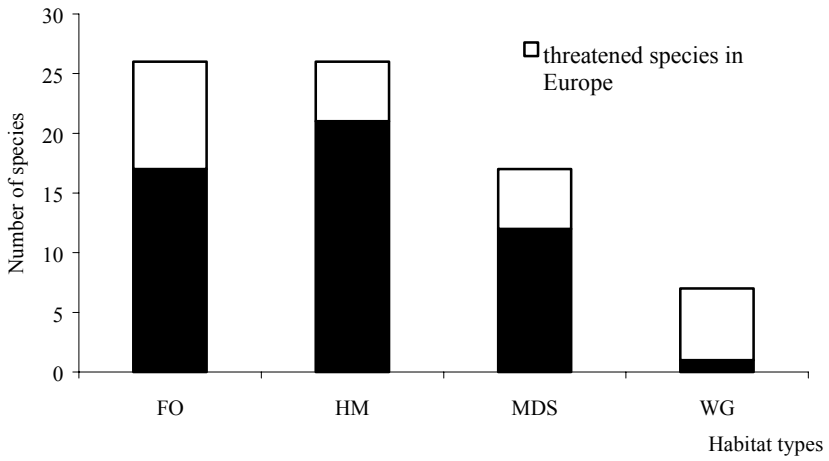

Fig 45. The number of species which are associated with particular habitat types in West Khentej, i.e. more than 50% of individuals were found in one habitat type, n=78. FO=forest opening, HM= herb meadow, MDS= mountain dry steppe, WG= wet grassland.

Butterfly fauna of West Khentej region comprises about 60 % of total Mongolian butterflies (Monkhbayar, 1999; Korshunov & Gorbunov, 1995; Tuzov, 1997; 2000). The butterfly species composition and their habitat requirements in West Khentej has been investigated poorly. Russian and Mongolian scientists created for the first time in the years 1963-1966 systematic lists of the Mongolian insect fauna as expedition' records (Ulikpan 2003).
Tatarinov & Dolgin (2001) mention that *Bolora freija* and *Boloria angarensis* are the species of sub-polar boreal forest. But some more species could be occur in West Khentej region: for instance, *Parnassius bremeri, P. poebus, P. eversmanni, Parnassius tenedius, Gonepteryx rhamni, Melitaea baicalensis, Rathora lathonia, Boloria napea, Coenonympha tullia, Erebia stubbendorfii, Melanargia halimede, Glaucopsyche alexis* (Korshunov & Gorbunov, 1995; Shiirevdamba et al., 1997).

5.5 Differences of the butterfly assemblages between habitats

The cluster analysis derived from the quantitative data of butterfly occupancy across the different habitat types in West Khentej shows an unexpected great similarity. Although the habitat type (e.g. vascular plant cover) does differ significantly from each other even in neighbouring habitats (mountain dry steppe and herb meadow habitat), it is not a barrier for different animal taxa. For endangered species that are typically restricted in their dispersal range and in the kinds of habitat through which they can disperse, factors such as spatial

configuration of the landscape and species-specific dispersal behaviors are of primary importance (Fahrig and Merriam, 1994). So, the role of the neighbouring habitats should play a role for the butterfly distribution, but the The differences between community structure of butterflies among different habitat types were not significant. 60% of total butterfly species were recorded in all habitat types of West Khentej region. These findings suggest that the butterflies of West Khentej show low habitat-specificity, probably due to high mobility (as suggested by mark-recapture rates, see chapter 4.8). Also other authors underline the occurrence of some species in various habitat types, e.g. the Mountain Argus *Aricia allous* (Geyer), Geranium Argus *Aricia eumedon* (Esper), Marine Blue *Cyaniris semiargus* (Rottemburg), Silver-washed Fritillary *Argynnis paphia* (L.) and Dark Green Fritillary *Argynnis aglaja* (L.) (Tatarinov & Dolgin, 2001).

Shreeve et al. (2001) classified British butterflies using the ecological attributes which are related to all stages of butterfly life-cycles. According to Shreeve et al. (2001) *Argynnis paphia, A. adippe* are dependent on a resource set that can occur in woodland, *Polyommatus icarus, Aricia agestis* are associated with herb-rich short-turf, *Aglais urticae, Inachis io, Polygonia c-album* are ruderal species, *Leptidea sinaps, Anthocharis cardamines, Pieris napi* are associated with wet meadows and riversides and *Papilio machaon, Lycaena dispar* were determined as fenland species. Those species of butterflies mentioned above can occur in all habitat types of West Khentej.

Species which were grouped together (e.g. specialist, generalist) by the measures of niche width were determined by the adult occurrences of butterfly species. In our study, the habitat specialist species are defined by their abundance within different types of habitat. For instance, the Violet Copper (*Lycaena helle)* of Germany breeds in wet, mesophile grassland marshes where the common Bistort (*Polygonium bistorta* L.), its foodplant is abundant (van Swaay & Warren, 1999; Fischer et al., 1999). The Violet Copper (*Lycaena helle)* is determined as a habitat specialist in West Khentej: because, (1) the measures of the niche width was smaller than (<0.5); (2) about 60 % of all individuals inhabit wet grassland habitats containing warm sparse ground vegetation in which *Anemone crinata, Polygonium viviparum* are prominent plant species. The Violet Copper (*Lycaena helle)* breeds in three main habitats in West Khentej: 1) herb (*Iris sanguinea* and *Alopecurus arundinaceus* communities) dominated habitats under *Salix* spp. and *Padus asiatica* shrub layer, 2) open wet grassland dominated by *Carex* spp., 3) open riparian and *Larix sibirica-Betula platyphylla* forest, where the understorey is dominated by mesophile grassland. Informations on the measures of niche width classified some species into four groupes of habitat specialists (e.g. forest opening, herb

meadow, wet grassland mountain dry steppe, forest opening-herb meadow species), but many species on the other hand (e.g. *Lycaena helle, Plebejus argyrognomon, E maturna, Oeneis norna, Nymphalis polichlorss, Lopinga achine, Lopinga deidemia..,*) were found in several different habitat types. Species with large distribution (e.g. species which occur everywhere in all habitat types), are more abundant species, and species which are feeding on various plant families (polyphagous) are in most cases generalist butterflies in West Khentej too. For example, in West Khentej, generalist species such as *Aporia crataegy, Anthocharis cardamines, Aphantopus hyperantus, Polyommatus semiargus, Pyrgus malvae, Pyrgus masculatus, Scolitantides orion, Everes argiades, Maculinea teleius, Argynnis adippe, Parnassius apollo, Papilio machaon, Carterocephalus palaemon,* and others are widespread and these species may be encountered in any habitat, throughout the West Khentej, even on mountain tops. The different habitat types habour a very similar assemblages of butterfly species at the adult stage (ANOVA, $F(3.12) = 2.62$; $p<0.09$).

The basic hypothesis to explain high species richness was «low human impact, large habitats and the connectivity between the habitats increase the species richness". That posits that various resources which are utilised by individuals or species are not restricted spatially in natural landscape. The connectivity between habitat increases the amount of habitat available to species by allowing movement and dispersal, and maximizes the potential population size (Ruediger et al., 1999). For example, *Papilio machaon* is one of the spectacular butterflies which is widespread in Europe, across Asia to Japan as well as in North America. It has declined recently in some European countries. This species is restricted to the single larval food-plant species (*Peucedanum palustre* (L.) in Europe, which is itself a local plant restricted to fenland in England (Dempster, 1995). The habitats throughout the range of the butterfly are becoming drier, either by natural processes, such as peat formation, or as a result of human activities (Dempster, 1995). In West Khentej, it prefers open habitats on the terrace in the river valley, forest opening, meadow steppe and mountain dry steppe. It utilises a wide range of host plants including *Apiaceae*.

As climate became warm, some species' life cycles have changed in some places (Bolotov, 2004). There is evidence for this in *Papilio machaon*, where populations have been more likely to produce two generations in 2001. Larvae of this species (*Papilio machaon*) feed upon *Cicuta virosa, Carum carvi, Peucedanum ssp., Angelica sp., Heracleum ssp., Daucus sp*., *Lomatium sp, Cymopterus, Foeniculum sp.* and *Artemisia sp.,* and specialise in one of those plant species within their biogeographical range (Thompson, 1998). Thompson suggested by his studies that the preference hierarchy for plant species was evolutionarily

dynamic within the *P. machaon* group as a whole, and it was much more conserved among some closely-related populations over broad geographic areas. In West Khentej there is a great range of potential food plants for *Papilio machaon*, so it is not restricted to by food to a certain season.

Pulliam (2000) discussed a variety of factors, in addition to competition, that influence the observed relationship between species distribution and the availability of suitable habitat. Variation in species niche or resource breadth has also been proposed as an explanation for the interspecific density-distribution relationship (Cowley, 2001). Brown (1984) argued that generalists are able to use a wide range of resources and would become both widespread and locally abundant, whilst most specialized species would be both local and rare. Finally it conclude that natural habitats offer important source for many butterfly species, and the surrounding landscapes has an influence on their ability to support diverse butterfly communities.

5.6 Biogeographic distribution and habitat selection

In this study, the palaearctic species constitute more than half of total butterfly fauna in each habitat types (see the chapter 4.4.4). According to the Rapoport's rule (Sanders, 2002; Barry Cox & Moore, 2000) species with wide geographical ranges and great altitudinal ranges should be more tolerant to different environmental conditions. In Fig. 46 it is shown for the Khentej, that both, number of species and their abundance increase with broader habitat use in particular for palearctic species.

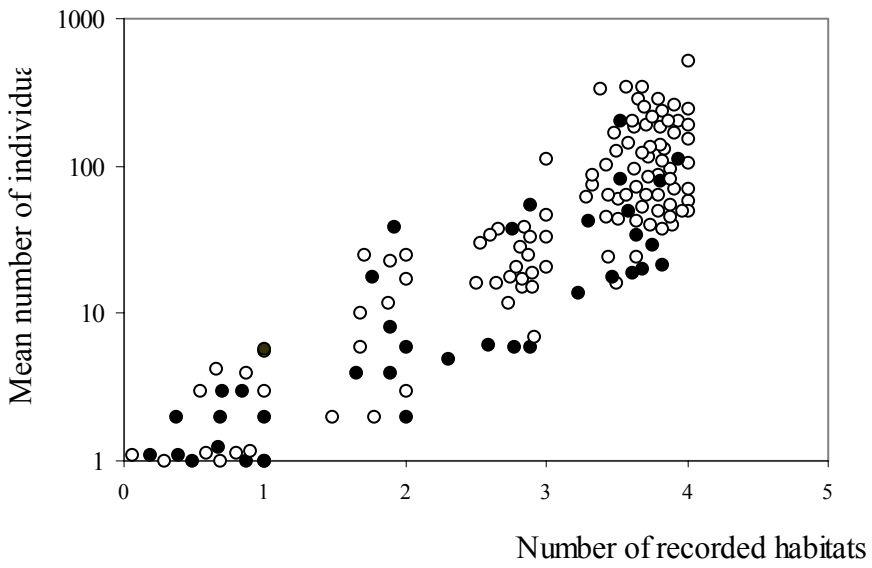

Figure 46. Butterfly occupancy at different habitat types. The filled circles show the species with Cental and East Asian distribution, the open circles show the species with Palaearctic and Holarctic distribution.

Cowley (2001) highlighted that the densities and distributions of British butterflies are positively correlated at local and national scales. The most important factors that influence the butterfly distribution might be food and microclimate of habitats (Douwes, 1975).

I suspected that the distributions of Central and East Asian specialist species are more confined to habitats typical for Central and East Asia (i.e. steppe biotopes) which was shown in chapter. 4.5. These findings correspond to the vegetation analysis (Dulamsuren, 2004) where more elements of Central and East Asia are recorded in grasslands and therefore the forest is more related to the Euro-Asiatic forest belt (palaearctic).

5.7 Population dynamics of selected species

The most important events affecting the recent population fluctuations of this natural area seemed to be climate variations. During the survey period some species showed a constant population level (e.g. *Aphantopus hyperantus*, *Inachis io, Plebejus subsolanus, Everes argiades, Lycaena helle, Coenonympha hero, Coenonympha oedippus, Cupido minimus, Polyommatus semiargus, Euphydryas maturna, Parnassius nomion, Mellicta phoebe, Aglais urtica*). However, several species (e.g. *Everes argiades*, *Papilio machaon*) showed a declining trend. Similar responses of population also occurred in other animals' group in the same landscape in the same survey period (2000-2003), population sizes of small mammals were diminished apparently, but different for each species (Sheftel et al. 2004). For small mammals, the population dynamics in this region was significantly correlated to the winter weather extremes (Sheftel et al. 2004).

The populations of *Aporia crataegy* and *Argynnis paphia* showed an increasing trend in 2000-2003. Similar results found Bolotov (2004) in north-western Siberia.

The fluctuation (i.e. mass production) of the pest populations were found in adjacent territories of West Khentej and it damaged about 40 thousand ha in the Irkutsk region, and 10 thousand ha in Buriatia (http:// www.unece.org). Sharov et al. (1999) noted that the winter temperature and forest susceptibility both can have effect in the survival rate of the *Lymantria dispar*. Moderate fluctuations in population size are more difficult to explain. They can be stochastical, reflecting variations in individual mortality, reproduction and dispersal (Lande, 2003).

5.8 Mobility of adults of selected species

Butterfly species which inhabit natural landscape are thought to be more mobile than species in human dominated, fragmented landscape. The mobility of *Lycaena virgaureae* has been studied in natural open landscape with herb rich vegetation cover. Males were recaptured more than females with a ratio of 26% to 13%. A similar result was detected in population studies of *Boloria eunomia* (Mennechez et al., 2003). The low recapture rate of *Lycaena virgaureae* could be explained by the high mobile pattern of flight. However, it also might be affected from the configuration of the study sites (Fischer, 1999, Schneider, 2003; Wang et al., 2004) and sampling intensity (Auckland et al., 2004). Average movement distances were 118 ± 113 m and 163 ± 143 m for male and female respectively. Female butterflies moved significantly greater distances than males. But adult movement was limited. Maximum range was 633 m for male and 705 m for female. Mean distances moved by *Lycaena virgaureae* were not higher than reported in other studies (Schneider, 2003). These findings are supported by Mennechez (2003), who concluded that the butterflies move longer in fragmented landscape than in a continuous system of landscape types. On the other hand the limited movement of adults can be explained by the habitat suitability (Shreeve, 1992). Shreeve noted that the area occupied by a population must consist of habitats which fulfil adults' functional categories such as mating, egg-laying, foraging, roosting and more. Habitat quality is an important factor that drives the distribution of butterfly species (Hanski, 1999; Thomas et al., 2001). It might be that the natural grassland of West Khentej is certainly favorable for the butterfly population. Thus, the species is "unwilling" to fly far from its home range. Many palearctic butterfly species are specialised in fragmented landscape in only one habitat type and must disperse between several patches (Rodriguez *et al.,* 1994; Baguette 2003; Bergman 2001; Pullin 1997).

In contrast, the percentage of recapture was lower (19%) in natural landscape compared to 29% in intensively used semi-natural grassland (Schneider, 2003). Those findings giverise to the supposition that their mobility is not restricted. Shreeve (1992) noted that some individuals, even of the most sedentary species could move longer, but these individuals usually show no predictable direction in their movement, and as far as known the majority does not attempt to return to their original habitat. Thus, the same species (*Lycaena virgaureae*) in another region is known to be higher mobile (Schneider, 2003; Douwes, 1975). My results indicate that the mobility of butterflies in the natural landscape is higher than in the fragmented and human dominated landscape at a smaller scale, but far movements are rare in the natural landscape.

5.9 Adult population size of *Lycaena virgaureae*

The main objective of this study section was to analyse the role of nectar plant availability in naturally open habitat for the adult population size of *Lycaena virgaureae*. The species is very common in West Khentej. 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 in a community (Porter & Thomas, 1992). Despite their ability to fly, most adult butterflies tend to stay within certain areas, usually where the required resources (adult nectar and larval hostplants) are abundant (Warren, 1992).

Population size of *Lycaena virgaureae* might be affected by the cover of its nectar plant. The female population size of *Lycaena virgaureae* was positively correlated with abundance *of Achillea asiatica* (Douwes, 1975) and *Aster tataricus,* but males were significantly correlated with *Potentilla fragarioides*. This may be interpreted by flowering phenology of nectar plants or palatability of those plants. The peak flowering period of *Potentilla fragarioides* occurs in July (Qin et al., 2003). The sex ratio of *Lycaena virgaureae* changed over time, with males dominating early in the flight period and females emerging after two weeks of males' first appearance. Males were commonly found basking on the vegetation, whereas females were observed in flying moment. Daily population estimates were obtained by the Jolly method (Krebs, 1989). Estimated size of one population during peak flight activity ranged between 842 and 2358 individuals. The estimated density was 124 individuals/ha. This was the first study on population size of a butterfly species in natural landscape of West Khentej region. However it is not a closed population but *Lycaena virgaureae* seems to live in West Khentej in large open populations.

5.10 Area effect

The species-area relationship of butterfly community was not significant for the selected study plots (R^2=0.18; t(12)=0.16; p<0.87:) in West Khentej (Fig. 47).

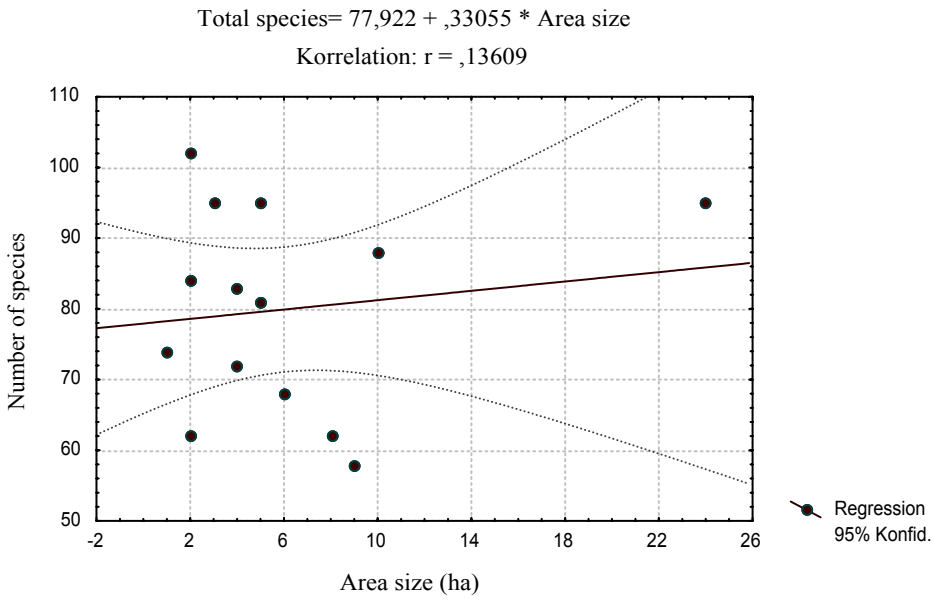

Figure 47. Correlation between the species frequencies and occurrence among sites. The result showed a weak trend toward a positive correlation. Data calculated using the multiple regression analyses (statgraphics 4.0).

In our region (West Khentej), for the large scale habitat mosaic, butterflies seem to have large open populations, which mask an effect of area

5.11 Seasonality

Butterflies undergo complete metamorphosis during their development. Some species fly few weeks each year, commonly they have only one generation (univoltine species), but there are also species with two or more generations per year (multivoltine species). More continuous flight periods may reflect several generations (Mühlenberg et al., 2000a), because the life lime of an individual is usually not longer than 3-4 weeks (Settele et al., 1999). For instance, *Cupido minimus*, *Neptis rivularis, Papilio machaon, Everes argiades, Aricia eumedon* (Foto 18)*, Coenonympha glycerion* are encountered as adults from May till August. The precise flight periods of a given species are predictable within broad limits, but are influenced by factors such as temperature and food quality during development, which may vary between years. For the remainder of the year, butterfly species are present as eggs, larvae or pupae (diapause) in which inclement seasons are passed, related to plant condition or phenology (e.g. Rodriguez et al., 1994). Most of the butterflies in the region exhibit winter diapause during the egg or larval stage (Tuzov 1997).

For comparison at the community level there was no significant variation between months in the number of the butterfly individuals captured, regardless of habitat (ANOVA; $F(8,76)=1.40$; $p<0.2084$) (Figure 48).

Foto 18. *Aricia eumedon*. The butterfly is on the wing from end of May to early August.

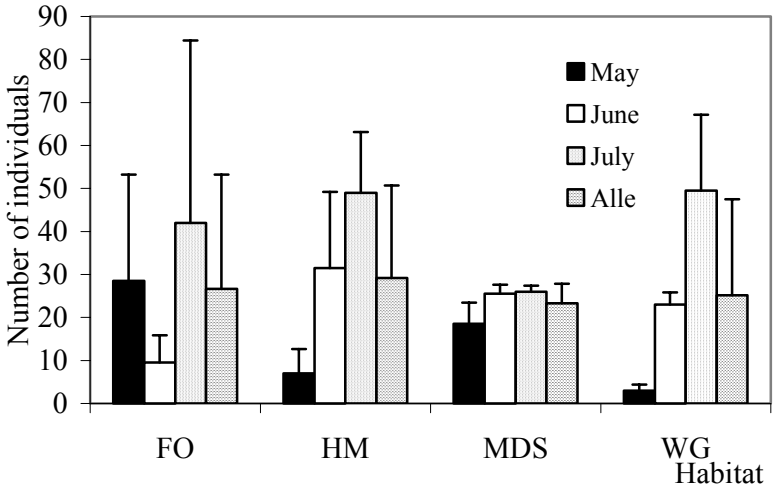

Figure 48. Mean abundance (and standard deviation) of butterflies captured in the three sampling months for the four habitats in West Khentej. Values based on one hour standard catch.

This diagram shows that many butterflies fly at mountain dry steppe and forest opening habitat in early spring season (e.g. in May). This findings could be linked with (1) microclimate of those habitats (Leimar et al., 2003; Dennis et al., 1999; Kitahara & Fujii 1994, Natuhara et al., 1999); and (2) early succession of vegetation cover (Steffan-Dewenter & Tscharntke 1997).

The relationship between the phenology of the host plant and insect population is of crucial importance (Murphy & White 1990). Gutierrez (1998) discussed phenological variation in the number of individuals of butterfly assemblages and showed a markedly seasonal pattern with an aestival maximum in Spain. However, the phenology of plants may respond to environmental factors which do not affect their associate herbivores in the same way (Cappuccino & Kareiva 1985). The timing and duration of the flowering period is one of the most important features of *Armeria velutina* patches, determining their quality for *Polyommatus semiargus* (Jaenike, 1990; Rodriguez, 1994).

In western Khentej, during the survey period (May-August in each year between 2000-2003) meteorological data showed little differences in seasonal variation (see 4.1).
I examined the butterfly faunal seasonality using the flight period (Figure 49). 12% of all species were flying during the whole summer season (May-August). From 149 species collected in all months of the study period, 30 species were flying from June until end of August.

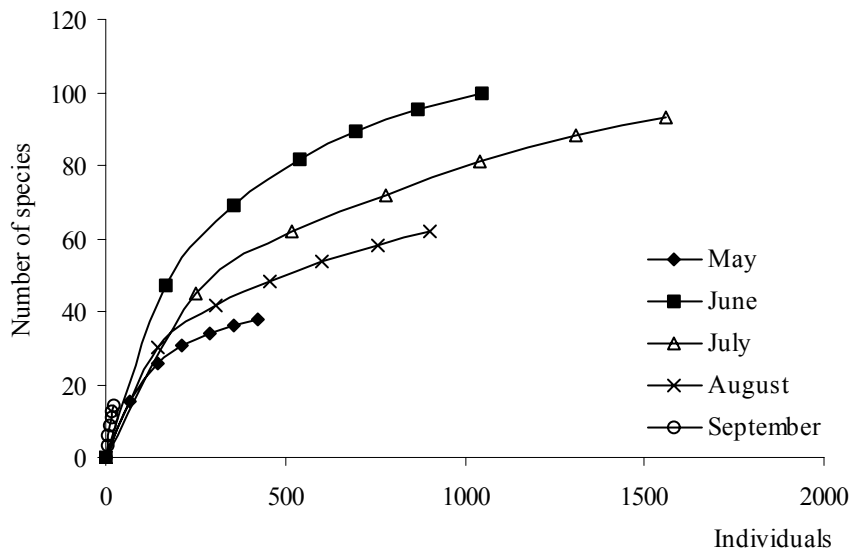

Figure 49. Number of butterfly species in each month. Most butterflies fly in June amd July.

From Fig. 49 we can conclude that the butterflies fly in the warmest period (June and July) and species richness decreases with falling temperature. Wolda (1988) suggested that on temperate mountains individual species fly for only a brief time and these flight periods vary from one year to the next and from one locality to another and thus to compare the faunal similarity of localities, one must collect during the entire flight season.

In temperate areas the diversity and species composition of the moth fauna changes during the year, similar to that of butterflies. Diversity is low in the spring, peaks in summer and then decreases (Taylor, 1978).

I analysed the butterfly flight periods of West Khentej and compared it with that in Germany. Flight period of butterfly species living in West Khentej was shorter than that of the same species in Germany (Figure 50). On the other hand, the majority of West Khentej species is usually univoltine, as well the time of being on the wing was shorter than in Germany. The difference between two samples was marginally significant (ANOVA, $F(1,62) = 4{,}32$; $p < 0.04$). I hypothesize the flight period of palearctic species in Mongolia is shorter than in Europe due to shorter growing season and higher radiation.

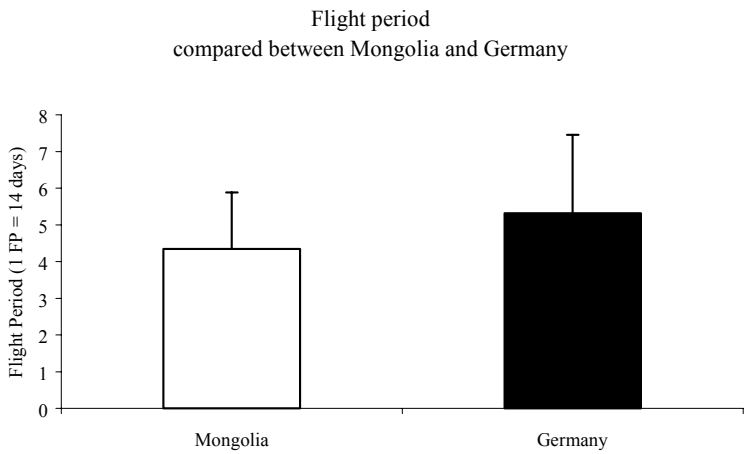

Figure 50. Flight period of butterfly species living in different regions. The difference between two samples was marginally significant significant (ANOVA, F (1,62) = 4.32; p < 0.04).

We examined the effect of average day temperature on butterfly species richness and also butterfly relative abundance. As a result the correlation between those parameters, we obtained a significant positive correlation ($r_s = 0.48$; $p<0.000$ and $r_s = 0.32$; $p<0.02$ respectively).

The result of the season (month) in relation to butterfly abundance and richness is shown in Table 21. Butterfly individuals and species richness were clear dependent on average temperature. In West Khentej, the mean maximum day temperature is highest in July (see

4.1). The butterfly individuals and species richness were highest in July (the average of butterfly individuals which could be caught per one hour was 68.33 and the mean number of species was 26.4) (Table 21). Splitting into families gave similar results:

Month	Mean number of Individuals	Mean number of species
May	27.66 ± 14.63	11.58 ± 6.76
June	56 ± 28.22	19.76 ± 7.68
July	68.33 ± 46.09	26.41 ± 8.68
August	48.91 ± 21.87	21.41 ± 5.82
Mean	50.34 ± 32.61	19.79 ± 8.87
Anavo	F(3.45)=3.88 p<0.01	F(3.45)=8.49 p<0.0001

Table 21. Mean number of the butterfly individuals and mean number of butterfly species which were captured per one sample. Numbers of individuals and species were significantly positive correlated with increasing temperature.

The mean number of individuals in each family varied significantly over the four main sampling months (ANOVA, F(18, 110)=3.94; p<0,000) (Figure 51).

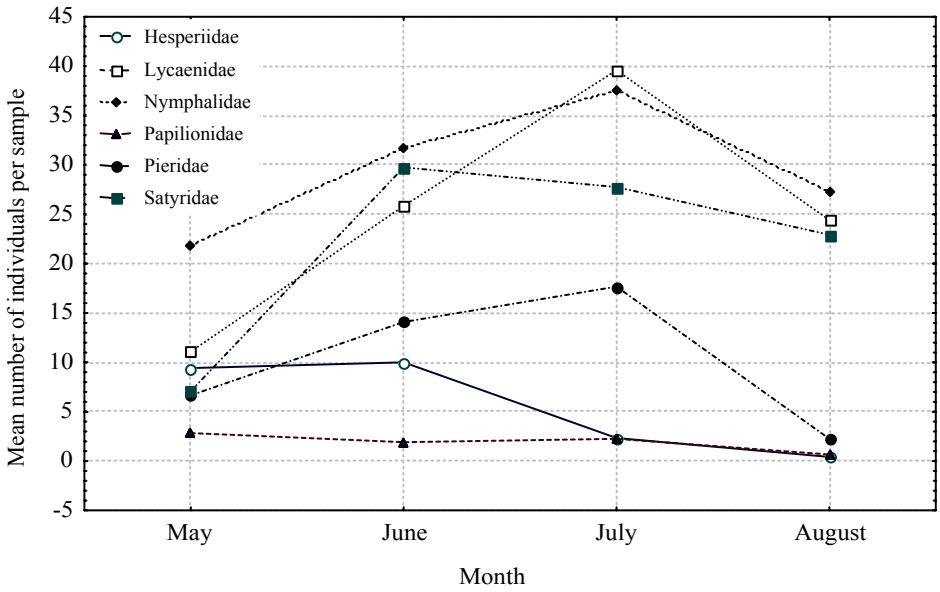

Figure 51. Mean abundance of butterflies over the four main sampling months in West Khentej, according to family. Number of samples was 48 hour (6 hour x 4 months x 2 years (2000 and 2001).

	Mean square effect	Mean square error	F(FG1,2) 3,44	p-Wert
Hesperiidae	285,8	44,42	6,43	0,001
Lycaenidae	1628	436	3,72	0,01
Nymphalidae	536	581	0,92	0,43
Papilionidae	10,05	5,26	1,91	0,14
Pieridae	586	157	3,71	0,01
Satyridae	1265	316	4	0,01

Table 22. Significant level of each families in different months.

The families Hesperiidae, Lycaenidae, Pieridae and Satyridae showed significant variations in different months (Table 22). In May, Nymphalids were markedly more common than members of other families. The families Nymphalidae, Satyridae and Lycaenidae were more abundant in June. Three families (Lycaenidae, Nymphalidae and Satyridae) reached their peak abundance during July.

Butterflies require different host plants and different succession stages of particular plants for egg laying. We usually describe the flight seasons in general terms, such as “early spring, late spring, summer, late summer” and these designations relate to local conditions (e.g. Settele et al., 1999). For example, *Papilio machaon* is a late spring butterfly and as well "late summer", it may appear in late July in West Khentej. As a general rule, the early spring aspect includes mainly Nymphalids (e.g. *Nymphalis vau-album, Aglais urticae, Polygonia c-album*) which butterflies emerge from hibernation in early spring. For the late spring aspect is *Papilio machaon* the example and several species of Lycaenids (e.g. *Nordmannia pruni, Cupido minimus, Lycaena helle, Scolitantides orion* and Hesperid butterflies). The early summer aspect include some Satyrids (mainly species from genus *Oeneis*) and some Pierids. Mid summer aspest is composed of *Maculinea teleius*, *Aporia crataegy, Coenonympha oedippus, C. glycerion, C. hero, Colias spp*., *Melitaea spp.* Late summer aspect includes *Parnassius nomion, P. apollo, Argynnis paphia, A. adippe, A. aglaja, A. niobe, Lycaena virgaureae*, *Erebia neriene, Minois dryas*. For autumn aspect stay *Nymphalis antiopa, Nymphalis vau-album, Polygonia c-album.* A few species fly mainly in spring or autumn.

5.12 Conservation status of Palaearctic species

Change of land use, which has serious consequences for the conservation of Lepidoptera and other wildlife, and loss of the habitats has lead to major declines of Lepidoptera in every

European country (Warren *et al.,* 1993). In European conditions the main threats reported are from agricultural improvements which affect 90% of threatened species, building developments (affecting 83%), increasing use of herbicides and pesticides (affecting 80%), and abandonment of agricultural land and changing habitat management (65%). The widespread loss and reduction in size of breeding habitats is affecting 83% of threatened species (van Swaay & Warren 1999). Afforestation of open habitats and habitat fragmentation are further threats to butterflies.

West Khentej region has significant high butterfly diversity, though there is no endemic species. Both taiga species and steppe species contribute to the species richness. This survey was the first investigation of the richness and relative abundance of butterfly species in northern Mongolia, just as only few studies to date concern biodiversity of large natural landscapes in eastern Palearctic.

In Mongolia 6 butterfly species (*Parnassius apollo, Parnassius eversmanni, Parnassius stubbendorfi, Parnassius phoebus, Parnassius tenedius, Papilio machaon)* are listed in the Mongolian Red Data Book (Shiirevdamba 1997). Approximately half of the palaearctic species which are found in West Khentej are also recorded in Germany and about 76% of those butterflies are listed as threatened species in the German Red Data Book (Bundesamt für Naturschutz, 1998)(Table 23).

Countries	Number of species	Number of shared species (also found in western Khentii)	Number of shared species listed in Red Data Book of related countries
West Khentii (northern Mongolia)	149		2
Europe	576	102	26
Germany	179	81	62
Russia	241	98	11
Finland	105	89	8*
England	60	33	9

Table 23. Number of the shared species in northern Mongolia and some European countries. Regarding at each national Red Data Book. we found the highest number of (76%) of shared species listed in Germany. *-the information known from Saarinen (2003).

The West Khentej region supports a high degree of biodiversity including plants, butterflies, moths, and other insects, birds and animals. There occur many butterfly species included as threatened in the Bern Convention (van Swaay and Warren, 1999) and national Red List of

plant and animals, *Leptidea morsei; Nymphalis vau album, Euphydryas intermedia, Triphysa phryne and Papilio machaon.* Overall 26 rare species (species mentioned at European Red Data Book) have been recorded in the natural landscape of West Khentej.

Swaay (1999) and Dennis (2004) noted that woodland and scrub are important for several species, but within these habitats many species rely on open areas and clearings or woodland margins and wood/grass mosaics. For example, the main habitat of *Euphydryas maturna* is deciduous and mixed forest with abundant flowery edges, roadsides, valleys and clearings in European countries. This species, threatened in Europe, is listed in Appendix II of Bern Convention. The threat is caused by changes in woodland management or felling or destruction of the forest. In West Khentej this species inhabits all four habitat types and is described as a dominant species in the region (see 4.4.1). Another example is *Coenonympha oedippus*. The species has declined tremendously over the last decades in European countries and it is now the most seriously threatened non-endemic species in Europe (Kudrna, 1986). The main habitat is wet or swampy unfertilized meadow and heath in forests or bogs, in Slovenia also mentioned in dry grassland (Swaay 1999). *Coenonympha oedippus* is also a dominant species in West Khentej. This species can be encountered everywhere in the study area of West Khentej. There are other species as well which are threatened by habitat loss in Europe but frequent in different habitat types in West Khentej, like *Lycaena helle, Coenonympha hero, C. oedippus, Nymphalis vau-album, Nymphalis polychloros, Maculinea teleius, Cupido minimus, Lycaena virgaureae, Erebia medusa, Polyommatus semiargus.*

This gives West Khentej a high conservation value, because it supports many species which are seriously threatened elsewhere, pronounced examples are the large open populations of *Lycaena virgaureae*, *Lycaena helle* and *Coenonympha oedippus* among many other species.

SUMMARY

This thesis provides an insight into the natural history of butterfly species which are found in the West Khentej mountains of northern Mongolia. The study area is located in the transition zone between southern Siberia and Asian steppe and it includes forests, woodlands, steppe, and different types of grassland, forming a heterogeneous landscape mosaic with nearly no human impact. The region has a rich flora with boreal, temperate and mandshurian elements. This study on West Khentej butterflies is the first investigation of species richness and relative abundances of butterfly species in northern Mongolia. The objectives of this research were: 1) to describe the butterfly fauna of West Khentej in terms of taxonomic composition and biogeography and temporal variability in natural communities, (2) to describe the

influence of landscape structure and vegetation on butterfly community by comparing habitat occupancy of West Khentej butterfly fauna in four different habitat types, 3) to analyse the habitat factors that influence butterfly diversity in natural landscape by comparing different grassland habitats, and (4) to assess the importance of the study region to the conservation of butterflies.

Different habitat types were identified according to vegetation analysis and butterfly communities were examined within these natural landscape to identify factors that influence the diversity and composition of butterfly assemblages. In four vegetation types (forest openings, herb meadow, mountain dry steppe, and wet grassland) the relative abundance, faunal similarity, species richness and other diversity measures were estimated with 4 study plots as replicates for three habitat types. The 12 plots were sampled twice every month from May to August for four years (2000-2003). The netting method was used for collecting the butterflies during a standardised 1 hour sample in an area each of 0,5 ha. The total sampling effort over four years was 164 catch hours. 150 butterfly species were recorded during the survey period in 9993 individuals. 15 species have been reported for the first time in the West Khentej region by this study.

Plant cover was analysed in detail only in two vegetation types, in herb meadow and mountain dry steppe. Estimated plant species richness in herb meadow and mountain dry steppe were 64 and 29, respectively. The plant community showed only 10% similarity in species composition between the two sampled habitats, documenting the difference between the moist tall herb meadow on river terraces and the dry short mountain steppe on southern slopes. But butterfly species were not significantly related to the vegetation cover. The butterfly community showed 80% similarity in species composition between these study sites. A total of 80 species were common in all four surveyed habitat types in West Khentej. The observed number of butterfly species was not significantly different between the four habitat types. The expected total species richness, calculated as ICE estimator was significantly different between the four habitat types. By this estimation the forest opening ranked highest in species richness. The log-normal dominance-diversity curve of butterfly species indicates a natural rich community.

The butterflies of western Khentej can be classified into four biogeographic categories, from which the palearctic group constitutes the biggest part with 59 % of the total species. Lycaenidae and Nymphalidae were the dominant families among palearctic and central Asian species, the two families together comprise 59% and 67%, respectively. Nymphalids also dominated the holarctic species assemblage (52%), whereas the dominant family (45%) of the

East Asian species belongs to the Satyridae. Among the species with a more restricted geographical distribution like the central Asian or eastern Asian species, the specialists (classified by niche width in habitat occupancy with < 0.5) had a higher percentage than species with broad geographical distribution. Species with higher abundance belong more to the generalists (niche width > 0.5). Palearctic species constituted a higher proportion of habitat generalists than of habitat specialists (71% and 46% respectively). Specialist species which geographical restriction to central and East-Asia were found more in grassland biotopes, but the specialist species with palearctic and holarctic distribution peaked at forest opening and forest margin biotopes. Butterflies with a taxonomically wide range of food plants (polyphagous) tend to be more widely distributed than butterflies that use only one species or genus of host plant (mono- and oligophagous). The majority (70% of total butterfly fauna of Khentej) in the study area are herb/grass feeders, 7% of the total were feeders on woods. Polyphagous species were dominant in West Khentej, and they constitute about 40% of total butterfly species. The distribution of monophagous and strongly oligophagous species are not significantly different among habitat types. In summary, the findings indicate that the butterflies of West Khentej show an overall low habitat-specificity.

Analyses of the relative abundances of 144 species from the survey period 2000-2003 revealed for few species an increasing trend and for few other species a decreasing trend, but most of the species showed relatively constant population size. Population fluctuation could be related in many cases to variable weather conditions. Flight period of butterfly species living in West Khentej was shorter than that of the same species in Germany. The majority of West Khentej species is usually univoltine, as well the time of being on the wing was shorter than in Germany. The difference was marginally significant.

Adult movement and population size of the scarce copper (*Lycaena virgaureae*) was estimated using the capture-recapture data. This species is near-threatened in Europe and was selected for some detailed analyses as a model. There were several significant relationships between the abundance of *Lycaena virgaureae* and its nectar plants. 19 % of 1345 marked individuals were recaptured within 4 weeks. The results showed that the mobility of these butterflies is higher in the natural landscape than in the fragmented and human dominated landscape at a smaller scale (comparison with data from Germany), but far movements are rare in the natural landscape. *Lycaena virgaureae* seems to live in West Khentej in large open populations. This is also suspected for most of the other species and may explain, why the species-area relationship of butterfly community was not significant for the selected study plots in West Khentej.

The West Khentej region supports a high number of butterflies species. In about 100 km² a similar species richness is found as in the entire Germany. Many butterfly species occur in West Khentej which are listed in Europe as threatened in the Bern Convention and national Red Data Books. The populations in the Khentej are large and widespread and there is so far no sign of threat or a decline beside natural fluctuations. These results clearly indicate the high value of West Khentej for the conservation of butterfly communities and they highlight the importance of naturalness in a heterogeneous landscape which sustains the coexistence of many species.

CONCLUSION

This survey was the first investigation of the richness and relative abundance of butterfly species in northern Mongolia. Few studies to date consider biodiversity of large natural landscapes in eastern Palearctic. The results do provide some interesting informations, especially with regard to the diversity of the butterfly species within the West Khentej region of northern Mongolia. Butterfly fauna of West Khentej region comprises about 60 % of total Mongolian butterfly fauna (Monkhbayar, 1999; Korshunov & Gorbunov, 1995; Tuzov, 1997; 2000). Many Palearctic butterfly species that are threatened in Europe are still common in West Khentej, probably as ecosystems in the Khentej are not fragmented and disturbed by humans (Heino & Hanski, 2001; Brown & Hutching, 1997; Gaston et al., 1999). The dominance-diversity curve of West Khentej butterfly species is similar to the dominance-diversity distribution of tropical trees (Hubbel, 2001), fitted best by the logseries (metacommunity), indicating natural rich communities. The hypothesis is that low population density of most species facilitates the coexistence of many species (e.g. Miyazaki et al., 2004).

The natural landscape of West Khentej currently provides an important opportunity for understanding the life history of butterflies under natural conditions without human influences. On the other hand butterflies are good indicators of habitat quality as they respond rapidly to modification of vegetation (Steffan-Dewenter & Tscharntke, 1997; Hellmann, 2002; Rodriguez et al., 1994) and global change of climate (Roy et al., 2001; Bolotov, 2004; Stefanescu et al., 2003; Roy & Sparks 2000; Raimondo et al., 2004; Warren et al., 2001; Dunn & Winkler, 1999; Crozier, 2003). The most important events affecting the recent biological history of this natural area could be the climate change. But the historical data base

of West Khentej from which trends in species distribution and their abundances could be evaluated is not documented.

This four years program was not enough time to obtain an outline of whole populations' processes of the entire plant and butterfly communities of the West Khentej ecosystem. It is necessary to perform meaningful experiments for butterflies' community ecology and to provide contributions to the conservation of butterfly species.

Up to now, the larval biology is not investigated and could further contributes to understand the life strategies of insect species, using the natural landscape in the buffer zone of the West Khentej Strictly Protected Area as an important reference region where many palearctic butterflies can live under natural ecological conditions and are not threatened like in the European human-dominated landscape.

Finally, this work has revealed beside the great species richness an unexpected high similarity between different vegetation types and an other pattern of mobility in natural landscapes. I emphasize to continue with investigations in order to understand more from life histories in natural, not human affected landscapes. If such is possible, it could be discovered many more secrets of butterflies life in natural landscape.

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LIST OF FUGURES

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APPENDIX

APPENDIX 1

Latin and English names of butterflies registered in West Khentej

HESPERIIDAE

Carterocephalus palaemon PALLAS, 1771	Chequered Skipper
Carterocephalus silvicola MEIGAN, 1828	Northern Checquered Skipper
Carterocephalus argyrostigma EVERSMANN, 1851	
Erynnis tages LINNAEUS, 1758	Dingy Skipper
Hesperia comma LINNAEUS, 1758	Silver-spotted Skipper
Muschampia cribrellum STAUDINGER, 1892	Spinose Skipper
Muschampia tessellum HUEBNER, 1803	Tessellated Skipper
Ochlodes sylvanus ESPER, 1778	Large Skipper
Pyrgus jupei ALBERTI, 1967	
Pyrgus maculatus BREMER et GREY, 1853	
Pyrgus malvae LINNAEUS, 1758	Grizzled Skipper
Pyrgus cinarae RAMBUR, 1839	Sandy Grizzled Skipper
Pyrgus sibirica REVERDIN, 1911	
Pyrgus serratulae RAMBUR, 1839	Olive Skipper

PAPILIONIDAE

Papilio machaon LINNAEUS, 1758	Swallowtail
Papilio xuthus LINNAEUS 1760	Asian Swallowtail
Parnassius apollo LINNAEUS, 1758	Apollo
Parnassius nomion FISCHER DE WALDHEIM, 1823	

PIERIDAE

Anthocharis cardamines LINNAEUS, 1758	Orange Tip
Aporia crataegi LINNAEUS, 1758	Black-veined white
Aporia hipa hippa BREMER, 1861	
Colias aurora ESPER, 1784	
Colias erate ESPER, 1805	Eastern Pale Clouded Yellow
Colias hyale LINNAEUS, 1758	
Colias palaeno LINNAEUS,	Pale Clouded Yellow
Colias poliographus MOTSCHULSKY,	
Colias staudingeri ALPHERAKY, 1881	
Colias heos HERBST, 1792	
Colias tyche BOEBER, 1812	Pale Arctic Clouded Yellow
Leptidea amurensis MENETRIES, 1859	
Leptidea morsei FENTON, 1881	Fenton's Wood White

Leptidea sinapsis LINNAEUS, 1758	Wood White
Pieris callidice Huebner, 1800	Bath White
Pieris chlorodice HUEBNER, 1808	
Pieris daplidice LINNAEUS, 1758	
Pieris napi LINNAEUS, 1758	Sharp-veined white
Pieris rapae LINNAEUS, 1758	Small White

SATYRIDAE

Aphantopus hyperantus LINNAEUS, 1758	Ringlet
Boeberia parmenio BOEBER, 1809	
Coenonympha amaryllis STOLL IN CRAMER, 1872	
Coenonympha glycerion BORKHAUSEN, 1788	Chestnut Heath
Coenonympha hero LINNAEUS, 1761	Scarce Heath
Coenonympha oedippus FABRICIUS, 1787	False Ringlet
Erebia aethiops ESPER, 1777	Scotch Argus
Erebia jeniseiensis TRYBOM, 1877	
Erebia konzhantschikovi SHELJUZHKO	
Erebia ligea LINNAEUS, 1758	Arran Brown
Erebia medusa DENIS & SCHIFFERMÜLLER, 1775	
Erebia neriene BOEBER, 1809	
Erebia discoidalis KIRBY*,* 1837	
Erebia niphonica JANSON, 1877	
Hemadara rurigena LEECH, 1890	
Hipparchia autonoe ESPER, 1783	
Hyponephele lycaon ROTTEMBURG, 1775	Dusky Meadow Brown
Hyponephele pasimelas STAUDINGER, 1886	
Lasiommata maera LINNAEUS, 1758	Large Wall Brown
Lethe diana diana BUTLER, 1866?	
Lopinga achine SCOPOLI, 1763	Woodland Brown
Lopinga deidamia EVERSMANN, 1851	
Minois dryas SCOPOLI, 1763	Dryad
Oeneis mongolica OBERTHUER, 1877	
Oeneis nanna MENETRIES; 1859	
Oeneis norna THUNBERG, 1791	Norse Grayling
Oeneis tarpeia PALLAS, 1771	
Oeneis sculda EVERSMANN, 1851	
Oeneis urda EVERSMANN, 1847	
Oeneis mulla STAUDINGER, 1881	
Satyrus stheno GRUM-GRSHIMAILO, 1887	
Triphysa phryne PALLAS, 1771	

NYMPHALIDAE

Aglais urticae LINNAEUS, 1758	Small Tortoiseshell
Araschnia levana LINNAEUS, 1758	Map
Argynnis adippe ROTTEMBURG, 1775	High Brown Fritillary
Argynnis aglaja LINNAEUS, 1758	Dark Green Fritillary
Argynnis niobe LINNAEUS, 1758	Niobe Fritillary
Argynnis paphia LINNAEUS, 1758	Silver-washed Fritillary
Boloria angarensis ERSCHOFF, 1870	
Boloria eunomia ESPER, 1799	Bog Fritillary
Boloria euphrosyne LINNAEUS, 1758	Pearl-bordered Fritillary
Boloria freija THUNBERG, 1791	Freija's Fritillary
Boloria oscarus EVERSMANN, 1844	
Boloria selene DENIS SCHIFFERMÜLLER, 1775	Small Pearl-bordered Fritillary
Boloria selenis EVERSMANN, 1837	
Boloria titania ESPER, 1793	Titania's Fritillary
Brenthis daphne DENIS SCHIFFERMÜLLER, 1775	Marbled Fritillary
Brenthis ino ROTTEMBURG, 1775	Lesser Marbled Fritillary
Euphydryas aurinia ROTTEMBURG, 1775	Marsh Fritillary
Euphydryas intermedia MENETRIES, 1859	Asian Fritillary
Euphydryas maturna LINNAEUS, 1758	Scarce Fritillary
Inachis io LINNAEUS, 1758	Peacock
Limenitis populi LINNAEUS, 1758	Poplar Admiral
Melitaea arcesia BREMER, 1864	Blackvein Fritillary
Melitaea cinxia LINNAEUS, 1758	Glanville Fritillary
Melitaea diamina LANG, 1789	False-heath Fritillary
Melitaea didyma ESPER, 1779	Spotted Fritillary
Melitaea phoebe DENIS SCHIFFERMÜLLER, 1775	Knapweed Fritillary
Melitaea athalia ROTTEMBURG, 1775	Heath Fritillary
Mellicta aurelia NICKERL, 1850	Nickerl's Fritillary
Mellicta britomartis ASSMANN, 1847	Assmann's Fritillary
Mellicta centralasiae WNUKOWSKY, 1929	
Mellicta plotina BREMER, 1861	
Neptis rivularis SCOPOLI, 1763	Hungarian Glider
Neptis sappho PALLAS, 1771	Common Glide
Nymphalis antiopa LINNAEUS, 1758	Camberwell Beauty
Nymphalis polychloros LINNAEUS 1758	Large Tortoiseshell
Nymphalis vau- album DENIS & SCHIFFERMÜLLER, 1775	Comma tortoise shell
Polygonia c-album LINNAEUS 1758	Comma
Polygonia interposita STAUDINGER, 1881	
Vanessa cardui LINNAEUS, 1758	Painted lady

LYCAENIDAE

Agriades aquilo wosnesensky MENETRIES, 1855	
Ahlbergia frivaldszkyi LEDERER, 1855	
Albulina orbitulus de PRUNNER, 1798	Alpine Argus
Aricia agestis DENIS &SCHIFFERMUELLER, 1775	Brown Argus
Aricia allous HÜBNER, 1819	Mountain Argus
Aricia eumedon ESPER, 1780	Geranium Argus
Celastrina argiolus LINNAEUS, 1758	Holly Blue
Celastrina fedoseevi KORSHUNOV et IVONIN, 1990	
Cupido minimus FUESSLY, 1775	Small Blue
Cupido osiris MEIGEN, 1829	Osiris Blue
Cupido prosecusa ERSCHOFF, 1874	
Everes argiades PALLAS, 1771	Short-tailed Blue
Everes fischeri EVERSMANN, 1843	
Glaucopsyche lycormas BUTLER, 1866	
Kretania eurypilus ? FREYER, 1851	Eastern Brown Argus
Lycaena dispar LEECH, 1894	Large Copper
Lycaena helle DENIS SCHIFFERMÜLLER, 1775	Violet Copper
Lycaena hippothoe LINNAEUS, 1761	Purple-edged Coppe
Lycaena virgaureae LINNAEUS, 1758	Scarce Copper
Maculinea arion LINNAEUS, 1758	Large Blue
Maculinea teleius BERGSTRÄSSER, 1779	Scarce Large Blue
Nordmannia pruni LINNAEUS, 1758	Black Hairstreak
Patricius lucifer STAUDINGER, 1867	
Plebejus argus LINNAEUS, 1758	Silver-studded Blue
Plebejus argyrognomon BERGSTRÄSSER, 1779	Reverdin's Blue
Plebejus eversmanni STAUDINGER, 1886	
Plebejus idas CURVOISIER, 1913	Idas Blue
Plebejus nushibi ZHDANKO, 2000	
Plebejus pylaon FISCHER von WALDHEIM, 1832	Zephyr Blue
Plebejus subsolanus EVERSMANN, 1851	
Polyommatus amandus SCHNEIDER, 1792	Amanda's Blue
Polyommatus cyane Eversmann, 1837	
Polyommatus semiargus ROTTEMBURG, 1775	Mazarine Blue
Polyommatus erotides STAUDINGER, 1892	False Eros Blue
Polyommatus eros OCHSENHEIMER, 1808	Eros Blue
Polyommatus icadius GRUM-GRSHIMAILO, 1890	
Polyommatus icarus ROTTEMBURG, 1775	Common Blue
Pseudophilotes bavius EVERSMANN, 1832	Bavius Blue
Scolitantides orion PALLAS, 1771	Chequered Blue
Thechla betulae crossa LINNAEUS, 1758	Brown Hairstreak

Thersamonolycaena splendens STAUDINGER, 1881

Vacciniina optilete KNOCH, 1781 Cranberry Blue

APPENDIX 2.
Number of individuals caught per 100 hour. FO= Forest Opening. HM= Herb meadow.MDS= Mountain Dry Steppe. WG= Wet grassland. N= total number of individuals.

Species	Habitats				N
	FO	HM	MDS	WG	
1	2	3	4	5	6
Aglais urticae Linnaeus, 1758	29,8	51	23,8	34,6	139
Agrodiaetus amandus Schneider, 1792	102	135	33,3	100	370
Ahlbergia frivaldszkyi Lederer, 1855	53,2	67,3	42,9	38,5	202
Albulina orbitula Prunner, 1798	38,3	83,7	11,9	26,9	161
Anthocharis cardamines Linnaeus, 1758	10,6	4,08	21,4	30,8	66,9
Aphantopus hyperantus Linnaeus, 1758	136	196	95,2	165	593
Aporia crataegi Linnaeus, 1758	255	467	383	50	1156
Aporia hipa hippa Bremer, 1861	0	6,12	0	0	6,12
*Araschnia levana*Linnaeus, 1758	27,7	28,6	2,38	0	58,6
Argynnis adippe Denis & Schiffermüller, 1775	70,2	77,6	7,14	115	270
Argynnis aglaja Linnaeus, 1758	68,1	75,5	81	50	275
Argynnis niobe Linnaeus, 1758	27,7	32,7	26,2	34,6	121
Argynnis paphia Linnaeus, 1758	74,5	265	171	181	692
Aricia agestis Denis & Schiffermüller, 1775	44,7	65,3	7,14	30,8	148
Aricia allous Hübner, 1819	4,26	12,2	0	0	16,5
Aricia eumedon Esper, 1780	128	261	107	104	600
Boeberia parmenio Boeber, 1809	72,3	190	129	19,2	410
Boloria angarensis Erschoff, 1870	23,4	42,9	2,38	3,85	72,5
Boloria eunomia Esper, 1799	10,6	8,16	0	11,5	30,3
Boloria euphrosyne Linnaeus, 1758	19,1	28,6	4,76	15,4	67,9
Boloria freija Thunberg, 1791	25,5	16,3	2,38	0	44,2
Boloria oscarus Eversmann, 1844	57,4	8,16	19	0	84,7
Boloria selene Denis & Schiffermüller, 1775	6,38	18,4	4,76	7,69	37,2
Boloria selenis Eversmann, 1837	46,8	22,4	38,1	3,85	111
Boloria titania Esper, 1793	12,8	16,3	2,38	0	31,5
Brenthis daphne Bergsträsser, 1780	66	91,8	54,8	53,8	266
Brenthis ino Rottemburg, 1775	115	167	42,9	200	525
Carterocephalus argyrostigma Eversmann, 1851	0	42,9	9,52	0	52,4
Carterocephalus palaemon Pallas, 1771	0	16,3	7,14	19,2	42,7
Carterocephalus silvicola Meigan, 1828	2,13	67,3	11,9	3,85	85,2
Celastrina argiolus Linnaeus, 1758	31,9	55,1	9,52	11,5	108
Celastrina fedoseevi Koeschunov et Ivonin, 1990	0	28,6	0	0	28,6
Coenonympha amaryllis Cramer, 1782	19,1	49	11,9	7,69	87,7
Coenonympha glycerion Borkhausen, 1788	177	418	54,8	146	796
Coenonympha hero Linnaeus, 1761	166	173	31	50	420
Coenonympha oedippus Fabricius, 1787	63,8	151	148	65,4	428
Colias alpherakii Staudinger, 1882	2,13	0	0	0	2,13
Colias aurora Esper, 1784	29,8	65,3	26,2	11,5	133
Colias erate Esper, 1804	0	4,08	0	0	4,08
Colias heos Herbst, 1792	10,6	24,5	0	30,8	65,9
Colias hyale Linnaeus, 1758	38,3	26,5	42,9	19,2	127
*Colias palaeno L*innaeus, 1761	0	2,04	0	3,85	5,89
Colias poliographus Motschulsky, 1860	2,13	2,04	0	0	4,17
Colias staudingeri Alpheraky, 1881	0	0	4,76	0	4,76
Colias tyche Boeber, 1812	53,2	98	110	34,6	295

APPENDIX 2. (continued)

1	2	3	4	5	6
Cupido minimus Fuessly, 1775	83	69.4	52.4	3.85	209
Cupido prosecusa Erschoff, 1874	0	0	0	3.85	3.85
Erebia aethiops Esper, 1777	53.2	16.3	11.9	23.1	104
Erebia jeniseiensis Trybom, 1877	4.26	0	4.76	0	9.02
Erebia ligea Linnaeus, 1758	0	4.08	35.7	0	39.8
Erebia medusa Denis & Denis & Schiffermüller, 1775	12.8	51	16.7	0	80.5
Erebia neriene Böber, 1809	95.7	184	112	80.8	472
Erebia niphonica Janson, 1877	0	2.04	4.76	0	6.8
Erebia sp?	0	2.04	0	0	2.04
Erynnis tages Linnaeus, 1758	12.8	14.3	40.5	0	67.5
Euphydryas aurina Rottemburg, 1775	6.38	4.08	2.38	0	12.8
Euphydryas intermedia Menetries, 1859	14.9	18.4	0	7.69	41
Euphydryas maturna Linnaeus, 1758	38.3	102	9.52	11.5	161
Everes argiades Pallas, 1771	285	129	66.7	242	723
Everes fischeri Eversmann, 1843	4.26	4.08	31	0	39.3
Glaucopsyche lycormas Butler, 1866	68.1	137	31	73.1	309
Hemadara rurigena Leech, 1890	8.51	65.3	0	42.3	116
Hesperia comma Linnaeus, 1758	10.6	2.04	21.4	0	34.1
Hipparchia autonoe Esper, 1783	4.26	0	0	0	4.26
Hyponephele lycaon Rottemburg, 1775	4.26	2.04	4.76	0	11.1
Inachis io Linnaeus, 1758	78.7	112	61.9	80.8	334
Kretania eurypilus Freyer, 1851	6.38	26.5	4.76	11.5	49.2
Lasiommato maero Linnaeus, 1758	4.26	0	9.52	0	13.8
Leptidea amurensis Menetries, 1859	36.2	110	21.4	23.1	191
Leptidea morsei Fenton, 1881	145	112	117	61.5	435
Leptidea sinapis Linnaeus, 1758	51.1	22.4	7.14	30.8	111
Lethe diana diana Butler, 1866?	0	2.04	0	0	2.04
Limenitus populi Linnaeus, 1758	8.51	28.6	0	0	37.1
Lopinga achine Scopoli, 1763	29.8	32.7	7.14	0	69.6
Lopinga deidamia Eversmann, 1851	31.9	51	2.38	3.85	89.2
Lycaena dispar amurensis Leech, 1894	8.51	12.2	21.4	3.85	46
Lycaena helle Denis & Schiffermüller, 1775	111	316	2.38	104	533
Lycaena hippothoe Linnaeus, 1761	2.13	0	0	0	2.13
Lycaena vigaureae Linnaeus, 1758	106	227	31	108	472
Maculinea arion Linnaeus, 1758	2.13	2.04	0	0	4.17
Maculinea teleius Bergshrässer, 1779	97.9	135	2.38	80.8	316
Melitaea arcesia Bremer, 1861	27.7	38.8	2.38	0	68.8
Melitaea cinxia Linnaeus, 1758	4.26	4.08	0	11.5	19.9
Melitaea diamina Lang, 1789	29.8	51	28.6	38.5	148

APPENDIX 2. (continued)

	1	2	3	4	5	6
Melitaea didyma Esper. 1779		68.1	116	145	73.1	403
Melitaea phoebe Denis & Schiffermüller. 1775		34	51	19	84.6	189
Mellicta athalia Rottemburg. 1775		51.1	135	9.52	34.6	230
Mellicta aurelia Nickerl. 1850		34	34.7	26.2	34.6	130
Mellicta britomartis Assmann. 1847		68.1	98	28.6	19.2	214
Mellicta centralasiae Wnukowsky. 1929		36.2	34.7	11.9	15.4	98.2
Mellicta plotina Bremer. 1861		19.1	12.2	4.76	26.9	63.1
Minois dryas Scopoli. 1763		123	171	162	162	618
Muschampia tessellum Hübner. 1803		12.8	40.8	19	38.5	111
Muschampia cribrellum obscurior Staudinger. 1892		8.51	16.3	52.4	0	77.2
Neptis rivularis Ssopoli. 1763		172	278	214	135	799
Neptis sappho Pallas. 1771		14.9	49	38.1	7.69	110
Nordmannia pruni Linnaeus. 1758		2.13	16.3	21.4	3.85	43.7
Nymphalis antiopa Linnaeus. 1758		40.4	30.6	45.2	42.3	159
Nymphalis polychloros Linnaeus. 1758		93.6	51	105	0	249
Nymphalis v-album Denis & Schiffermüller. 1775		85.1	79.6	102	84.6	352
Ochlades sylvanus Esper. 1778		21.3	8.16	4.76	0	34.2
Ochlodes venata Bremer & Grey. 1853		4.26	0	0	0	4.26
Oeneis mongolica Oberthür. 18..		6.38	0	0	0	6.38
Oeneis nanna Menetries. 1859		27.7	91.8	117	11.5	248
Oeneis norno Thunberg. 1791		0	14.3	38.1	0	52.4
Oeneis sculda Eversmann. 1851		132	196	117	30.8	475
Oeneis tarpeia Pallas. 1771		10.6	0	2.38	0	13
Oeneis urda Eversmann. 1847		46.8	118	100	11.5	277
Papilio machaon Linnaeus. 1758		27.7	153	157	46.2	384
Parnassius apollo Linnaeus. 1758		0	6.12	2.38	7.69	16.2
Parnassius nomion nomion Fisher von Waldheim. 1823		42.6	49	54.8	19.2	166
Patricius lucifer Staudinger. 1867		0	6.12	2.38	0	8.5
Pieris chlorodice Hübner. 1808		0	2.04	0	0	2.04
Pieris napi Linnaeus. 1758		27.7	8.16	0	7.69	43.5
Pieris rapae Linnaeus. 1758		19.1	2.04	0	0	21.2
Plebejus argyrognomon mongolica Bergsträsser. 1779		42.6	12.2	83.3	11.5	150
Plebejus eversmanni Staudinger. 1886		17	8.16	0	0	25.2
Plebejus idas naruena Curvoisier. 1913		97.9	198	90.5	73.1	459
Plebejus pylaon Fischer von Waldheim. 1832		4.26	14.3	7.14	7.69	33.4
Plebejus subsolanus Eversmann. 1851		151	351	152	92.3	747
Polygonia c-album Linnaeus. 1758		51.1	51	59.5	23.1	185
Polygonia interposita Staudinger. 1881		2.13	2.04	16.7	34.6	55.5
Polyommatus cyane Eversmann. 1837		0	2.04	0	0	2.04
Polyommatus eroitides Staudinger. 1892		6.38	0	0	0	6.38

APPENDIX 2. (continued)

1	2	3	4	5	6
Polyommatus eros Ochsenheimer, 1808	0	0	0	3.85	3.85
Polyommatus icadius Grum-Grshimailo, 1890	0	0	0	3.85	3.85
Polyommatus icarus Rottemburg, 1775	21.3	24.5	23.8	19.2	88.8
Polyommatus semiargus Rottemburg, 1775	80.9	67.3	14.3	15.4	178
Pyrgus carthami Hübner, 1813	2.13	0	0	0	2.13
Pyrgus cinarae Ramber, 1839	27.7	22.4	11.9	3.85	65.9
Pyrgus jupei Alberti, 1967	0	6.12	2.38	7.69	16.2
Pyrgus malvae Linnaeus, 1758	27.7	83.7	66.7	3.85	182
Pyrgus masculatus masculatus Bremer & Grey, 1853	46.8	49	69	38.5	203
Pyrgus sibirica Reverdin, 1911	21.3	36.7	21.4	0	79.4
Pyrgys serratulae Rambur, 1839	0	38.8	14.3	0	53.1
Rimisia miris miris Staudinger,	2.13	0	0	0	2.13
Satyrus stheno Grum- Grshimailo, 1887	2.13	0	0	0	2.13
Scolitantides orion Pallas, 1771	2.13	63.3	59.5	23.1	148
Techla betula crossa Linnaeus, 1758	6.38	0	0	0	6.38
Thersamonolycaena splendens Staudinger, 1881	0	0	14.3	0	14.3
Thersamonolycaena violacea Staudinger, 1892	0	0	9.52	0	9.52
Triphysa phryne Pallas, 1771	21.3	0	66.7	0	87.9
Vacciniina optilete Knoch, 1781	12.8	91.8	0	11.5	116
Vanessa cardui Linnaeus, 1758	12.8	4.08	31	0	47.8

APPENDIX 3.
List of the vascular plant species presented at two different habitat types of West Khentej. HM = Herb meadow, MDS = Mountain Dry Steppe. This table is shown the original data which collected from each study plots. Some data excluded anywhere from these table due to comparing between habitats.

Species name	HM2	HM3	MDS3	MDS4	Total individuals
Achillea asiatica	139	29			168
Aconitum sp.		4			4
Alchemilla gubanovii	2				2
Allium sp	4		3		7
Alyssum lenense				4	4
Anemone crinita		16			16
Artemisia dracunculus	6				6
Artemisia frigida			8	2	10
Artemisia integrifolia	77	1	7	26	111
Artemisia mongolica	151	32			183
Artemisia tanacetifolia	199	12			211
Aster alpinus	1				1
Aster tataricus	9				9
Bupleurum bicaule			2		2
Poa sp.		41	1		42
Bromus sp.	309	20		2	331
Carex arnellii	788	300	14	102	1,204
Carex pediformis	137				137
Carum carvi		41			41
Cicuta virosa		14			14
Cleistogenes squarrosa				15	15
Crepis sibirica				13	13
Dianthus versicolor	45	6			51
Elymus gmelinii	3				3
Equisetum arvense	15	66			81
Equisetum pratensis	4	35			39
Festuca lenensis			1	2	3
Filipendula palmata	4	14			18
Galium boreale	5	34			39
Galium sp?	104	50			154
Galium verum	127	26		7	160
Geranium pratense	26	38			64
Geum aleppicum	3				3
Goniolimon speciosum				1	1
Hemerocalls minor	5				5
Hieraceum virosum	2	1			3
Iris sanguinea		54			54
Koeleria macrantha			28	7	35
Lactuca sibirica		1			1
Lieium pumilum				7	7
Lilium daurica		3			3
Linaria acutiloba	2				2

APPENDIX 3 (continued)

Oxytropis myriophylla			14		14
Papaver nudicaule	5				5
Patrinia sibirica				6	6
Pedicularis sp?		3			3
Phlomoides tuberosa	7	1			8
Poa botryoides	128			8	136
Poa pratensis	39				39
Polemonium racemosum		5			5
Polygala sibirica			1	1	2
Polygonatum odoratum	6	1			7
Polygonium sibiricum	62	15			77
Bistorta viviparum		5			5
Aconogonon alpinum	7				7
Potentilla acaulis			59	218	277
Potentilla bifurca	3				3
Potentilla multifida	10				10
Potentilla tanacetifolia	43			24	67
Potentilla viscosa			34	6	40
Pulsatilla sp			16	22	38
Ranunculus japonicus		24			24
Rhodiola rosea		1			1
Rosa acicularis	5	1			6
Rumex sp		1			1
Sanguisorba officinalis	63	20			83
Schizonepeta multifida	3			3	6
Scorzonera radiata				5	5
Scutellaria scordifolia	17	36			53
Spiraea flexuosa	71				71
Spiraea media	10				10
Taraxacum mongolicum				2	2
Thalictrum simplex	23				23
Thalictrum squarrosum	11	21			32
Thymus dahuricus			6	8	14
Trifolium lupinaster	11				11
Valeriana officinalis	7				7
Vicia amoena	45	39			84
Vicia unijuga		8			8
Sum	2743	1019	197	488	4447

APPENDIX 4.

Herbaceous plant community composition presented at the four habitat types of West Khentej. A total of 61 species recorded in herb meadow and 29 species in mountain dry steppe. HM=Herb meadow, MDS= mountain dry steppe, 10m² - numbers of the individuals presented in 10m² plots, %= percent of the species which found in total plot biomass.

Species name	HM	$10m^2$	%	MDS	$10m^2$	%
Achillea asiatica	168	210	4.47		0	0
Aconitum sp.	4	5	0.11		0	0
Alchemilla sp.	2	2.5	0.05		0	0
Allium sp.	4	5	0.11	3	7.5	0.438
Alyssum lenense		0	0	4	10	0.584
Anemone crinita	16	20	0.43		0	0
Artemisia dracunculus	6	7.5	0.16		0	0
Artemisia frigida		0	0	10	25	1.46
Artemisia integrifolia	78	97.5	2.07	33	82.5	4.818
Artemisia mongolica	183	229	4.86		0	0
Artemisia tanacetifolia	211	264	5.61		0	0
Aster alpinus	1	1.25	0.03		0	0
Aster tataricus	9	11.3	0.24		0	0
Bepleurum bicaule		0	0	2	5	0.292
Poa botryoides	41	51.3	1.09	1	2.5	0.146
Bromus pumpelliunus	329	411	8.74	2	5	0.292
Carex arnellii	1,088	1,360	28.9	116	290	16.93
Carex pediformis	137	171	3.64		0	0
Carum carvi	41	51.3	1.09		0	0
Cicuta virosa	14	17.5	0.37		0	0
Cleistogenes squarrosa		0	0	15	37.5	2.19
Crepis sibirica		0	0	10	25	1.46
Dianthus versicolor	51	63.8	1.36		0	0
Elymus gmelinii	3	3.75	0.08		0	0
Equisetum arvense	81	101	2.15		0	0
Equisetum pratense	39	48.8	1.04		0	0
Festuca lenensis		0	0	3	7.5	0.438
Filipendula palmata	18	22.5	0.48		0	0
Galium boreale	39	48.8	1.04		0	0
Galium sp?	154	193	4.09		0	0
Galium verum	153	191	4.07	7	17.5	1.022
Geranium pratense	64	80	1.7		0	0
Geum aleppicum	3	3.75	0.08		0	0
Goniolimon speciosum		0	0	1	2.5	0.146
Grepis sibirica		0	0	3	7.5	0.438
Hemerocalls minor	5	6.25	0.13		0	0
Hieraceum virosum	3	3.75	0.08		0	0
Iris sanguinea	54	67.5	1.44		0	0

APPENDIX 4 (continued)

Lactuca sibirica	1	1.25	0.03		0	0
Lilium pumilum		0	0	7	17.5	1.022
Lilium dauricum	3	3.75	0.08		0	0
Linaria acutiloba	2	2.5	0.05		0	0
Oxytropis myriophylla		0	0	14	35	2.044
Papaver nudicaule	5	6.25	0.13		0	0
Patrinia sibirica		0	0	6	15	0.876
Pedicularis sp?	3	3.75	0.08		0	0
Phlomoides tuberosa	8	10	0.21		0	0
Poa botryoides	128	160	3.4	8	20	1.168
Poa pratensis	39	48.8	1.04		0	0
Polemonium racemosum	5	6.25	0.13		0	0
Polygala sibirica		0	0	2	5	0.292
Polygonatum odoratum	7	8.75	0.19		0	0
Polygonium sibiricum	77	96.3	2.05		0	0
Bistorta alopecuroides	5	6.25	0.13		0	0
Aconogonon alpinum	7	8.75	0.19		0	0
Potentilla acaulis		0	0	277	692.5	40.44
Potentilla bifurca	3	3.75	0.08		0	0
Potentilla multifida	10	12.5	0.27		0	0
Potentilla tanacetifolia	43	53.8	1.14	24	60	3.504
Potentilla viscosa		0	0	40	100	5.839
Pulsatilla sp		0	0	38	95	5.54
Ranunculus japonicus	24	30	0.64		0	0
Rhodiola rosea	1	1.25	0.03		0	0
Rosa acicularis	6	7.5	0.16		0	0
Rumex sp	1	1.25	0.03		0	0
Sanguisorba officinalis	83	104	2.21		0	0
Schizonepeta multifida	3	3.75	0.08	3	7.5	0.438
Scorzonera radiata		0	0	5	12.5	0.73
Scutellaria scordifolia	53	66.3	1.41		0	0
Spiraea flexuosa	71	88.8	1.89		0	0
Spiraea media	10	12.5	0.27		0	0
Taraxacum mongolicum		0	0	2	5	0.292
Thalictrum simplex	23	28.8	0.61		0	0
Thalictrum squarrosum	32	40	0.85		0	0
Thymus dahuricus		0	0	14	35	2.044
Trifolium lupinaster	11	13.8	0.29		0	0
Valeriana officinalis	7	8.75	0.19		0	0
Vicia amoena	84	105	2.23		0	0
Vicia unijuga	8	10	0.21		0	0
Sum	3,762	4,703	100%	685	1,713	100%

APPENDIX 5.

The most abundant plant genera found at two habitat types which are known as important foodplant resource for some butterfly species. The information of foodplants is collected from source of the following literature: Tuzov, 1997 and 2000; Korshunov, 1995. HM= herb meadow, MDS= Mountain Dry Steppe.

Habitat	Plant's genera	Foodplants for
HM	***Carex***	*Aphantopus hyperantus, Coenonympha oedippus, Erebia ligea, Erebia neriene, Erebia niphonica, Lopinga achine, Minois dryas, Oeneis norna, Coenonumpha hero, Thriphysa phryne,, Hesperia comma,*
	Artemisia	*Papilio machaon, Vanessa cardui, Euphydryas maturna, Melitaea didyma,*
	Bromus	*Carterocephalus palaemon, C. silvicola, Erebia medusa, Minois dryas, H. comma*
	Achillea	*Melitaea cinxia*
	Poa	*Aphantopus hyperantus, Coenonympha oedippus, Erebia ligea, Erebia neriene, Erebia niphonica, Lopinga achine, Minois dryas, Oeneis norna, Coenonumpha hero, C.glycerion, Erebia aethiopis, Erebia medusa, Hipparchia autonoe, Hyponephele lycaon, Lasiommato maero, Lopinga deidamia, Oeneis tarpeia, Hesperia comma, Carterocephalus silvicola, Ochlades sylvanus, Boeberia parmenio*
	Polygonium	*Boloria titania, Lycaena helle, Boloria eunomia*
	Sanguisorba	*Brenthis daphne, Brenthis ino, Maculinea teleius,*
	Vicia	*Colias erate, Colias hyale, Colias heos, Leptidea morsei, L. sinapis, Neptis sappho, Celastrina argiolus, Plebeijus argus, P. idas, P. subsolanus, Polyommatus amandus, Leptidea amurensis*
	Spiraea	*Neptis rivularis, Ahlbergia frivaldszkyi, Pyrgus maculatus, Aporia crataegy, Brenthis ino*
	Potentilla	*Muschampia cribrellum, Pyrgus malvae, P. sibirica, P. carthami, Pyrgus serratulae*
	Valeriana	*Melitaea diamina, Melitaea didyma, Mellicta athalia,*
	Filipendula	*Neptis rivularis, Aporia crataegy, Boloria titania*
	Linaria	*Melitaea didyma, Mellicta britomartis,*
	Trifolium	*Melitaea didyma, Everes argiades, Plebeijus argus, P. argyrognomon, P. idas, Glaucopsyche lycormas, Polyommatus semiargus, P. icarus, Colias erate, Colias poliographus, L. sinapis,*
	Geranium	*Aricia agestis, A. allous, A eumedon, Euphydryas aurinia,*
	Rumex	*Laycaena dispar, Lycaena helle, Lycaena virgaureae*
	Phlomis	*Muschampia tessellum*
MDS	***Potentilla***	*Muschampia cribrellum, Pyrgus malvae, P. sibirica, P. carthami, Pyrgus serratulae*
	Carex	*Aphantopus hyperantus, Coenonympha oedippus, Erebia ligea, Erebia neriene, Erebia niphonica, Lopinga achine, Minois dryas, Oeneis norna, Coenonumpha hero, Thriphysa phryne,, Hesperia comma,*
	Artemisia	*Papilio machaon, Vanessa cardui, Euphydryas maturna, Melitaea didyma,*
	Poa	*Aphantopus hyperantus, Coenonympha oedippus, Erebia ligea, Erebia neriene, Erebia niphonica, Lopinga achine, Minois dryas, Oeneis norna, Coenonumpha hero, C.glycerion, Erebia aethiopis, Erebia medusa, Hipparchia autonoe, Hyponephele lycaon, Lasiommato maero, Lopinga deidamia, Oeneis tarpeia, Hesperia comma, Carterocephalus silvicola, Ochlades sylvanus, Boeberia parmenio*
	Thymus	*Maculinea orion*
	Oxytropis	*Cupido minimus, Polyommatus icarus, P. eros, Colias tyche*
	Allium	*Albulina orbitulus*
	Festuca	*Erebia medusa, E. neriene, Lasiommata maera, Minois dryas, Oeneis tarpeia, Hesperia comma,*

APPENDIX 6.

Average monthly precipitation of Bugant meteostation

	Jan.	Feb.	March	Apr.	Mai	June	Juli	Aug.	Sep.	Oct.	Nov.	Dec.
1999	-20,4	-18,0	-12,0	3,6	13,5	16,3	21,5	15,6	8,3		-7,3	-16
2000	-24,4	-17,7	-5,8	4,5	12,7	18,8	19,6	18,1	11,8			-19,0
2001	-26,9	-18,8	-6,9	3,7	12,8	20,9	21,6	18,7	11,3	2,6	-11,4	-25,0
2002	-19,4	-19	-3,1	3,1	13,8	19,8	23	19,8	10	-2,3	-13,6	-23,1
2003	-20,7	-13,8	-6	5,8								

Average monthly precipitation of Bugant meteostation

	Jan.	Feb.	March	Apr	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1999	1,3	0,7	4	5,9	4,7	20,5	18	42	26,6		1,9	1,8
2000	0,4	0,4	0,8	7,6	28	27,9	61	49,2	16,7			6
2001	2,6	0,2	4,7	2,1	2,1	1,2	66	78,9	16,3	4,3	2,9	2,6
2002	5,4	1,6	6	19	45	44,5	45,8	78,6		57,1	12,1	6,6
2003	9,6	6,8	0,9	17,7								

APPENDIX 7.

Niche width of butterflies in West Khentej. Fo= Forest opening, HM= Herb meadow, WG= Wet grassland, MDS = Mountain dy steppe, NWi= niche width, stand.NWi= standard niche width.

Species	(FO)	(HM)	(MDS)	(WG)	NWi	stand.NWi
Aglais urticae LINNAEUS, 1758	0,21	0,37	0,2	0,25	3,69	0,9
Agrodiaetus amandus SCHNEIDER, 1792	0,28	0,36	0,1	0,27	3,45	0,82
Ahlbergia frivaldszkyi LEDERER, 1855	0,26	0,33	0,2	0,19	3,81	0,94
Albulina orbitula PRUNNER, 1798	0,24	0,52	0,1	0,17	2,77	0,59
Anthocharis cardamines LINNAEUS, 1758	0,16	0,06	0,3	0,46	2,92	0,64
Aphantopus hyperantus LINNAEUS, 1758	0,23	0,33	0,2	0,28	3,76	0,92
Aporia crataegi LINNAEUS, 1758	0,22	0,4	0,3	0,04	3,09	0,7
Aporia hipa hippa BREMER, 1861	0	1	0	0	1	0
Araschnia levana LINNAEUS, 1758	0,47	0,49	0	0	2,16	0,39
Argynnis adippe DENIS et SCHIFFERMÜLLER, 1775	0,26	0,29	0	0,43	3,01	0,67
Argynnis aglaja LINNAEUS, 1758	0,25	0,28	0,3	0,18	3,89	0,96
Argynnis niobe LINNAEUS, 1758	0,23	0,27	0,2	0,29	3,95	0,98
Argynnis paphia LINNAEUS, 1758	0,11	0,38	0,2	0,26	3,47	0,82
Aricia agestis DENIS & SCHIFFERMÜLLER, 1775	0,3	0,44	0	0,21	3,01	0,67
Aricia allous HÜBNER, 1819	0,26	0,74	0	0	1,62	0,21
Aricia eumedon ESPER, 1780	0,21	0,44	0,2	0,17	3,37	0,79
Boeberia parmenio BOEBER, 1809	0,18	0,46	0,3	0,05	2,89	0,63
Boloria angarensis ERSCHOFF, 1870	0,32	0,59	0	0,05	2,18	0,39
Boloria eunomia ESPER, 1799	0,35	0,27	0	0,38	2,94	0,65
Boloria euphrosyne LINNAEUS, 1758	0,28	0,42	0,1	0,23	3,19	0,73
Boloria freija THUNBERG, 1791	0,58	0,37	0,1	0	2,12	0,37
Boloria oscarus EVERSMANN, 1844	0,68	0,1	0,2	0	1,92	0,31
Boloria selene DENIS & SCHIFFERMULLER, 1775	0,17	0,49	0,1	0,21	3,01	0,67
Boloria selenis EVERSMANN, 1837	0,42	0,2	0,3	0,03	2,97	0,66
Boloria titania ESPER, 1793	0,41	0,52	0,1	0	2,28	0,43
Brenthis daphne BERGSTRÄSSER, 1780	0,25	0,34	0,2	0,2	3,8	0,93
Brenthis ino ROTTEMBURG, 1775	0,22	0,32	0,1	0,38	3,32	0,77
Carterocephalus argyrostigma EVERSMANN, 1851	0	0,82	0,2	0	1,42	0,14
Carterocephalus palaemon PALLAS, 1771	0	0,38	0,2	0,45	2,65	0,55
Carterocephalus silvicola MEIGAN, 1828	0,02	0,79	0,1	0,05	1,55	0,18
Celastrina argiolus LINNAEUS, 1758	0,3	0,51	0,1	0,11	2,73	0,58
Celastrina fedoseevi KORSHUNOV et IVONIN, 1990	0	1	0	0	1	0
Coenonympha amaryllis CRAMER, 1782	0,22	0,56	0,1	0,09	2,59	0,53
Coenonympha glycerion BORKHAUSEN, 1788	0,22	0,53	0,1	0,18	2,75	0,58
Coenonympha hero LINNAEUS, 1761	0,39	0,41	0,1	0,12	2,89	0,63
Coenonympha oedippus FABRICIUS, 1787	0,15	0,35	0,3	0,15	3,46	0,82
Colias alpherakii STAUDINGER, 1882	1	0	0	0	1	0
Colias aurora ESPER, 1784	0,22	0,49	0,2	0,09	2,95	0,65
Colias erate ESPER, 1804	0	1	0	0	1	0
Colias heos HERBST, 1792	0,16	0,37	0	0,47	2,62	0,54
Colias hyale LINNAEUS, 1758	0,3	0,21	0,3	0,15	3,68	0,89
Colias palaeno LINNAEUS, 1761	0	0,35	0	0,65	1,83	0,28
Colias poliographus MOTSCHULSKY, 1860	0,51	0,49	0	0	2	0,33
Colias staudingeri ALPHERAKY, 1881	0	0	1	0	1	0
Colias tyche BOEBER, 1812	0,18	0,33	0,4	0,12	3,4	0,8
Cupido minimus FUESSLY, 1775	0,4	0,33	0,3	0,02	3,01	0,67
Cupido prosecusa ERSCHOFF, 1874	0	0	0	1	1	0
Erebia aethiops ESPER, 1777	0,51	0,16	0,1	0,22	2,9	0,63
Erebia jeniseiensis TRYBOM, 1877	0,47	0	0,5	0	1,99	0,33
Erebia ligea LINNAEUS, 1758	0	0,1	0,9	0	1,23	0,08
Erebia medusa DENIS & SCHIFFERMÜLLER, 1775	0,16	0,63	0,2	0	2,13	0,38
Erebia neriene BÖBER, 1809	0,2	0,39	0,2	0,17	3,6	0,87
Erebia niphonica JANSON, 1877	0	0,3	0,7	0	1,72	0,24
Erebia discoidalis KIRBY, 1837	0	1	0	0	1	0

APPENDIX 7. (continued)

Erynnis tages LINNAEUS, 1758	0,19	0,21	0,6	0	2,27	0,42
Euphydryas aurina ROTTEMBURG, 1775	0,5	0,32	0,2	0	2,62	0,54
Euphydryas intermedia MENETRIES, 1859	0,36	0,45	0	0,19	2,71	0,57
Euphydryas maturna LINNAEUS, 1758	0,24	0,63	0,1	0,07	2,15	0,38
Everes argiades PALLAS, 1771	0,39	0,18	0,1	0,34	3,24	0,75
Everes fischeri EVERSMANN, 1843	0,11	0,1	0,8	0	1,55	0,18
Glaucopsyche lycormas BUTLER, 1866	0,22	0,44	0,1	0,24	3,22	0,74
Hemadara rurigena LEECH, 1890	0,07	0,56	0	0,36	2,2	0,4
Hesperia comma LINNAEUS, 1758	0,31	0,06	0,6	0	2,02	0,34
Hipparchia autonoe ESPER, 1783	1	0	0	0	1	0
*Hyponephele lycaon R*OTTEMBURG, 1775	0,38	0,18	0,4	0	2,72	0,57
Inachis io LINNAEUS, 1758	0,24	0,34	0,2	0,24	3,82	0,94
Kretania eurypilus FREYER, 1851	0,13	0,54	0,1	0,23	2,69	0,56
Lasiommato maero LINNAEUS, 1758	0,31	0	0,7	0	1,74	0,25
Leptidea amurensis MENETRIES, 1859	0,19	0,58	0,1	0,12	2,52	0,51
Leptidea morsei FENTON, 1881	0,33	0,26	0,3	0,14	3,72	0,91
Leptidea sinapis LINNAEUS, 1758	0,46	0,2	0,1	0,28	3,02	0,67
Lethe diana diana Butler, 1866?	0	1	0	0	1	0
Limenitus populi LINNAEUS, 1758	0,23	0,77	0	0	1,55	0,18
Lopinga achine SCOPOLI, 1763	0,43	0,47	0,1	0	2,42	0,47
Lopinga deidamia EVERSMANN, 1851	0,36	0,57	0	0,04	2,18	0,39
Lycaena dispar LEECH, 1894	0,18	0,27	0,5	0,08	3,04	0,68
Lycaena helle DENIS & SCHIFFERMUELLER, 1775	0,21	0,59	0	0,19	2,31	0,44
Lycaena hippothoe LINNAEUS, 1761	1	0	0	0	1	0
Lycaena vigaureae LINNAEUS, 1758	0,23	0,48	0,1	0,23	2,96	0,65
Maculinea arion LINNAEUS , 1758	0,51	0,49	0	0	2	0,33
Maculinea teleius BERGSTRÄSSER, 1779	0,31	0,43	0.1	0,26	2,91	0,64
Melitaea arcesia BREMER, 1861	0,4	0,56	0	0	2,08	0,36
Melitaea cinxia LINNAEUS, 1758	0,21	0,21	0	0,58	2,35	0,45
Melitaea diamina LANG, 1789	0,2	0,35	0,2	0,26	3,78	0,93
Melitaea didyma ESPER, 1779	0,17	0,29	0,4	0,18	3,64	0,88
Melitaea phoebe DENIS & SCHIFFERMÜLLER, 1775	0,18	0,27	0,1	0,45	3,16	0,72
Mellicta athalia ROTTEMBERG, 1775	0,22	0,59	0	0,15	2,4	0,47
Mellicta aurelia NICKERL, 1850	0,26	0,27	0,2	0,27	3,95	0,98
Mellicta britomartis ASSMANN, 1847	0,32	0,46	0,1	0,09	2,97	0,66
Mellicta centralasiae WNUKOWSKY, 1929	0,37	0,35	0,1	0,16	3,33	0,78
Mellicta plotina BREMER, 1861	0,3	0,19	0,1	0,43	3,15	0,72
Minois dryas SCOPOLI, 1763	0,2	0,28	0,3	0,26	3,94	0,98
Muschampia tessellum HUEBNER, 1803	0,11	0,37	0,2	0,35	3,36	0,79
Muschampia cribrellum obscurior STAUDINGER, 1892	0,11	0,21	0,7	0	1,93	0,31
Neptis rivularis SCOPOLI, 1763	0,22	0,35	0,3	0,17	3,74	0,91
Neptis sappho PALLAS, 1771	0,14	0,45	0,3	0,07	2,91	0,64
Nordmannia pruni LINNAEUS, 1758	0,05	0,37	0,5	0,09	2,57	0,52
Nymphalis antiopa LINNAEUS, 1758	0,25	0,19	0,3	0,27	3,92	0,97
Nymphalis polychloros LINNAEUS, 1758	0,38	0,2	0,4	0	2,78	0,59
Nymphalis v-album DENIS & SCHIFFERMUELLER, 1775	0,24	0,23	0,3	0,24	3,96	0,99
Ochlades sylvanus ESPER, 1778	0,62	0,24	0,1	0	2,16	0,39
Ochlodes venata BREMER et GREY, 1853	1	0	0	0	1	0
Oeneis mongolica OBERTHUER, 18..	1	0	0	0	1	0
Oeneis nanna MENETRIES, 1859	0,11	0,37	0,5	0,05	2,67	0,56
Oeneis norno THUNBERG, 1791	0	0,27	0,7	0	1,66	0,22
Oeneis sculda EVERSMANN, 1851	0,28	0,41	0,2	0,06	3,21	0,74
Oeneis tarpeia PALLAS, 1771	0,82	0	0,2	0	1,43	0,14
Oeneis urda EVERSMANN, 1847	0,17	0,43	0,4	0,04	2,91	0,64
Papilio machaon LINNAEUS, 1758	0,07	0,4	0,4	0,12	2,89	0,63

APPENDIX 7. (continued)

Parnassius apollo LINNAEUS, 1758	0	0,38	0,1	0,47	2,56	0,52
Parnassius nomion Fisher von Waldheim, 1823	0,26	0,3	0,3	0,12	3,62	0,87
Patricius lucifer STAUDINGER, 1867	0	0,72	0,3	0	1,68	0,23
Pieris chlorodice HUEBNER, 1808	0	1	0	0	1	0
Pieris napi LINNAEUS, 1758	0,64	0,19	0	0,18	2,13	0,38
Pieris rapae LINNAEUS, 1758	0,9	0,1	0	0	1,21	0,07
Plebejus argyrognomon BERGSTRÄSSER, 1779	0,28	0,08	0,6	0,08	2,48	0,49
Plebejus eversmanni STAUDINGER, 1886	0,68	0,32	0	0	1,78	0,26
Plebejus idas naruena CURVOISIER, 1913	0,21	0,43	0,2	0,16	3,39	0,8
Plebejus pylaon FISCHER von WALDHEIM, 1832	0,13	0,43	0,2	0,23	3,35	0,78
Plebejus subsolanus EVERSMANN, 1851	0,2	0,47	0,2	0,12	3,14	0,71
Polygonia c-album LINNAEUS, 1758	0,28	0,28	0,3	0,12	3,67	0,89
Polygonia interposita STAUDINGER, 1881	0,04	0,04	0,3	0,62	2,07	0,36
Polyommatus cyane Eversmann, 1837	0	1	0	0	1	0
Polyommatus eroitides STAUDINGER, 1892	1	0	0	0	1	0
Polyommatus eros OCHSENHEIMER, 1808	0	0	0	1	1	0
Polyommatus icadius GRUM-GRSHIMAILO, 1890	0	0	0	1	1	0
Polyommatus icarus ROTTEMBURG, 1775	0,24	0,28	0,3	0,22	3,96	0,99
Polyommatus semiargus ROTTEMBURG, 1775	0,45	0,38	0,1	0,09	2,75	0,58
Pyrgus carthami HUEBNER, 1813	1	0	0	0	1	0
Pyrgus cinarae RAMBER, 1839	0,42	0,34	0,2	0,06	3,04	0,68
Pyrgus jupei ALBERTI, 1967	0	0,38	0,1	0,47	2,56	0,52
Pyrgus malvae LINNAEUS, 1758	0,15	0,46	0,4	0,02	2,7	0,57
Pyrgus masculatus BREMER et GREY, 1853	0,23	0,24	0,3	0,19	3,81	0,94
Pyrgus sibirica REVERDIN, 1911	0,27	0,46	0,3	0	2,79	0,6
Pyrgys serratulae RAMBUR, 1839	0	0,73	0,3	0	1,65	0,22
Rimisia miris miris STAUDINGER,	1	0	0	0	1	0
Satyrus stheno GRUM-GRSHIMAILO, 1887	1	0	0	0	1	0
Scolitantides orion PALLAS, 1771	0,01	0,43	0,4	0,16	2,71	0,57
Techla betula crossa LINNAEUS, 1758	1	0	0	0	1	0
Thersamonolycaena splendens STAUDINGER, 1881	0	0	1	0	1	0
Thersamonolycaena violacea STAUDINGER, 1892	0	0	1	0	1	0
Triphysa phryne PALLAS, 1771	0,24	0	0,8	0	1,58	0,19
Vacciniina optilete KNOCH, 1781	0,11	0,79	0	0,1	1,55	0,18
Vanessa cardui LINNAEUS, 1758	0,27	0,09	0,6	0	2,01	0,34

APPENDIX 8.
Diversity indices in all study plots. FO=Forest opening, HM=Herb meadow, MDS=Mountaon dry steppe. WG=wet grassland

Habitat	Mean observed number of species	Mean number of individuals	Single-tons	Estimated total species richness	Expected total species richness	Mean Fisher's alpha diversity	Mean Simpson diversity
FO1	95 ± 7.32	884 ± 77.49	19	108.13 ± 8.26	111.41 ± 9.88	27 ± 1.64	41.32 ± 3.84
FO2	95 ± 4.32	883 ± 100.53	16	104.44 ± 3.19	107.8 ± 8.38	27.01 ± 1.64	56.53 ± 5.19
FO3	72 ± 9.14	288 ± 32.16	21	89.12 ± 13.91	88.96 ± 9.69	30.81 ± 2.89	37.1 ± 3.2
FO4	84 ± 7.16	545 ± 77.78	14	91.85 ± 8.92	91 ± 4.95	27.75 ± 2	38.49 ± 2.87
HM	89 ± 8.42	793 ± 71.47	19	101.68 ± 8.19	119.08 ± 19.27	25.72 ± 1.64	45.68 ± 9.01
HM1	83 ± 8.57	790 ± 137.2	13	90.87 ± 9.3	92.39 ± 6.8	23.39 ± 1.51	33.81 ± 4.36
HM2	62 ± 10.99	520 ± 94.29	8	65.22 ± 13.86	68.4 ± 5.92	18.35 ± 1.42	25.03 ± 1.21
HM3	85 ± 7.95	980 ± 122.91	11	90.54 ± 9.14	92.56 ± 5.96	22.35 ± 1.36	43.33 ± 3.04
HM4	95 ± 4.64	1,134 ± 165.73	9	99.76 ± 1.82	98.68 ± 3.31	24.68 ± 1.41	48.3 ± 8.93
MDS	71 ±4.76	394 ± 30.89	17	84.32 ± 9.85	84.14 ± 8.33	25.28 ± 2.09	39.2 ± 3.5
MDS1	58 ± 1.94	475 ± 34.79	6,6	60.22 ± 3.18	59.25 ± 1.63	17.33 ± 1.6	23.72 ± 4.88
MDS2	68 ± 7.47	503 ± 55.26	11	73.29 ± 10.01	80.1 ± 9.73	21.2 ± 1.63	32.59 ± 2.84
MDS3	74 ± 9.74	391 ± 56.73	23	94.85 ± 15.96	98.05 ± 13.31	27.02 ± 2.23	40.64 ± 3.41
MDS4	58 ± 6.39	361 ± 49.92	15	68.78 ± 9.83	86.13 ± 20.9	19.53 ± 1.72	34.18 ± 2.67
WG	91 ± 5.74	1,052 ± 96.24	13	98.16 ± 3.15	101.56 ± 7.67	23.9 ± 1.4	42.21 ± 5.78

APPENDIX 9.

List of the butterfly species captured in surroundings of Khonin Nuga, West Khentej. HM=Herb Meadow, MDS= Mountain Dry Steppe, WG= Wet Grassland, FO= Forest Openning. CI=Chorological index (Kudarna 1986), describing the biogeographic disposition (i.e., the natural resistance potential) of European species. VI= Vulnerability Index (biogeographic condition). The CI value increases with the reduction of the biogeographic disposition and the VI increases with the increase of anthropogenic threat to the species. Threat status (a) = the species are listed in red data book of European butterflies, Threat status(b)= the species are listed in red data book of Germany. LR(nt)-lower risk, near threatened, VU-Vulnerable, EN- Endangered, Ex- Extinct, CR- Critically endangered.

*- Candidates for Appendix II of the Convention of Bern (strictly protected species) in systematic order, threat status extinct, critically endangered or endangered in Europe, ** -Species already on Appendix II of the Bern Convention at present and considered threatened in Europe, ***- Species already on Appendix II of the Bern Convention at present and considered threatened in Europe, threat status vulnerable.

Species name	Geographic range	Habitat	Threat status(a)	Threat status(b)	CI	VI
HESPERIIDAE						
Carterocephalus palaemon Pallas	Holarctic	HM; MDS; WG		LR (nt)		
Carterocephalus silvicola Meigan	Palaearctic	HM; MDS; WG; FO		EN		
Carterocephalus argyrostigma Eversmann	East-Asia	HM; MDS;				
Erynnis tages Linnaeus	Central-Asia	HM; MDS; FO		LR (nt)		
Hesperia comma Linnaeus	Palaearctic	HM; MDS; FO		VU		
Muschampia cribrellum Staudinger	Palaearctic	HM; MDS; FO	LR (nt)			
Muschampia tessellum Huebner	Palaearctic	HM; MDS; WG; FO				
Ochlades sylvanus Esper	Palaearctic	HM; MDS; FO				
Ochlades venata Bremer et Grey	East-Asia	FO				
Pyrgus jupei Alberti	Palaearctic	HM; MDS; WG;				
Pyrgus maculatus Bremer et Grey	East-Asia	HM; MDS; WG; FO				
Pyrgus malvae Linnaeus	Palaearctic	HM; MDS; FO		LR (nt)		
Pyrgus cinarae Rambur	Palaearctic	HM; MDS; FO				
Pyrgus serratulae Rambur	Palaearctic	HM; MDS; WG		EN		
Pyrgus sibirica Reverdin	East-Asia	HM; MDS; FO				
PAPILIONIDAE						
Papilio machaon Linnaeus	Holarctic	HM; MDS; WG; FO		LR (nt)	5	
Papilio xuthus Linnaeus	East-Asia	HM				
Parnassius apollo Linnaeus	Palaearctic	HM; MDS; WG	VU***	CR	8	3
Parnassius nomion Fischer de Waldheim	Central-Asia	HM; MDS; WG; FO				
PIERIDAE						
Anthocharis cardamines Linnaeus	Palaearctic	MDS; WG; FO		0	5	
Aporia crataegi Linnaeus	Palaearctic	HM; MDS; WG; FO		LR (nt)	5	
Aporia hippa hippa Bremer	East-Asia	HM				
Colias poliographus	(Central) East-Asia	HM; FO				
Colias palaeno Linnaeus	Palaearctic	FO; WG	LR (nt)	EN	8	4
Colias erate Esper	Palaearctic	HM			8	
Colias aurora Esper	East-Asia	HM; MDS; WG; FO				
Colias hayle Linnaeus	Palaearctic	HM; MDS; WG; FO		0	6	
Colias heos Herbst	Holarctic	FO; HM				
Colias staudingeri Alpheraky	East -Palaearctic	MDS				
Colias tyche Boeber	East-Asia	HM; MDS; WG; FO				
Leptidea amurensis Menetries	Palaearctic	HM; MDS; WG; FO				
Leptidea morsei Fenton	Palaearctic	HM; MDS; WG; FO	CR*		8	
Leptidea sinapis Linnaeus	Palaearctic	HM; MDS; WG; FO		LR (nt)	5	
Pieris callidice Hübner	Palaearctic	FO			10	
Pieris chlorodice Huebner	Holarctic	HM			10	
Pieris daplidice Linnaeus	Palaearctic	FO		0	5	
Pieris napi Linnaeus	Holarctic	HM; WG; FO		0	4	
Pieris rapae Linnaeus	Palaearctic	HM; FO		0	4	

APPENDIX 9. (continued)

SATYRIDAE							
Aphantopus hyperantus Linnaeus	Palaearctic	HM; MDS; WG; FO			0	6	
Boeberia parmenio Boeber	Central-Asia	HM; MDS; WG; FO					
Coenonympha amaryllis Stoll in Cramer	Central-Asia	HM; MDS; WG; FO				11e	
Coenonympha glycerion Borkhausen	Palaearctic	HM; MDS; WG; FO		VU		7	
Coenonympha hero Linnaeus	Palaearctic	HM; MDS; WG; FO	VU***	CR		10	5
Coenonympha oedippus Fabricius	Palaearctic	HM; MDS; WG; FO	CR**	Ex		12	5
Erebia aethiops Esper	Palaearctic	HM; MDS; WG; FO	LR (nt)	VU		7	
Erebia jeniseiensis Trybom	East-Asia (Japan)	FO; MDS					
Erebia kozhantschikovi Sheljuzhko	Central-Asia	FO					
Erebia ligea Linnaeus	Palaearctic	HM;MDS		LR (nt)		6	
Erebia medusa Denis & Schiffermueller	Palaearctic	HM; MDS; FO	VU	LR (nt)		6	
Erebia neriene Boeber	East-Asia	HM; MDS; WG; FO					
Erebia niphonica Janson	East-Asia (Japan)	HM; MDS					
Hemadara rurigena Leech	East-Asia	HM; WG; FO					
Hipparchia autonoe Esper	Palaearctic	FO				9	
Hyponephele lycaon Rottemburg	Palaearctic	HM; MDS; FO		EN		7	
Hyponephele pasimelas Staudinger	East-Asia	GM					
Lasiommato maero Linnaeus	Palaearctic	MDS, FO		LR (nt)		5	
Lethe diana diana Butler	East-Asia	HM					
Lopinga achine Scopoli	Palaearctic	HM; MDS; FO	VU***	CR		8	
Lopinga deidamia Eversmann	East-Asia (Japan)	HM; MDS; WG; FO					
Minois dryas Scopoli	Palaearctic	HM; MDS; WG; FO		EN		8	1
Oeneis mongolica Oberthuer	East-Asia (Mongolia)	FO					
Oeneis nanna Menetries	East-Asia	HM; MDS; WG; FO					
Oeneis norna Thunberg	Holarctic	HM;MDS				11	
Oeneis tarpeia Pallas	Palaearctic	FO; MDS				9	
Oeneis sculda Eversmann	Holarctic	HM; MDS; WG; FO					
Oeneis urda Eversmann	East-Asia	HM; MDS; WG; FO					
Satyrus stheno Grum-Grshimailo	Central-Asia	FO					
Thriphysa phryne Pallas	Palaearctic (Central-Asia)	FO; MDS	CR*			9	
NYMPHALIDAE							
Aglais urticae Linnaeus	Palaearctic	HM; MDS; WG; FO			0	4	
Araschnia levana Linnaeus	Palaearctic	HM; MDS; FO			0	7	
Argynnis paphia Linnaeus	Palaearctic	HM; MDS; WG; FO			0	5	
Boloria angarensis Erschoff	East-Asia (Siberia)	HM; FO				8	
Boloria eunomia Esper	Holarctic	HM; MDS; FO		EN		10	3
Boloria euphrosyne Linnaeus	Palaearctic	HM; MDS; FO		VU		5	
Boloria freija Thunberg	Holarctic	MF				11	
Boloria oscarus Eversmann	Holarctic	HM; MDS; FO					1
Boloria selene Denis & Schiffermueller	Palaearctic	HM; MDS; WG; FO		LR (nt)		5	
Boloria selenis Eversmann	Palaearctic	HM; MDS; WG; FO				11	
Boloria titania Esper	Holarctic	HM; MDS; FO	VU	VU		10	
Brenthis daphne Denis & Schiffermueller	Palaearctic	HM; MDS; WG; FO		CR		8	
Brenthis ino Rottemburg	Palaearctic	HM; MDS; WG; FO		LR (nt)		7	
Euphydryas aurinia Rottemburg	Holarctic	HM; MDS; FO	VU***	EN		8	2
Euphydryas intermedia Menetries	Holarctic	HM; WG; FO	EN*				
Euphydryas maturna Linnaeus	Holarctic	HM; MDS; WG; FO	VU***	CR		9	2
Fabriciana adippe Denis & Schiffermueller	Palaearctic	HM; MDS; WG; FO		VU		5	
Fabriciana niobe Linnaeus	Palaearctic	HM; MDS; WG; FO		EN		5	
Inachis io Linnaeus	Palaearctic	HM; MDS; WG; FO			0	4	
Limenitus populi Linnaeus	Palaearctic	FO; HM		EN		7	2
Melitaea arcesia Bremer	Central-Asia	HM; MDS; FO					

APPENDIX 9. (continued)

Melitaea cinxia Linnaeus	Palaearctic	HM; WG; FO		EN	5	
Melitaea diamina Lang	Palaearctic	HM; MDS; WG; FO		VU	7	2
Melitaea didyma Esper	Palaearctic	HM; MDS; WG; FO		EN	7	
Melitaea phoebe Denis & Schiffermueller	Holarctic	HM; MDS; WG; FO		EN	7	
Mellicta athalia Rottemburg	Holarctic	HM; MDS; WG; FO		VU	5	
Mellicta aurelia Nickerl	Palaearctic	HM; MDS; WG; FO	VU	VU	9	
Mellicta britomartis Assmann	Holarctic	HM; MDS; WG; FO	VU	VU	9	
Mellicta centralasiae Wnukowsky	Central-Asia (Siberia)	HM; MDS; WG; FO				
Mellicta plotina Bremer	Palaearctic	HM; MDS; WG; FO				
Mesoacidalia aglaja Linnaeus	Palaearctic	HM; MDS; WG; FO		LR (nt)	5	
Neptis rivularis Scopoli	Palaearctic	HM; MDS; WG; FO			9	2
Neptis sappho Pallas	Palaearctic	HM; MDS; WG; FO	LR (nt)		10	
Nymphalis antiopa Linnaeus	Palaearctic	HM; MDS; WG; FO		LR (nt)	6	
Nymphalis polychloros Linnaeus	Palaearctic	HM; MDS; FO		VU	6	
Nymphalis vau- album Denis & Schiffermueller	East-Asia	HM; MDS; WG; FO	VU			
Polygonia c-album Linnaeus	Palaearctic	HM; MDS; WG; FO			5	
Polygonia interposita Staudinger	Central-Asia	HM; MDS; WG; FO				
Vanessa cardui Linnaeus	Holarctic	HM; MDS; FO		0	4	
LYCAENIDAE						
Agriades aquilo wosnesensky Menetries	Holarctic	HM			11	
Agrodiaetus amandus Schneider	Palaearctic	HM; MDS; WG; FO		0	7	1
Ahlbergia frivaldskyi Lederer	Palaearctic	HM; MDS; WG; FO				
Albulina orbitulus de Prunner	Palaearctic	HM; MDS; WG; FO		R	9	
Aricia agestis Denis & Schiffermueller	Palaearctic	HM; MDS; WG; FO		LR (nt)	7	
Aricia allous Hübner	Palaearctic	FO; HM			8	
Aricia eumedon Esper	Palaearctic	HM; MDS; WG; FO		EN	7	
Celastrina argiolus Linnaeus	Palaearctic	HM; MDS; WG; FO			4	
Celastrina fedoseevi Korshunov et Ivonin	East-Asia	HM				
Cupido minimus Fuessly	Palaearctic	HM; MDS; WG; FO		LR (nt)	6	
Cupido osiris Meigen	Palaearctic	FO		Ex	9	
Cupido prosecusa Erschoff	Central-Asia	WG; MDS				
Everes argiades Pallas	Palaearctic	HM; MDS; WG; FO		EN	6	
Everes fischeri Eversmann	Palaearctic	HM; MDS; FO		EN	9	
Glaucopsyche lycormas Butler	Central-Asia	HM; MDS; WG; FO				
Kretania eurypilus Freyer	Holarctic	HM; MDS; WG; FO			11	
Lycaena dispar Haworth	Palaearctic	HM; MDS; WG; FO		EN	10	6
Lycaena helle Denis & Schiffermueller	Palaearctic	HM; MDS; WG; FO	VU	CR	10	4
Lycaena hippothoe Linnaeus	Palaearctic	FO	LR (nt)	EN	7	
Lycaena vigaureae Linnaeus	Palaearctic	HM; MDS; WG; FO	LR (nt)	VU	7	
Maculinea arion Linnaeus	Palaearctic	FO; HM	EN**	EN	7	1
Maculinea teleius Bergstraesser	Palaearctic	HM; WG; FO	VU***	EN	8	3
Nordmannia pruni Linnaeus	Palaearctic	HM; MDS; WG; FO		LR (nt)	6	
Patricius lucifer Staudinger	Central-Asia	HM; MDS				
Plebejus argus Linnaeus	Palaearctic	MDS; HM		VU	5	
Plebejus argyrognomon mongolica Bergstraesser	Palaearctic	HM; MDS; WG; FO	LR (nt)	VU	7	
Plebejus eversmanni Staudinger	Central-Asia	HM; MDS				
Plebejus idas naruenus Curvoisier	Palaearctic	HM; MDS; WG; FO		EN	5	
Plebejus nushibi Zhdanko	Holarctic	MDS				
Plebejus pylaon Fischer von Waldheim	Palaearctic	HM; MDS; WG; FO			9	
Plebejus subsolanus Eversmann	East-Asia	HM; MDS; WG; FO				
Polymmatus semiargus Rottemburg	Palaearctic	HM; MDS; WG; FO		LR (nt)	5	
Polyommatus cyane Eversmann	Palaearctic	HM			11	
Polyommatus eroitides Staudinger	Central-Asia	FO	CR			
Polyommatus eros Ochsenheimer	Palaearctic c	WG	LR (nt)	R	10	
Polyommatus icadius Grum-Grschimailo	Central-Asia	WG				
Polyommatus icarus Rottemburg	Palaearctic	HM; MDS; WG; FO			4	
Rimisia miris miris Staudinger	Central-Asia	FO				
Scolitantides orion Pallas	Palaearctic	HM; MDS; WG; FO	VU	CR	8	
Thechla betulae Linnaeus	Palaearctic	FO			6	
Thersamonolycaena splendens Staudinger	Central-Asia (Mongolia)	MDS				
Vacciniina optilete Knoch	Palaearctic	FO; HM		EN	8	3

APPENDIX 10.

List of the butterflies which mentioned in Red Data Book of Germany.

Extinct	Rare	Critical
C. oedippus	*Plebbejus orbitulus*	*B. daphne*
Cupido osiris	*Polyommatus eros*	*C. hero*
		E. maturna
	Endangered	*L. achine*
Vulnerable	*A. niobe*	*Lycaena helle*
A. adippe	*A. eumedon*	*P. apollo*
B. euphrosyne	*B. eunomia*	*S. orion*
B. titania	*C. silvicola*	
C. glycerion	*C. palaeno*	**Near Threatened**
E. aethiops	*C. argiades*	*Aporia crataegy*
H. comma	*E. aurinia*	*Argynnis aglaja*
L.virgaureae	*H. lycaon*	*Aricia agestis*
M. athalia	*L. populi*	*Boloria selene*
M. aurelia	*L.dispar*	*Brenthis ino*
M. Britomartis	*Maculinea arion*	*C. palaemon*
M. diamina	*M. teleius*	*Cupido minimus*
N. polychloros	*M. cinxia*	*Erebia ligea*
P.argus	*M. dydima*	*Erebia medusa*
P. argyrognomon	*M phoebe*	*Erynnis tages*
	M. drays	*Lasiommata maera*
	P.idas	*Leptidea sinapis*
	V. optilete	*Pyrgus malvae*
	Pyrgus carthami	
	P. serratulae	

APPENDIX 11.
Feeding behaviour of butterfly families.

Families	Patterns of Host Plant use	Species name
Hesperiidae	Oligophagous	*Carterocephalus palaemon* Pallas
		Carterocephalus silvicola Meigan
		Pyrgus maculatus Bremer et Grey
		Pyrgus sibirica Reverdin
	Polyphagous	*Erynnis tages* Linnaeus
		Hesperia comma Linnaeus
		Pyrgus malvae Linnaeus
		Pyrgus serratulae Rambur
	Strongly oligophagous	*Muschampia cribrellum* Staudinger
		Muschampia tessellum Huebner
Lycaenidae	Monophagous	*Maculinea teleius* Bergstraesser
	Oligophagous	*Agrodiaetus amandu*s Schneider
		Aricia agestis Denis & Schiffermueller
		Cupido minimus Fuessly
		Cupido osiris Meigen
		Everes fischeri Eversmann
		Glaucopsyche lycormas Butler
		Lycaena helle Denis & Schiffermueller
		Lycaena hippothoe Linnaeus
		Maculinea arion Linnaeus
		Nordmannia pruni Linnaeus
		Plebejus argus Linnaeus
		Plebejus argyrognomon mongolica Bergstraesser
		Plebejus idas naruenus Curvoisier
		Polymmatus semiargus Rottemburg
	Polyphagous	*Celastrina argiolus* Linnaeus
		Everes argiades Pallas
		Patricius lucifer Staudinger
		Plebejus pylaon Fischer von Waldheim
		Plebejus subsolanus Eversmann
		Thechla betulae Linnaeus
		Vacciniina optilete Knoch
	Strongly oligophagous	*Ahlbergia frivaldskyi* Lederer
		Albulina orbitulus de Prunner
		Aricia allous Hübner
		Aricia eumedon Esper
		Lycaena dispar Haworth
		Lycaena vigaureae Linnaeus
		Plebejus eversmanni Staudinger
		Polyommatus eroitides Staudinger
		Polyommatus icadius Grum-Grschimailo
		Polyommatus icarus Rottemburg
		Scolitantides orion Pallas

APPENDIX 11. (continued)

Nymphalida	Monophagous	*Mellicta plotina* Bremer
	Oligophagous	*Limenitus populi* Linnaeus
		Neptis rivularis Scopoli
		Neptis sappho Pallas
	Polyphagous	*Aglais urticae* Linnaeus
		Araschnia levana Linnaeus
		Argynnis paphia Linnaeus
		Boloria eunomia Esper
		Boloria euphrosyne Linnaeus
		Boloria freija Thunberg
		Boloria oscarus Eversmann
		Boloria selene Denis & Schiffermueller
		Boloria titania Esper
		Brenthis daphne Denis & Schiffermueller
		Brenthis ino Rottemburg
		Euphydryas aurinia Rottemburg
		Euphydryas maturna Linnaeus
		Fabriciana adippe Denis & Schiffermueller
		Fabriciana niobe Linnaeus
		Inachis io Linnaeus
		Melitaea cinxia Linnaeus
		Melitaea diamina Lang
		Melitaea didyma Esper
		Melitaea phoebe Denis & Schiffermueller
		Mellicta athalia Rottemburg
		Mellicta aurelia Nickerl
		Mellicta britomartis Assmann
		Mesoacidalia aglaja Linnaeus
		Nymphalis antiopa Linnaeus
		Nymphalis polychloros Linnaeus
		Nymphalis vau- album Denis & Schiffermueller
		Polygonia c-album Linnaeus
		Vanessa cardui Linnaeus
	Strongly oligophagous	*Boloria angarensis* Erschoff
		Boloria selenis Eversmann
		Euphydryas intermedia Menetries
Papilionidae	Oligophagous	*Parnassius apollo* Linnaeus
		Parnassius nomion Fischer de Waldheim
	Polyphagous	*Papilio machaon* Linnaeus
		Papilio xuthus Linnaeus

APPENDIX 11. (continued)

Pieridae	Monophagous	*Colias palaeno* Linnaeus
	Oligophagous	*Anthocharis cardamines* Linnaeus *Colias aurora* Esper *Colias erate* Esper *Colias hayle* Linnaeus *Colias poliographus* *Leptidea morsei* Fenton *Leptidea sinapis* Linnaeus *Pieris chlorodice* Huebner *Pieris napi* Linnaeus
	Polyphagous	*Aporia crataegi* Linnaeus *Colias heos* Herbst *Colias tyche* Boeber *Pieris callidice* Hübner *Pieris daplidice* Linnaeus *Pieris rapae* Linnaeus
	Strongly oligophagous	*Aporia hippa hippa* Bremer *Leptidea amurensis* Menetries
Satyridae	Monophagous	*Lethe diana diana* Butler
	Oligophagous	*Boeberia parmenio* Boeber *Coenonympha amaryllis* Stoll in Cramer *Coenonympha glycerion* Borkhausen *Erebia aethiops* Esper *Erebia medusa* Denis & Schiffermueller *Hyponephele lycaon* Rottemburg *Lasiommato maero* Linnaeus *Lopinga deidamia* Eversmann *Oeneis tarpeia* Pallas
	Polyphagous	*Aphantopus hyperantus* Linnaeus *Coenonympha hero* Linnaeus *Coenonympha oedippus* Fabricius *Erebia kozhantschikovi* Sheljuzhko *Erebia ligea* Linnaeus *Erebia neriene* Boeber *Erebia niphonica* Janson *Lopinga achine* Scopoli *Minois dryas* Scopoli *Oeneis norna* Thunberg *Oeneis urda* Eversmann
	Strongly oligophagous	*Hipparchia autonoe* Esper *Oeneis nanna* Menetries *Thriphysa phryne* Pallas

APPPENDIX 12.
Species list of habitat sharing.

Species	FO	HM	MDS	WG	No of habitats used
Carterocephalus silvicola	0,02	0,79	0,1	0,05	4
Everes fischeri	0,11	0,1	0,8	0	4
Polygonia interposita	0,04	0,04	0,3	0,62	4
Euphydryas maturna	0,24	0,63	0,1	0,07	4
Lopinga achine	0,43	0,47	0,1	0	4
Plebejus argyrognomon	0,28	0,08	0,6	0,08	4
Leptidea amurensis	0,19	0,58	0,1	0,12	4
Nordmannia pruni	0,05	0,37	0,5	0,09	4
Coenonympha amaryllis	0,22	0,56	0,1	0,09	4
Kretania eurypilus	0,13	0,54	0,1	0,23	4
Oeneis nanna	0,11	0,37	0,5	0,05	4
Euphydryas intermedia	0,36	0,45	0	0,19	4
Pyrgus malvae	0,15	0,46	0,4	0,02	4
Scolitantides orion	0,01	0,43	0,4	0,16	4
Celastrina argiolus	0,3	0,51	0,1	0,11	4
Coenonympha glycerion	0,22	0,53	0,1	0,18	4
Polyommatus semiargus	0,45	0,38	0,1	0,09	4
Albulina orbitula	0,24	0,52	0,1	0,17	4
Boeberia parmenio	0,18	0,46	0,3	0,05	4
Coenonympha hero	0,39	0,41	0,1	0,12	4
Erebia aethiops	0,51	0,16	0,1	0,22	4
Papilio machaon	0,07	0,4	0,4	0,12	4
Anthocharis cardamines	0,16	0,06	0,3	0,46	4
Neptis sappho	0,14	0,45	0,3	0,07	4
Oeneis urda	0,17	0,43	0,4	0,04	4
Colias aurora	0,22	0,49	0,2	0,09	4
Lycaena vigaureae	0,23	0,48	0,1	0,23	4
Boloria selenis	0,42	0,2	0,3	0,03	4
Mellicta britomartis	0,32	0,46	0,1	0,09	4
Boloria selene	0,17	0,49	0,1	0,21	4
Cupido minimus	0,4	0,33	0,3	0,02	4
Leptidea sinapis	0,46	0,2	0,1	0,28	4
Lycaena dispar	0,18	0,27	0,5	0,08	4
Pyrgus cinarae	0,42	0,34	0,2	0,06	4
Aporia crataegi	0,22	0,4	0,3	0,04	4
Plebejus subsolanus	0,2	0,47	0,2	0,12	4
Melitaea phoebe	0,18	0,27	0,1	0,45	4
Mellicta plotina	0,3	0,19	0,1	0,43	4
Boloria euphrosyne	0,28	0,42	0,1	0,23	4
Glaucopsyche lycormas	0,22	0,44	0,1	0,24	4
Oeneis sculda	0,28	0,41	0,2	0,06	4
Everes argiades	0,39	0,18	0,1	0,34	4
Brenthis ino	0,22	0,32	0,1	0,38	4
Mellicta centralasiae	0,37	0,35	0,1	0,16	4
Plebejus pylaon	0,13	0,43	0,2	0,23	4
Aricia eumedon	0,21	0,44	0,2	0,17	4

APPPENDIX 12.
Species list of habitat sharing (continued)

Muschampia tessellum	0,11	0,37	0,2	0,35	4
Colias tyche	0,18	0,33	0,4	0,12	4
Plebejus idas naruena	0,21	0,43	0,2	0,16	4
Agrodiaetus amandus	0,28	0,36	0,1	0,27	4
Argynnis paphia	0,11	0,38	0,2	0,26	4
Coenonympha oedippus	0,15	0,35	0,3	0,15	4
Erebia neriene	0,2	0,39	0,2	0,17	4
Parnassius nomion	0,26	0,3	0,3	0,12	4
Melitaea didyma	0,17	0,29	0,4	0,18	4
Colias hyale	0,3	0,21	0,3	0,15	4
Polygonia c-album	0,28	0,28	0,3	0,12	4
Aglais urticae	0,21	0,37	0,2	0,25	4
Leptidea morsei	0,33	0,26	0,3	0,14	4
Neptis rivularis	0,22	0,35	0,3	0,17	4
Aphantopus hyperantus	0,23	0,33	0,2	0,28	4
Brenthis daphne	0,25	0,34	0,2	0,2	4
Melitaea diamina	0,2	0,35	0,2	0,26	4
Ahlbergia frivaldszkyi	0,26	0,33	0,2	0,19	4
Inachis io	0,24	0,34	0,2	0,24	4
Pyrgus masculatus	0,23	0,24	0,3	0,19	4
Argynnis aglaja	0,25	0,28	0,3	0,18	4
Nymphalis antiopa	0,25	0,19	0,3	0,27	4
Argynnis niobe	0,23	0,27	0,2	0,29	4
Mellicta aurelia	0,26	0,27	0,2	0,27	4
Minois dryas	0,2	0,28	0,3	0,26	4
Nymphalis v-album	0,24	0,23	0,3	0,24	4
Polyommatus icarus	0,24	0,28	0,3	0,22	4
Vacciniina optilete	0,11	0,79	0	0,1	3
Colias palaeno	0	0,35	0	0,65	3
Boloria oscarus	0,68	0,1	0,2	0	3
Muschampia cribrellum	0,11	0,21	0,7	0	3
Hesperia comma	0,31	0,06	0,6	0	3
Vanessa cardui	0,27	0,09	0,6	0	3
Boloria freija	0,58	0,37	0,1	0	3
Erebia medusa	0,16	0,63	0,2	0	3
Pieris napi	0,64	0,19	0	0,18	3
Boloria angarensis	0,32	0,59	0	0,05	3
Lopinga deidamia	0,36	0,57	0	0,04	3
Ochlades sylvanus	0,62	0,24	0,1	0	3
Hemadara rurigena	0,07	0,56	0	0,36	3
Erynnis tages	0,19	0,21	0,6	0	3
Boloria titania	0,41	0,52	0,1	0	3
Lycaena helle	0,21	0,59	0	0,19	3
Melitaea cinxia	0,21	0,21	0	0,58	3
Mellicta athalia	0,22	0,59	0	0,15	3
Parnassius apollo	0	0,38	0,1	0,47	3
Pyrgus jupei	0	0,38	0,1	0,47	3
Colias heos	0,16	0,37	0	0,47	3
Euphydryas aurina	0,5	0,32	0,2	0	3
Carterocephalus palaemon	0	0,38	0,2	0,45	3

APPPENDIX 12.
Species list of habitat sharing (continued).

Hyponephele lycaon	0,38	0,18	0,4	0	3
Nymphalis polychloros	0,38	0,2	0,4	0	3
Pyrgus sibirica	0,27	0,46	0,3	0	3
Maculinea teleius	0,31	0,43	0	0,26	3
Boloria eunomia	0,35	0,27	0	0,38	3
Argynnis adippe	0,26	0,29	0	0,43	3
Aricia agestis	0,3	0,44	0	0,21	3
Pieris rapae	0,9	0,1	0	0	2
Erebia ligea	0	0,1	0,9	0	2
Carterocephalus argyrostigma	0	0,82	0,2	0	2
Oeneis tarpeia	0,82	0	0,2	0	2
Limenitus populi	0,23	0,77	0	0	2
Triphysa phryne	0,24	0	0,8	0	2
Aricia allous	0,26	0,74	0	0	2
Oeneis norno	0	0,27	0,7	0	2
Pyrgys serratulae	0	0,73	0,3	0	2
Patricius lucifer	0	0,72	0,3	0	2
Erebia niphonica	0	0,3	0,7	0	2
Lasiommato maero	0,31	0	0,7	0	2
Plebejus eversmanni	0,68	0,32	0	0	2
Colias poliographus	0,51	0,49	0	0	2
Erebia jeniseiensis	0,47	0	0,5	0	2
Maculinea arion	0,51	0,49	0	0	2
Melitaea arcesia	0,4	0,56	0	0	2
Araschnia levana	0,47	0,49	0	0	2
Aporia hipa hippa	0	1	0	0	1
Celastrina fedoseevi	0	1	0	0	1
Colias alpherakii	1	0	0	0	1
Colias erate	0	1	0	0	1
Colias staudingeri	0	0	1	0	1
Cupido prosecusa	0	0	0	1	1
Erebia sp?	0	1	0	0	1
Hipparchia autonoe	1	0	0	0	1
Lethe diana diana	0	1	0	0	1
Lycaena hippothoe	1	0	0	0	1
Ochlodes venata	1	0	0	0	1
Oeneis mongolica	1	0	0	0	1
Pieris chlorodice	0	1	0	0	1
Polyommatus cyane	0	1	0	0	1
Polyommatus eroitides	1	0	0	0	1
Polyommatus eros	0	0	0	1	1
Polyommatus icadius	0	0	0	1	1
Pyrgus carthami	1	0	0	0	1
Rimisia miris miris	1	0	0	0	1
Satyrus stheno	1	0	0	0	1
Techla betula crossa	1	0	0	0	1
Thersamonolycaena splendens	0	0	1	0	1
Thersamonolycaena violacea	0	0	1	0	1

APPENDIX 13.
Geographic range of butterfly species and their habitat occupancy.

Habitat occupancy	Geographic range	*Species*
All	Centra-Asia	*Boeberia parmenio*
		Coenonympha amaryllis
		Glaucopsyche lycormas
		Mellicta centralasiae
		Parnassius nomion
	East-Asia	*Colias aurora*
		Colias tyche
		Erebia neriene
		Oeneis nanna
		Oeneis urda
		Plebejus subsolanus
		Pyrgus masculatus
		Pyrgus sibirica
	Holarctic	*Euphydryas aurina*
		Kretania eurypilus
		Melitaea phoebe
		Mellicta britomartis
		Nymphalis v-album
		Oeneis sculda
		Carterocephalus palaemon
		Papilio machaon
	Palaearctic	*Aglais urticae*
		Agrodiaetus amandus
		Ahlbergia frivaldszkyi
		Albulina orbitula
		Anthocharis cardamines
		Aphantopus hyperantus
		Aporia crataegi
		Argynnis aglaja
		Argynnis niobe
		Argynnis paphia
		Aricia eumedon
		Boloria euphrosyne
		Boloria selene
		Boloria selenis
		Brenthis daphne
		Brenthis ino
		Celastrina argiolus
		Coenonympha glycerion
		Coenonympha hero
		Coenonympha oedippus
		Colias hyale
		Cupido minimus
		Erebia aethiops
		Everes argiades
		Inachis io
		Leptidea amurensis
		Leptidea morsei
		Leptidea sinapis
		Lycaena dispar
		Lycaena vigaureae
		*Maculinea teleius**
		Melitaea diamina
		Melitaea didyma
		Mellicta aurelia
		Mellicta plotina
		Minois dryas
		Muschampia tessellum
		Neptis rivularis

APPENDIX 13. (continued)

All habitat	Palaearctic	*Parnassius apollo**
		*Pyrgus jupei**
		Neptis sappho
		Nordmannia pruni
		Nymphalis antiopa
		Parnassius nomion
		Plebejus idas naruena
		Plebejus pylaon
		Polygonia c-album
		Polyommatus icarus
		Polyommatus semiargus
		Pyrgus cinarae
		Pyrgus malvae
		Scolitantides orion
FO	Centra-Asia	*Colias alpherakii*
		Polyommatus eroitides
		Rimisia miris miris
		Satyrus stheno
	East-Asia	*Ochlodes venata*
		Oeneis mongolica
	Holarctic	*Pieris napi*
		Boloria oscarus
		Vanessa cardui
	Palaearctic	*Hipparchia autonoe*
		Hyponephele lycaon
		Lasiommato maero
		Lycaena hippothoe
		Nymphalis polychloros
		Ochlades sylvanus
		Oeneis tarpeia
		Pieris rapae
		Pyrgus carthami
		Techla betula crossa
FO/HM	Centra-Asia	*Colias poliographus*
		Melitaea arcesia
		Plebejus eversmanni
	East-Asia	*Boloria angarensis*
		Lopinga deidamia
	Holarctic	*Boloria freija*
		Boloria titania
	Palaearctic	*Euphydryas maturna*
		Araschnia levana
		Aricia allous
		Lopinga achine
		Maculinea arion
		Melitaea arcesia
FO/WG	Holarctic	*Boloria eunomia*
		Euphydryas intermedia
	Palaearctic	*Argynnis adippe*
		Aricia agestis
		Colias heos

APPENDIX 13. (continued)

HM	Centra-Asia	*Patricius lucifer*
	East-Asia	*Aporia hipa hippa*
		Carterocephalus
		Celastrina fedoseevi
		Hemadara rurigena
		Lethe diana diana
	Holarctic	*Mellicta athalia*
		Pieris chlorodice
	Palaearctic	*Carterocephalus silvicola*
		Colias erate
		Colias palaeno
		Erebia medusa
		Limenitus populi
		Lycaena helle
		Polyommatus cyane
		Vacciniina optilete
MDS	Centra-Asia	*Colias staudingeri*
		Erynnis tages
		Thersamonolycaena splendens
		Triphysa phryne
	East-Asia	*Erebia jeniseiensis*
		Erebia niphonica
		Erebia sp?
		Thersamonolycaena violacea
	Holarctic	*Oeneis norno*
	Palaearctic	*Erebia ligea*
		Everes fischeri
		Hesperia comma
		Muschampia cribrellum obscurior
		Plebejus argyrognomon mongolica
		Pyrgys serratulae
WG	Centra-Asia	*Cupido prosecusa*
		Polygonia interposita
		Polyommatus icadius
	Palaearctic	*Melitaea cinxia*
		Polyommatus eros

APPENDIX 14.
Classification of feeding behaviour of West Khentej butterflies. Monophagous (feeding on one species of host plant); strongly oligophagous (restricted to one genus); oligophagous (feeding on one plant family); polyphagous (feeding on more than 2 families)

Classification of feeding behaviour	**Generalist**	**Specialist**
Monophagous	*Maculinea teleius*	*Pyrgus carthami*
	Mellicta plotina	
Oligophagous	*Agrodiaetus amandus*	*Carterocephalus silvicola*
	Anthocharis cardamines	*Colias erate*
	Boeberia parmenio	*Colias poliographus*
	Carterocephalus palaemon	*Erebia medusa*
	Coenonympha amaryllis	*Everes fischeri*
	Coenonympha glycerion	*Lasiommato maero*
	Colias hyale	*Limenitus populi*
	Cupido minimus	*Lopinga deidamia*
	Glaucopsyche lycormas	*Lycaena helle*
	Leptidea morsei	*Lycaena hippothoe*
	Leptidea sinapis	*Maculinea arion*
	Maculinea teleius	*Oeneis tarpeia*
	Neptis rivularis	*Pieris chlorodice*
	Neptis sappho	*Pieris napi*
	Nordmannia pruni	*Plebejus argyrognomon*
	Parnassius apollo	
	Parnassius nomion	
	Plebejus idas naruena	
	Polyommatus semiargus	
	Pyrgus masculatus masculatus	
	Pyrgus sibirica	
Strongly oligophagous	*Ahlbergia frivaldszkyi*	*Boloria angarensis*
	Albulina orbitula	*Hipparchia autonoe*
	Aricia eumedon	*Muschampia cribrellum*
	Boloria selenis	*Plebejus eversmanni*
	Euphydryas intermedia	*Polyommatus eroitides*
	Leptidea amurensis	*Polyommatus icadius*
	Lycaena dispar	*Triphysa phryne*
	Lycaena vigaureae	
	Muschampia tessellum	
	Oeneis nanna	
	Polyommatus icarus	
	Scolitantides orion	
Polyphagous	*Aglais urticae*	*Araschnia levana*
	Aphantopus hyperantus	*Boloria freija*
	Aporia crataegi	*Boloria oscarus*
Generalist	*Argynnis adippe*	*Boloria titania*
	Argynnis aglaja	*Erebia ligea*
Inachis io	*Argynnis niobe*	*Erebia niphonica*
Melitaea diamina	*Argynnis paphia*	*Erynnis tages*
Melitaea didyma	*Boloria eunomia*	*Euphydryas maturna*
Melitaea phoebe	*Boloria euphrosyne*	*Hesperia comma*
Mellicta aurelia	*Boloria selene*	*Lopinga achine*
Mellicta britomartis	*Brenthis daphne*	*Melitaea cinxia*
Minois dryas	*Brenthis ino*	*Mellicta athalia*
Nymphalis antiopa	*Celastrina argiolus*	*Oeneis norno*
Nymphalis polychloros	*Coenonympha hero*	*Patricius lucifer*
	Coenonympha oedippus	*Pieris rapae*
	Colias tyche	*Pyrgys serratulae*
	Erebia neriene	*Techla betula crossa*
	Euphydryas aurina	*Vacciniina optilete*
	Everes argiades	*Vanessa cardui*

APPENDIX 15. The number of individuals caught per 100 hour in each years.

Species	2000	2001	2002	2003	Total
Aporia crataegi	115	154	429	530	1227
Argynnis paphia	117	200	302	284	903
Neptis rivularis	132	182	216	300	830
Plebejus subsolanus	164	207	204	236	812
Coenonympha glycerion	221	89	282	211	804
Everes argiades	326	239	91	61	717
Aricia eumedon	94	114	149	266	623
Minois dryas	200	186	176	61	623
Lycaena helle	60	207	213	120	601
Aphantopus hyperantus	232	86	158	89	564
Brenthis ino	211	143	84	66	504
Plebejus idas naruena	85	161	173	84	503
Lycaena vigaureae	179	150	136	134	598
Erebia neriene	132	114	231	11	489
Oeneis sculda	81	29	216	164	489
Leptidea morsei	74	146	113	139	473
Coenonympha hero	121	129	91	125	466
Boeberia parmenio	40	79	133	193	446
Coenonympha oedippus	38	82	80	241	441
Melitaea didyma	49	96	51	218	415
Papilio machaon	17	114	204	77	413
Agrodiaetus amandus	140	136	38	75	389
Nymphalis v-album	30	129	33	180	371
Inachis io	55	143	91	73	362
Maculinea teleius	51	146	60	95	353
Glaucopsyche lycormas	60	107	133	30	330
Colias tyche	30	118	104	77	329
Oeneis urda	30	79	113	86	308
Oeneis nanna	2	71	178	20	272
Argynnis aglaja	121	39	62	45	268
Brenthis daphne	81	43	78	64	265
Nymphalis polychloros	28	21	13	200	262
Mellicta athalia	38	61	69	84	252
Cupido minimus	28	93	71	57	248
Argynnis adippe	126	57	36	30	248
Polygonia c-album	6	143	67	16	232
Mellicta britomartis	62	36	33	98	228
Leptidea amurensis	17	86	96	25	223
Ahlbergia frivaldszkyi	0	57	58	100	215
Pyrgus malvae	9	61	18	123	210
Pyrgus masculatus	19	50	62	77	209
Polyommatus semiargus	38	71	18	80	207
Melitaea phoebe	11	111	49	30	200
Albulina orbitula	19	89	49	34	191
Euphydryas maturna	21	46	60	57	185
Nymphalis antiopa	11	107	33	32	183
Parnassius nomion	45	57	51	27	180
Plebejus argyrognomon	23	29	13	89	154

Appendix 15. (continued)

Species	2000	2001	2002	2003	Total
Colias aurora	26	46	44	34	150
Scolitantides orion	0	21	47	82	150
Melitaea diamina	45	39	11	55	150
Aricia agestis	53	14	40	39	146
Aglais urticae	11	43	33	59	146
Hemadara rurigena	0	93	22	25	140
Colias hyale	38	46	31	20	136
Mellicta aurelia	21	36	24	50	131
Leptidea sinapis	21	79	11	20	131
Muschampia tessellum	0	86	33	11	130
Argynnis niobe	49	61	18	2	130
Boloria selenis	38	32	24	27	122
Vacciniina optilete	34	7	42	39	122
Celastrina argiolus	2	29	53	36	120
Mellicta centralasiae	19	61	18	20	118
Neptis sappho	9	21	62	25	117
Erebia aethiops	66	32	9	0	107
Lopinga deidamia	11	32	38	25	106
Erebia medusa	4	43	36	18	101
Coenonympha amaryllis	11	29	22	39	100
Triphysa phryne	13	32	11	41	97
Boloria oscarus	13	21	9	52	95
Carterocephalus silvicola	0	4	69	18	91
Polyommatus icarus	30	21	9	30	90
Pyrgus sibirica	0	14	24	50	89
Melitaea arcesia	9	39	33	7	88
Lopinga achine	13	39	22	14	88
Pyrgus cinarae	0	43	16	25	83
Boloria angarensis	28	14	20	18	80
Muschampia cribrellum	0	7	29	43	79
Boloria euphrosyne	13	32	22	9	76
Araschnia levana	6	29	22	16	73
Anthocharis cardamines	4	39	9	16	68
Erynnis tages	4	0	4	59	68
Kretania eurypilus	17	29	2	9	57
Carterocephalus argyrostigma	2	0	4	50	57
Pyrgys serratulae	0	0	56	0	56
Polygonia interposita	0	39	16	0	55
Colias heos	34	0	11	9	54
Mellicta plotina	26	0	0	27	53
Boloria freija	15	14	11	11	52
Oeneis norno	2	0	29	20	51
Vanessa cardui	4	11	29	7	51
Pieris napi	17	21	2	9	50
Euphydryas intermedia	2	21	16	9	48
Lycaena dispar amurensis	6	7	16	18	47
Celastrina fedoseevi	0	39	7	0	46
Limenitus populi	0	14	20	11	46
Ochlades sylvanus	0	25	13	7	45

Appendix 15. (continued)

Species	2000	2001	2002	2003	Total
Carterocephalus palaemon	0	18	0	25	43
Nordmannia pruni	13	0	27	2	42
Boloria titania	9	18	9	5	40
Hesperia comma	0	14	4	20	39
Everes fischeri	6	0	4	27	38
Erebia ligea	2	0	29	7	38
Boloria selene	11	0	2	23	36
Plebejus eversmanni	0	21	9	5	35
Pieris rapae	2	29	2	0	33
Plebejus pylaon	15	4	7	7	32
Boloria eunomia	9	0	0	18	27
Aricia allous	2	4	11	2	19
Melitaea cinxia	4	7	4	2	18
Parnassius apollo	2	7	0	7	16
Pyrgus jupei	0	7	7	2	16
Thersamonolycaena splendens	4	4	7	0	14
Thersamonolycaena violacea	0	14	0	0	14
Euphydryas aurina	4	0	0	9	13
Lasiommato maero	4	0	4	5	13
Oeneis tarpeia	6	0	2	5	13
Hyponephele lycaon	9	0	2	0	11
Techla betula crossa	0	11	0	0	11
Erebia niphonica	2	7	0	0	9
Patricius lucifer	2	0	2	5	9
Erebia jeniseiensis	6	0	2	0	9
Hipparchia autonoe	0	7	0	0	7
Aporia hipa hippa	0	0	4	2	7
Oeneis mongolica	4	0	0	2	7
Polyommatus eroitides	6	0	0	0	6
Colias palaeno	0	4	2	0	6
Ochlodes venata	0	0	0	5	5
Colias erate	0	0	2	2	4
Colias staudingeri	0	0	4	0	4
Colias poliographus	4	0	0	0	4
Maculinea arion	4	0	0	0	4
Cupido prosecusa	0	4	0	0	4
Satyrus stheno	0	4	0	0	4
Polyommatus cyane	0	0	0	2	2
Pyrgus carthami	0	0	0	2	2
Rimisia miris miris	0	0	0	2	2
Erebia sp?	0	0	2	0	2
Lethe diana diana	0	0	2	0	2
Pieris chlorodice	0	0	2	0	2
Colias alpherakii	2	0	0	0	2
Lycaena hippothoe	2	0	0	0	2
Polyommatus eros	2	0	0	0	2
Polyommatus icadius	2	0	0	0	2

Species	2000	2001	2002	2003	Total
Neptis rivularis	132	182	216	300	830
Neptis sappho	9	21	62	25	117
Nordmannia pruni	13	0	27	2	42
Nymphalis antiopa	11	107	33	32	183
Nymphalis polychloros	28	21	13	200	262
Nymphalis v-album	30	129	33	180	371
Ochlades sylvanus	0	25	13	7	45
Ochlodes venata	0	0	0	5	5
Oeneis mongolica	4	0	0	2	7
Oeneis nanna	2	71	178	20	272
Oeneis norno	2	0	29	20	51
Oeneis sculda	81	29	216	164	489
Oeneis tarpeia	6	0	2	5	13
Oeneis urda	30	79	113	86	308
Papilio machaon	17	114	204	77	413
Parnassius apollo	2	7	0	7	16
Parnassius nomion	45	57	51	27	180
Patricius lucifer	2	0	2	5	9
Pieris chlorodice	0	0	2	0	2
Pieris napi	17	21	2	9	50
Pieris rapae	2	29	2	0	33
Plebejus argyrognomon	23	29	13	89	154
Plebejus eversmanni	0	21	9	5	35
Plebejus idas naruena	85	161	173	84	503
Plebejus pylaon	15	4	7	7	32
Plebejus subsolanus	164	207	204	236	812
Polygonia c-album	6	143	67	16	232
Polygonia interposita	0	39	16	0	55
Polyommatus cyane	0	0	0	2	2
Polyommatus eroitides	6	0	0	0	6
Polyommatus eros	2	0	0	0	2
Polyommatus icadius	2	0	0	0	2
Polyommatus icarus	30	21	9	30	90
Polyommatus semiargus	38	71	18	80	207
Pyrgus carthami	0	0	0	2	2
Pyrgus cinarae	0	43	16	25	83
Pyrgus jupei	0	7	7	2	16
Pyrgus malvae	9	61	18	123	210
Pyrgus masculatus	19	50	62	77	209
Pyrgus sibirica	0	14	24	50	89
Pyrgys serratulae	0	0	56	0	56
Rimisia miris miris	0	0	0	2	2
Satyrus stheno	0	4	0	0	4
Scolitantides orion	0	21	47	82	150
Techla betula crossa	0	11	0	0	11
Thersamonolycaena splendens	4	4	7	0	14
Thersamonolycaena violacea	0	14	0	0	14
Triphysa phryne	13	32	11	41	97
Vacciniina optilete	34	7	42	39	122
Vanessa cardui	4	11	29	7	51

Appendix 16. Adult population estimates of *Lycaena virgaureae* in open herb meadow habitat type. Data collected between 25 July and 24 August 2004 for 24 days.

	Proportion marked		Size of marked population		Estimated population size (Nt)		Standard error (Nt)	
Sample	Male	Female	Male	Female	Male	Female	Male	Female
1	0,01	0,33	0	0	0	0	0	0
2	0,133	0,33	121	1,5	907	4,5	0,32	5,28
3	0,095	0,2	82,6	5	863	25	1,3	5,1
4	0,224	0,6	151	10,3	675	17	1,6	4,91
5	0,175	0,05	413	28	2358	560	12,76	4,15
6	0,333	0,214	236	65	706	303	5,22	2,58
7	0,295	0,031	195	64	661	2048	3,48	2,62
8	0,246	0,111	208	59,5	842	535	4,03	2,81
9	0,478	0,5	171	16	357	32	2,46	4,67
10	0,225	0,041	187	60	826	1442	3,14	2,79
11	0,305	0,078	147	147	481	1895	1,44	0,91
12	0,386	0,104	255	200	660	1917	6,03	3,16
13	0,48	0,171	217	236	4523	1377	4,41	4,7
14	0,454	0,122	135	142	297	1156	0,92	0,7
15	0,608	0,157	77,4	211	127	1345	1,52	3,63
16	0,9	0,195	58	224	64	1150	2,35	4,18
17	0,571	0,055	35	230	61	4140	3,33	4,44
18	0,333	0,253	27	256	81	1011	3,67	5,55
19	0,428	0,237	2	122	5	515	4,73	0,15
20	1	0,316	-	147	-	467	-	0,91
21	0,333	0,235	-	257	-	1092	-	5,59
22	1	0,2	-	303	-	1515	-	7,5
23	0,333	0,278	-	225	-	810	-	4,22
24	1	0,389	-	6	-	15	-	5,09