Planning a migration corridor for the highly endangered grasshopper *Chorthippus pullus* (Orthoptera, Acrididae) in the Rottensand (Pfynwald, VS): biodiversity aspects.

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ZUSAMMENFASSUNG

Im Pfynwald (VS, Schweiz) wurde eine Untersuchung zum Habitat-Management des Kiesbank-Grashüpfers *Chorthippus pullus* (Acrididae, Gomphocerinae) durchgeführt. Dort befinden sich drei Reliktpopulationen dieser vom Aussterben bedrohten Art. Eine dieser Populationen lebt im Rottensand, in einem kleiner werdenden suboptimalen Habitat; auf ihr liegt das Hauptaugenmerk dieser Arbeit. Ungefähr 700 m davon entfernt liegt ein grossflächiges Schottergebiet mit Pioniervegetation. Dieses entstand als 1993 ein Hochwasser einen Dammbruch verursachte. Die karge Fläche stellt im heutigen Zustand ein geeignetes Habitat für *C. pullus* dar. Aus früheren Beobachtungen geht hervor, dass diese flugunfähige Art emigrieren kann, falls ein Durchgang zum neuen Besiedlungsort besteht. Eine derzeitige Migration ist unmöglich, da die Vegetation bereits zu dicht ist. Die Schaffung eines Korridors soll die Reliktpopulation mit der Schotterfläche verbinden und eine Besiedlung des neuen Habitats ermöglichen. Die Struktur des Korridors muss die Habitatansprüche erfüllen, d.h. ein breiter und vegetationsarmer Durchgang mit grossem Rohbodenanteil soll geschaffen werden. Da sich das Gebiet in einer sowohl entomologisch wertvollen als auch für die Schweiz einmaligen Landschaft mit xerothermophiler Vegetation befindet, müssen die Folgen eines Korridors genau bedacht werden.

Das Untersuchungsgebiet wurde mithilfe folgender Parameter in 7 Zonen unterteilt: Vegetation (vorhandene Arten, Höhe, Deckung, Dichte), Boden (Rohboden, Moosbedeckung, Steine, Kies, Sand, totes Pflanzenmaterial) und Exposition zu Wind und Sonne. In den Zonen wurden lineare Probeflächen gewählt und Untersuchungsflächen mit speziellen Bodenbedingungen. Die Steppenflora war von *Artemisia campestris*, *Astragalus onobrychis* und *Stipa pennata* dominiert. Eine Bestandsaufnahme ausgewählter Arten der Taxa Orthoptera, Heteroptera, Sphecidae, Coleoptera und Myrmeleonidae wurde durchgeführt. Die Insekten wurden mit einer Kombination von visueller Suche und Keschern erfasst. Bei insgesamt 6 Durchgängen (von Juni bis August) wurden jeweils durchschnittlich 236 Heuschrecken (aus 4 Familien), 30 Wanzen (aus 8 Familien), 21 Käfer (aus 11 Familien), 20 Grabwespen (6 ausgewählte Arten) und 252 Ameisenlöwen (nur eine Art) gefunden. Von Bedeuteung waren die grosse Anzahl von *Bembecinus tridens* und von *Myrmeleon bore*.

Eine grosse Vielfalt an Insekten war auf *Scabiosa triandra*, *Verbascum thapsus*, *Centaurea vallesiaca* und *Acinos arvensis*, alles ausgesprochene Trockenheitszeiger, zu finden.

Wir untersuchten die Mobilität von *C. pullus* anhand von markierten Tieren (individueller Farbcode und reflektierende Folie). Nachts wurde die Fläche mit einer Stirnlampe abgesucht. Von 48 markierten adulten *C. pullus* (28 ♂♂, 20 ♀♀) wurden 41 Tiere nachts mindestens einmal wieder gefunden. Die maximale Distanz zwischen den Fundorten betrug 32 m (♂) und 17 m (♀);

der Mittelwert der zurückgelegten Distanz lag bei 0.9 m pro Tag. 10 Tiere wurden immer am selben Ort gefunden (5 ♂♂).

SUMMARY

At Pfynwald (VS, Switzerland) an investigation to the habitat management of a relic population of the grasshopper *Chorthippus pullus (*Acrididae, Gomphocerinae) was carried out, which is situated at Rottensand, in a shrinking and unsuitable habitat. A breaching of the dike caused by a flood in 1993 created a large, gravelly area ca. 700 m away from the population. This plain, which is particularly poor in vegetation, would represent a suitable habitat for *C. pullus*. From earlier observations it is known that *C. pullus* is able to emigrate, if a path exists. The present population should be connected with the floodplain through a corridor, to enable a colonisation of the new habitat. A current migration of *C. pullus* is impossible, because the vegetation is too dense. The structure of the corridor should cover the needs for reproduction, which includes an open passage containing a large proportion of bare soil and rather sparse vegetation. Since the area lies in a region of high entomological value and vegetation unique for Switzerland, the consequences of a corridor must be valued carefully. The investigated area was divided into 7 zones with regard to the following parameters: vegetation (occurring species, cover, height, density), soil (fraction of bare soil, moss cover, stones, gravel, sand, litter) and exposure to wind and insolation. Linear transects were chosen in the zones and plots were defined where particular soil conditions predominated. The steppe flora was dominated by *Artemisia campestris*, *Astragalus onobrychis* and *Stipa pennata.* A biological inventory of selected species of the taxa Orthoptera, Heteroptera, Sphecidae, Coleoptera and Myrmeleonidae was carried out, by a combination of visual search and sweep-netting.

On average 236 grasshoppers (belonging to 4 families), 30 true bugs (belonging 8 families), 21 beetles (belonging to 11 families), 20 digger wasps (6 selected species) and 252 ant lions (one species only) was found on 6 visits from June to August. The digger wasp *Bembecinus tridens* and the ant lion *Myrmeleon bore* are of special faunistic interest. A large diversity of insects was found on *Scabiosa triandra*, *Verbascum thapsus*, *Centaurea vallesiaca* and *Acinos arvensis*, all of them indicators of extreme drought.

To analyse the mobility of *C. pullus*, the animals were marked with an individual color code and a reflecting tag. At night the area was scanned with a head lamp. 48 adult *C. pullus* (28 ♂♂, 20 ♀♀) were marked, 41 animals were found at least twice, having covered maximal distances up to 32 m

(♂) and 17 m (♀) respectively; the average distance covered was 0.9 m per day. 10 animals were found always at the same place (5 ♂).

Key words:

Pfynwald, *C. pullus*, migration corridor, Orthoptera, Heteroptera, Sphecidae, Myrmeleonidae, diversity, habitat quality, reflector marking

1. INTRODUCTION

Location

The Pfynwald is a part of a nature reserve in Central Valais (CH). It is known as the largest pine forest in Central Europe (WERNER, 1985; BENDEL *et al*., 2005). It is situated 500-700 m a.s.l., surrounded by high mountains and represents one of the driest locations in Switzerland. The whole nature reserve encompasses 10 km^2. Between Susten and Sierre the river Rhone flows through the Pfynwald and creates one of the last natural riverine landscapes of Switzerland. The dynamic river bed, containing braided stretches and gravel islands, reaches a width of almost 200 m.
Due to several floods, the Pfynwald became a mosaic of pine forest, xeric steppes and gravelly or sandy surfaces. A typically inner alpine climate, meaning aridness and very high temperatures in summer, generates a steppe vegetation. Repeated inundations lead to building of dikes along the river to protect farmland (BILLE & WERNER, 1986). The last dike was finished in the 1960's, separating the alluvial plain Rottensand totally from the rivers dynamic. As a consequence pine (*Pinus sylvestris*) forests extended and steppe habitats became fragmented (WERNER, 1985). During a high water in October 1993, the dike broke and the Rhone flooded parts of the Rottensand, destroying ca. 6 ha of forest and steppe vegetation and depositing gravel and sand, creating a huge bare floodplain (Appendix, Fig. 1). After the flood, the dike was repaired, but in October 2000 another flood occurred in the same place, the water flowing through the plain for 2 days (J. Zettel, pers. comm.). During the last decades a large diversity of habitats developed, from dynamic floodplains to xeric steppes, the Pfynwald becoming a hotspot of biodiversity in the Swiss Alps.

Chorthippus pullus

A typical representative of the floodplains is *Chorthippus pullus* (Acrididae, Gomphocerinae, Appendix, Fig. 2). THORENS & NADIG (1997) described it as extremely stenotopic. It is cryptically colored and brachypter with red hind tibiae and black knees (BELLMANN, 2006; BAUR *et al*., 2006). It lives in small populations in alpine gravel-beds in Middle Europe as well as in subatlantic sandy heathlands in Eastern Germany (MAAS *et al*., 2002). The xero-thermophilic species can occur in a variety of habitats, as sandy areas poor in vegetation and gravel areas along rivers, dry meadows, heathlands, clearings, forests edges and forest tracks. In Switzerland the alpine habitats of *C. pullus* are restricted to gravel banks of alpine rivers – the remaining populations occur on the rivers Inn, Rhine, Sense, Dranse de Ferret and Rhone (data of Centre

Suisse de Cartographie de la Faune (CSCF), Neuchâtel). These habitats are endangered due to river embankments, hydroelectric power stations, as well as sand and gravel removals (SCHWARZ-WAUBKE, 1997; MAAS *et al*., 2002).

Until recently, only two populations of *C. pullus* have been known to exist at Pfynwald. One population is situated in a forest clearing called Russenbrunnen (FREIVOGEL, 2003; STEINER, 2006; WALTHER, 2006), the other population lives at the other side of the Rhone at Rottensand (WUNDER, 2001; FREIVOGEL, 2003). Both of them are separated from the dynamics of the river. In the framework of their diploma theses, FREIVOGEL (2003) and WALTHER (2006) both stressed the protection of *C. pullus* at Pfynwald by generating, restoring and protecting suitable habitats and by the recommendation of a migration corridor.

With a corridor established, the Rottensand-population will have the chance to leave its present, suboptimal habitat and move to the new gravel plain. BERGGREN *et al*. (2002) showed that corridor structure may favour the dispersal of *Metrioptera roeseli*. Earlier investigations on *C. pullus* at Pfynwald were carried out by FREIVOGEL (2003), WALTHER (2006) and STEINER (2006), focusing on population structure, habitat quality, habitat preference, influence of ecological parameters and nutritional ecology.

The Rottensand-population lives in a dry side channel of the Rhone which remained mostly free of trees and shrubs for a long time and was isolated by the surrounding pine forest. In 1998 young growth of pines and deciduous trees was removed, in order to restore the open habitat. WUNDER (2001) investigated the influence of habitat structures on Saltatoria in the same location as the present study. She found only three individuals of *C. pullus* emigrating from the relic population. Less than 700 m away the new gravelly floodplain offers optimal habitat structures for *C. pullus*, and future inundations will maintain the quality of the gravel banks. Unfortunately there is no possibility for *C. pullus* to reach the floodplain. FREIVOGEL (2003) showed that *C. pullus* avoids a vegetation cover that leads to a shaded area above 60 % in the morning or above 7 % at noon, as it is the case between the actual population and its future habitat. If the cover of herbs was larger than 35 % or if the cover of woody plants exceeded 8 % the densities of *C. pullus* were strongly decreasing. To increase the chance of survival of the population of *C. pullus* in the Rottensand, a migration corridor with sparse vegetation is necessary to enable the grasshopper the access to the optimal and large habitat.

The population of *C. pullus* at Rottensand was described by FREIVOGEL in 2003 to contain a smaller than minimal viable population number. The planned revitalization of the Rhone (KBM 1997) will bring more water to the floodplain and even improve the good habitat quality for *C. pullus*.

The observations of a few individuals of *C. pullus* outside the isolated habitat (beyond a barrier of dense vegetation) illustrate that the species tries to escape from the small and degrading habitat island (J. Zettel, pers. comm.). In the confined relic population on the other side of the Rhone WALTHER (2006) observed *C. pullus* emigrating on a narrow sandy footpath through the dense riverine forest, obviously in search of better habitat structures.

Corridor structures

Because it is not known how fast *C. pullus* will emigrate under the mentioned conditions, this corridor has to be of a sufficient size and structure for functioning as a breeding habitat itself for several generations. The aim of the present study is to contribute basic data for an optimal planning of a migration corridor. But at the same time other rare species should not be put at risk. For this purpose an inventory of the insects present on the track of a possible corridor is made. It is part of a long term project dealing with the influence of inundations of endangered insects as digger wasps (ZEHNDER & ZETTEL, 1999), wild bees (LOEFFEL *et al*., 1999), ants (GROSSRIEDER & ZETTEL, 1999), grasshoppers (MÜLLER & ZETTEL, 1999) and true bugs (WITSCHI & ZETTEL, 2002).

The following questions were investigated in the field:
Regarding the area where the corridor will be proposed, which animals are occurring? Based on their ability to move and on their incapability to evade: Which species must be protected whilst constructing the corridor? And where is it absolutely impossible to place the corridor, due to locally present species?

2. MATERIAL AND METHODS

2.1 Study site

The investigations in the field took place between May and August 2006 at Pfynwald (VS, Switzerland), in the area Rottensand. It is situated between 560 and 575 m a.s.l. and was described by WERNER (1985), MÜLLER & ZETTEL (1999) and CARRON (1999). Due to the predominant inner alpine climatic conditions, the area escapes the rainfalls of the Atlantic and Mediterranean low pressure zones (WERNER, 1985). The climate consists of continental but also oceanic characteristics and includes hot and dry summers as well as large diurnal and seasonal temperature amplitudes (Appendix, Fig. 3). The Rottensand is part of the driest region of Switzerland.
Compared to the Midlands, half the amount of rainfall is measured at the study site, but more than twice as many days with sunshine were counted (WERNER, 1985). Clear air favours the incoming radiation and on summer days the surface heats up to over 75 ˚C. But there is also an intense cooling in the Rottensand during the night. Due to absence of clouds, radiant energy is emitted from the soil (MÜLLER, 1998). Animals in this environment, especially insects living near the soil surface, need to be well adapted to the varying climatic conditions.
The soil of the floodplain contains mainly alluvial gravel from the nearby Illgraben: Dolomite lime, gypsum and silica. Due to the heavy embanking of the Rhone, mainly for the protection of arable land, the dynamic processes on the floodplain were stopped (WERNER, 1985). Today only extreme floods damaging the dikes, can lead to a disturbance of the surface: In 1993, a new and gravelly floodplain of ca. 4 ha was created. It consists of deposits of different texture; in the center, where the strongest force was acting, boulders and stones were placed. The border areas consist of fine sandy sediments. In October 2000 another flood occurred in the same area and restructured the surface. Due to the aridity, the biological activity is low and the soils are poor in humus.
A large decrease in biodiversity has been observed in the last few years, according to the 'Concept de Réseau écologique de la Plaine du Rhône' (REC, 2005). This concept focus on a higher connectivity between the existing biotopes and improved conditions for the animals and plants. The development of the concept needs more detailed analyses about the needs of the affected species. Detailed projects will be elaborated by the RER (Réseau écologique régionaux).

A relic population of the endangered *C. pullus* exists in an old anabranch of the river Rhone. The current habitat encompasses about 1200 m^2 and is completely surrounded by pine forest. The soil surface is a mixture of sandy patches, coarse gravel, boulders and moss cover (Appendix, Fig. 4). Also bunches of grass and herbs occur.

2.1.1 Habitat parameters

2.1.1.1 Zone characteristics

A classification into vegetation zones was carried out in April and May 2006; in order to characterise different habitat types. 11 zones were described, using the following parameters: Soil composition (gravel, sand, boulders), bare soil (fraction), plant occurrence, moss cover, grass, herbs, bushes, trees and presence of dead plant material. One of the zones represents the habitat of the relic population of *C. pullus*.

2.1.1.2 Vegetation and soil surface

A description of the transects (see 2.2.1) was carried out three times at the end of May, June and July resp.. All the plants touching the transect line were registered as occurring species and their frequency was established (after MÜHLENBERG, 1993). The species magnitude of Braun-Blanquet was used, excluding the lowest two categories (r and **+ ;** Table 1), therefore some species might not be listed.
Within the transects, the percentage of bare soil was estimated in five classes (Table 2). Plant species were identified with LAUBER & WAGNER (2001) and with a species list of Pfynwald (WERNER, 1985).

Table 1: Categories of plant cover.

category	plant cover (%)
1	1-5
2	6-25
3	26-50
4	51-75
5	76-100

Table 2: Classes of the bare soil surface.

class	bare soil (%)
1	0-20
2	20-40
3	40-60
4	60-80
5	80-100

2.2 Insect inventory

2.2.1 Sampling methods

In 7 zones a 40 m linear transect was defined. Some of these transects were divided into two sub-transects of 20 m . One additional 40 m transect was established in a narrow passage adjacent to the area of the relic population. This would have been the only way for *C. pullus* to leave the present habitat, because the rest of the area was surrounded by pine forest. This transect was chosen to check whether *C. pullus* is trying to emigrate through this path.

The linear transects were subdivided into stretches of 5 m. In addition four plots of 25 m^2 and one of 12.5 m^2 were assigned, because they represented singular sandy or gravelly patches within a different environment. They were subdivided into squares of 2.5 m side length. The transects were divided into three main groups, that were always visited in the same order, but within the groups the order of the visits was randomized. This was done to avoid a large difference in time period between two controls of a certain transect. The visits in each transect were carried out alternately in the morning or afternoon. By this the interval time between two visits was 10 to 21 days. Each transect was visited 6 times between 9 a.m. and 12 a.m. and between 2 p.m. and 5 p.m. from July 1 to August 24 2006. The recording of the insects was carried out at temperatures being above 22 ˚C, wind being not too strong and cloud cover being less than 2/8.

At first, the observer walked along the beginning of a linear transect until the end of the first 5 m subdivision. By gently swinging a sweep-net (26 cm x 19 cm, handle 70 cm) the animals were animated to show escape behaviour. For identification they were put into plastic tubes. On a second scanning, the observer walked slowly along a 5 m stretch carrying out 16 strokes with the net. This was done to complete the search in the heterogeneous vegetation. Applying these two methods, one intercept represented a stripe of 5 m length and 1.5 m width. Within one 2.5 m x 2.5 m plot the scanning was done in two lines, while walking in a loop. At first also the visual scanning was done and secondly the sweep-netting, each line containing 8 sweep-net strokes, altogether 16 per square. Each transect was alternately searched from one end or the other. For one transect, one to two hours of scanning and identifying of the insects were needed.

The taxa Orthoptera, Heteroptera, Sphecidae, Coleoptera and Myrmeleonidae were chosen as indicators for habitat quality.

2.2.2 Handling

The captured individuals were identified in the field with a magnifying glass (10 x). After cooling down for some minutes in a cooler, in order to reduce the escape behaviour, the animals were released in the middle of the transect where they had been caught.

When a microscope or detailed keys were necessary for the identification, the insects were killed with ethyl acetate and identified under a dissecting microscope, with the literature and reference collections listed in Table 3. A reference collection of difficult species was also taken into the field.

2.2.3 Identification

For the identification of the insects the following literature and scientific advice was used:

Table 3: Literature and expert advice for the identification of insects.

taxa	literature	expert advice
Heteroptera	WACHMANN (1989); SAUER (1996)	reference collection (WITSCHI, 2001), Denise Wyniger
Orthoptera	BAUR *et al.* (2006); BELLMANN (2006)	
Sphecidae	DE BEAUMONT (1964); DOLLFUSS (1991); SCHMIEDEKNECHT (1930)	reference collection (ZEHNDER, 1996), Felix Amiet
Coleoptera	ZAHRADNIK (1985); HARDE & SEVERA (1989); FREUDE *et al.* (1965- 89)	Christoph Germann, Charles Huber, Claudio Niggli
Myrmeleonidae	GEPP & HÖLZEL (1989)	Roman Bucher

2.2.4 Species spectrum and abundance

Orthoptera: Orthoptera represented the most abundant group of caught insects distributed over the site. Several studies about grasshoppers at Pfynwald have been conducted (WALTHER, 2006; STEINER, 2006; BÄRTSCHI, 2005; URECH, 2003; FREIVOGEL, 2003; GRICHTING, 2002; MÜHLHEIM, 2002; WUNDER, 2001; HOLDEREGGER, 1999; MÜLLER, 1998). After GARDINER *et al.* (2005) plot and transect counts involving 'flushing' grasshoppers from the vegetation is the most rapid and easiest sampling method for grassland ecosystems. At moderate or high grasshopper densities in short vegetation, sweep-netting is the only quick and inexpensive method (OLFERT & SLINKARD, 1999).

Heteroptera: The fauna of true bugs on steppes and extensive meadows at Pfynwald was investigated by BÄRTSCHI (2005), JORIS (2002) and WITSCHI (2001). The latter used four different sampling methods to monitor the heteropteran fauna: sweep-netting, visual search, beating specimens from the plants, and pitfall traps. JORIS applied a combination of sweep-netting and visual search. In the present study the visual search was necessary as ground-dwelling or hidden species are usually missed with the sweep-net. Pitfall traps were not used because they turned out to bring numerous side catches, as young lizards (WITSCHI, 2001).

Sphecidae: The transects containing sandy patches with a fairly compact soil structure represent potential nesting habitats for a number of digger wasps. Observations on Sphecidae at Pfynwald were carried out by BÄRTSCHI (2005), ZEHNDER (1996) and JÄGER (1995). In the present study, a selection of 6 large and sand-nesting digger wasp species was monitored. The methods sweep-netting and visual search illustrate only a snap-shot of the site, more detailed studies would include observations of the plots over a given time period.

Coleoptera: With our sampling methods only conspicuous beetles or beetles in the vegetation could be monitored. As no pitfall traps were used, ground-dwelling species, such as Carabidae, were neglected.

Myrmeleonidae: Antlions occur in sandy patches with sparse vegetation (GEPP & HÖLZEL, 1989). As their abandoned funnels do not persist for a long time, they were counted as individuals. From each plot with antlions a random sample of 10 individuals was taken for identification.

2.2.5 *Chorthippus pullus*

On aerial photographs, the area containing the relic population of *C. pullus* was divided into a grid of 37 squares of 5 m x 5 m (Appendix, Fig. 12). Thus the smallest measurable moving distance was 5 m. Between July 15 and August 16 the area was scanned 5 times in loops, at intervals of ca. one week. The search was started alternately from the eastern or the western end, and was carried out under favourable weather conditions. It took four to six hours to scan the whole area. The animals were caught with a sweep-net and marked with colors and reflecting tape (details are given later in this chapter). The reflector foil was applied on July 15 and 21. The positions of the animals were recorded on a map. After cooling down, they were released in the middle of the square where they had been caught.

Observations during night were done three times between July 20 and August 4. After dusk, the area was systematically scanned with a head lamp and a torch (Mag lite, 3 D-Cell) by walking along the edge of the area and illuminating the site from different sides. The visibility of the reflector foil in the dark was very good, if the beam of the reflected light was not disturbed by shrubs or boulders. When a marked individual was found, a little numbered flag was placed on the spot and the position was plotted on the map the next morning.

At first adult *C. pullus* were marked with one color dot on the pronotum. Additionally, they were marked with a reflecting flag at one of the hind femora ("Scotchlite – 3290 Reflective sheeting", Appendix, Fig. 2). With a waterproof and lightproof pen (Staedtler permanent, Lumocolor), an individual number was written on the flag, in case it would fall off and only the foil was found. After the first night observation it turned out that the foils easily fall off. Later an individual four digit color code was applied, consisting of two points on the top and one on each side of the pronotum. The color marking was done with edding 780 opaque paint markers. Individual markings were applied only after the observation, that the foils did not stick enough and were partly lost.

To avoid injuries during marking, the animals were anaesthetized with CO_2. They were released after cooling down (FREIVOGEL, 2003; HOLDEREGGER, 1999; WALTHER, 2006). The whole marking procedure, with a very careful handling, took on average 5 minutes per individual. Larvae of *C. pullus* could not be distinguished from other *Chorthippus* species, therefore only adults were marked. The advantages and disadvantages of this frequently used method are discussed by HAGLER & JACKSON (2001; INGRISCH & KÖHLER, 1998; JANSSEN, 1993; ZÖLLER, 1995; HOLDEREGGER, 1999; FREIVOGEL, 2003; WALTHER, 2006).

2.3 Statistics

The differences in species abundance between the linear transects and between the plots were compared with a Kruskal-Wallis test. The similarities of the transects were interpreted with a Principal Component Analysis (PCA) or Redundancy Analysis (RDA, Euclidean-based), taking communities of the insect taxa into account. These data were calculated for a uniform area of 25 m^2, and square-root-transformed. A Monte Carlo Permutation test was applied to identify the influence of ecological parameters. The similarity of transects was also illustrated with Wainstein's indices – a combination of the values of Jaccard and Renkonen (WAINSTEIN, 1967, in MÜHLENBERG, 1993). To illustrate the species diversity, the Shannon-Index H_s (basis ln) and the Evenness E_s (Simpson) were calculated for each transect. Also the dominant species and its dominance index

were computed (MÜHLENBERG, 1993). Too small catch numbers were excluded from the analyses. The data of Orthoptera, Sphecidae, Heteroptera or Coleoptera were analysed separately.
Correlations of species, ecological variables and plants were done with Spearman's coefficients.
The population size of *C. pullus* was roughly estimated with the Petersen-Lincoln-Index. The moving distances of *C. pullus* were defined as the farthest distance between the recapture points. The differences between movement of males and females were compared with a Kruskal-Wallis test.
The analyses were carried out with the programs Canoco 4.5, SPSS 13.0, MVSP 3.1 and Ecological Methodology (Krebs, 2006). The work with aerial photographs and on the maps was carried out in GIS (Idrisi, Version 32.2).

3. RESULTS

3.1 Study site

3.1.1 Habitat parameters

3.1.1.1 Zone characteristics

A map of the study site and its division into zones is given in Fig. 1. Most of the surrounding area is covered by dense pine forest, the North-West of the site adjoins the earlier described large gravelly floodplain. A description of the study site and of the different zone characteristics is given in Table 1 (Appendix) and Appendix, Figs. 4, 5a-f. The abbreviations and transect names are given in Table 4. Additionally to the transects within the zones 5 plots of special interest were investigated as sandy or gravelly plots.

Table 4: Abbreviations of transects and plot names; MS* was excluded from zone comparisons. See also Fig. 1.

	transects:		**plots:**
SM	sandy mosaic	**SP**	sandy plot
GM	gravelly mosaic	**GP**	gravelly plot
MS	mosaic with shrubs		
GR	grass dominated area		
GA	gravel anthropogenic area		
TA	transition area between CP and forest		
CP	area with *C. pullus*		
MS*	mosaic with shrubs*		

3.1.1.2 Vegetation

The percentages of vegetation cover in the zones are given in Fig. 2. The completion of the vegetation to 100 % is the fraction of bare soil. A maximum of bare soil was found in GP and SP, whereas MS and GR contained mainly vegetation and only 20 - 25 % of bare soil. A large fraction of woody plants was present in CP, herbs dominated in MS, TA and CP and grasses were mainly found in GR and MS.

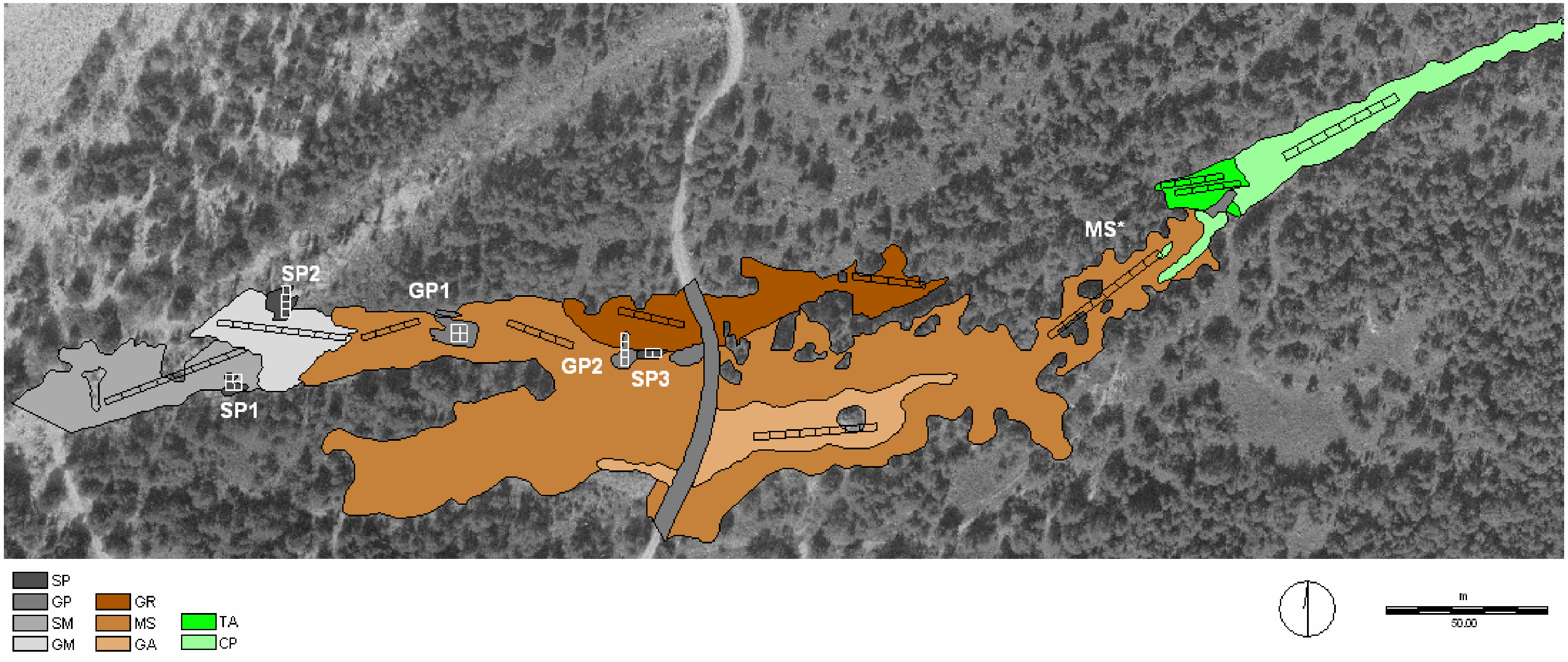


Fig. 1 : Zonation of the study site; linear transects (black grid) measure 40 m (or 2 x 20 m), with subdivisions of 5 m. Plots (white grid) were individually chosen and subdivided into 2.5 x 2.5 m. The relic population of *C. pullus* was located in zone CP. MS* served as a control transect, to check whether migration of *C. pullus* out of CP was taking place.

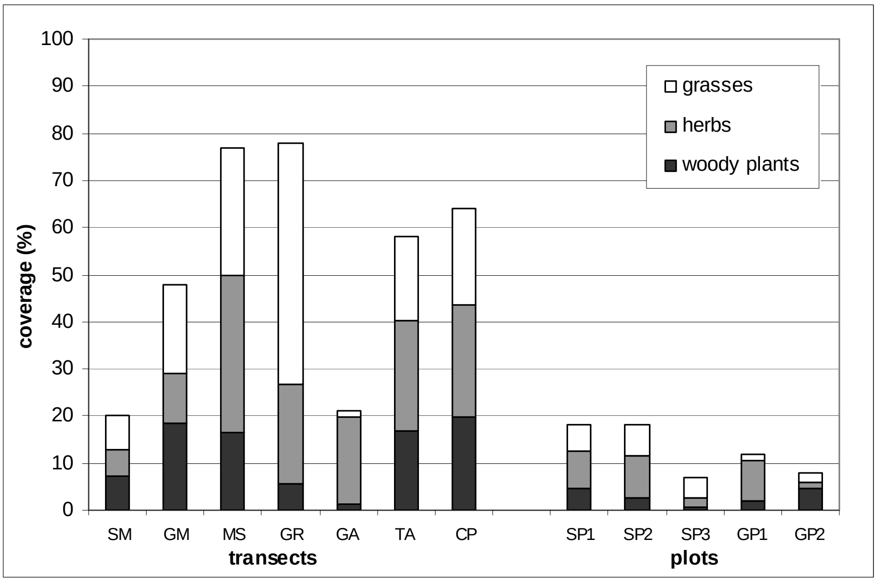


Fig. 2: Vegetation cover in transects and plots. The completion to 100 % is the fraction of bare soil. The abbreviations are written out in Table 5.

The plant frequencies in the different transects are given in the Table 2 (Appendix). *Artemisia campestris*, *Astragalus onobrychis* and *Bromus erectus* were the most common plants at the study site and occurred in all transects and plots. *Euphorbia seguieriana*, *Koeleria vallesiana* and *Stipa pennata* were found in every zone (SP1- 3 were averaged, also GP1 and GP2). 13 plant species grew only in one zone, for example *Melampyrum pratense*, an indicator of acidity, *Agropyron pungens* a typical pioneer species or *Cirsium arvense* growing on compact sandy soil. MS showed the highest diversity containing 27 species. SP was by far the poorest with 10 species. (Transect MS* was excluded from the comparisons, since it was influenced by the directly adjacent forest. See the position of the transect MS* in Fig. 1.)

3.1.1.3 Temperature

A thermologger (GRANT Squirrel SQ-1200) registered the temperature of the air (2 m above soil surface), of the soil surface and 5 cm below surface in hourly intervals. All daily values were calculated as an average value between 7 a.m. and 7 p.m.

The daily mean temperatures of the months are given in Table 5 and Fig. 3 (Appendix). The mean daytime temperature was 22.9 ˚C in the air and 37.2 ˚C on the surface during the observation period (June to August). July 25 was the hottest day, with a maximal air temperature of 39.8 ˚C and a surface temperature of 75.1 ˚C at 4 p.m. The minimal temperature was -1.3 ˚C at 3 a.m. (air) on June 3 and +0.8 ˚C (surface) resp..

Table 5: Monthly temperatures of air (2 m height), surface and soil (5 cm below surface). The data were averaged from 7 a.m. to 7 p.m..

month	**air (˚C)**	**surface (˚C)**	**soil (˚C)**
April	14.9	24.3	13.8
May	18.4	28.5	18.2
June	24.4	40.2	24.8
July	24.9	40.7	25.0
August	19.5	30.6	20.6
September	21.1	29.9	19.0
October	15.2	19.7	12.5

Compared to other years spring temperatures were quite low. For instance on May 9 and 10 the daily average of the air temperature dropped to 10 ˚C. Another cold spell was recorded on June 2, when the air temperature dropped again to 11 ˚C. Also in late summer the temperature decreased awhile: On August 13 the average of the air temperature dropped to 12 ˚C, but increased again to usual range shortly after. The largest differences between surface and air (and also between surface and soil) were recorded in June and July.

3.2 Insects: Biodiversity and abundance

Myrmeleonidae were numerically the dominant insect group in SP2, SM and SP1 (Fig. 3), where at least 35 specimens were registrated at each visit. All the identified Myrmeleonidae belonged to *Myrmeleon bore*. Looking at the other taxa, in all but one transect Orthoptera were present in superior numbers. Most of the Orthoptera were found in TA and CP, whereas in all of the plots only small numbers were counted. The maximum of Heteroptera was in GP1, followed by SP3.

Despite favourable weather, Sphecidae were sparsely found at the study site. By far the dominant species was *Bembecinus tridens*, from which a colony was found in SP2. In the other transects Sphecidae were not frequently caught. The largest number of Coleoptera was found in MS and SP2.

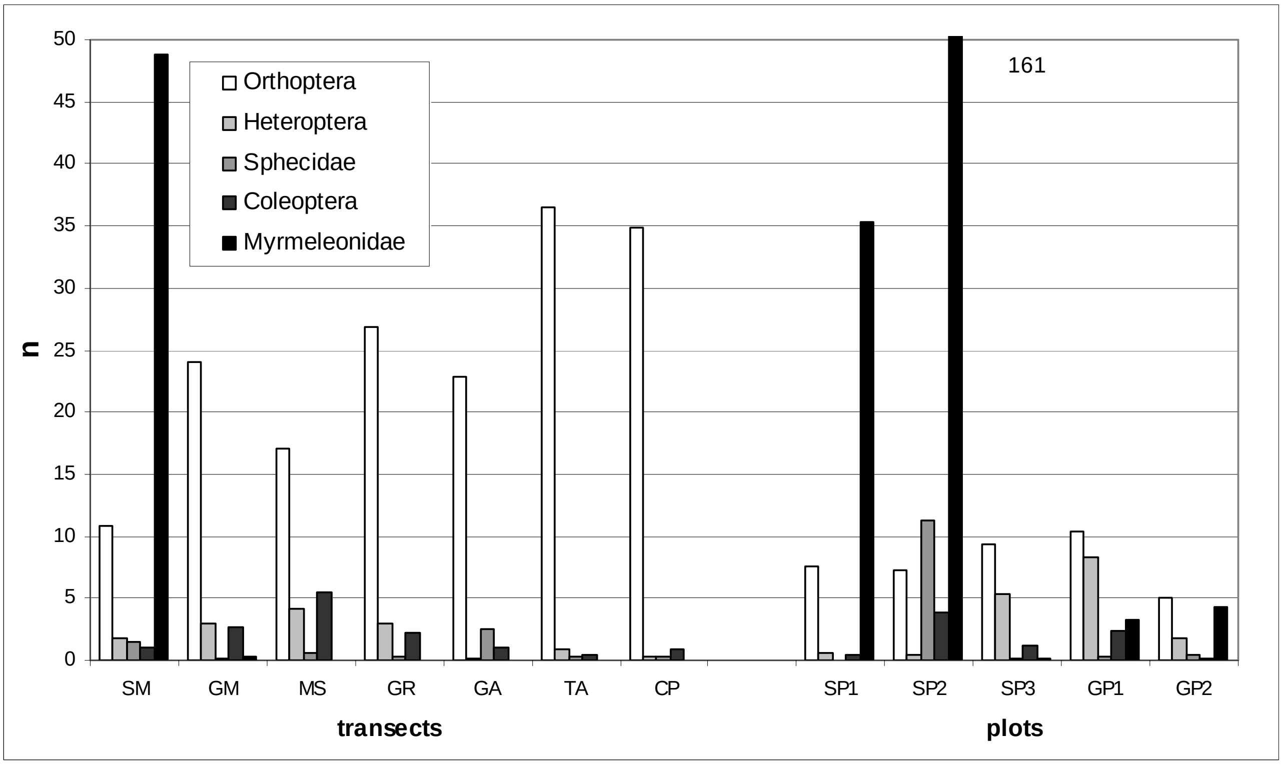


Fig. 3: Abundance of the investigated taxa. The values are averaged of the 6 search actions. For abbreviations see Table 4.

3.2.1 Orthoptera

3.2.1.1 Species spectrum and abundances

An average of 236 Orthoptera was recorded at each visit, 12 species out of 4 families (see Figs. 4 and 5). Catantopidae were most abundant on account of *Calliptamus italicus*, which was the dominant species of the Orthoptera (see dominance in Appendix, Table 3). Acrididae included 7 species, whereof *Oedipoda caerulescens* was the most common. *Platycleis albopunctata* was the most frequent of the Tettigoniidae and *Oecanthus pellucens* was the only and frequently occurring species of the Gryllidae.

C. italicus made up 29 % of the total catches. *O. caerulescens* and *O. pellucens* were also present in large numbers (13 % and 8 %). The former had its maximum in CP, the latter in MS.

The maximal abundance of ***C. italicus*** was obtained in the second half of June, where 137 specimens were found in total. Until the end of August, the numbers decreased slightly. The transect GR contained the most *C. italicus*, in contrary to SM and SP1 (see Appendix, Table 4).

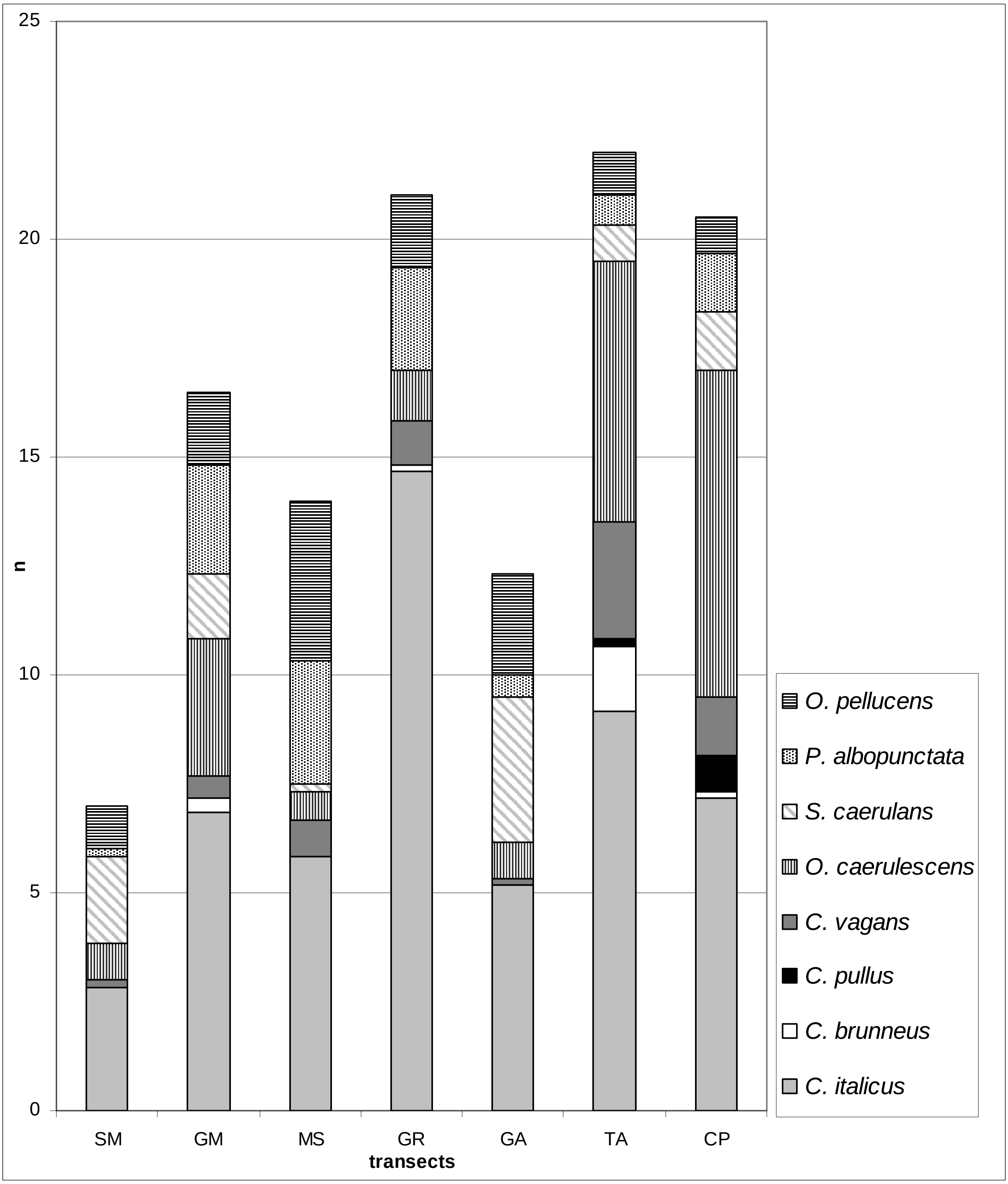


Fig. 4: Orthoptera frequencies in the transects. The values are the average catch number per visit.

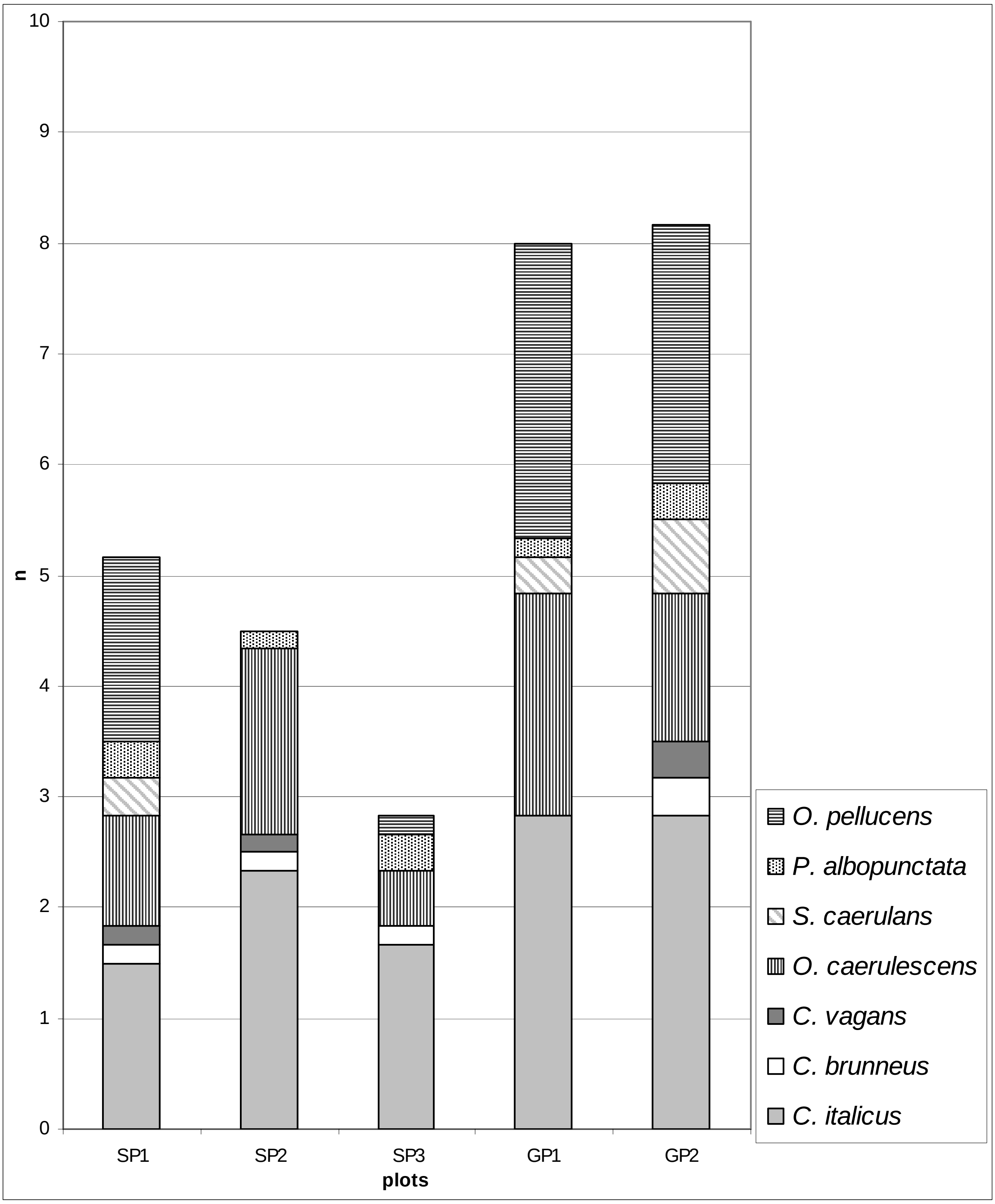


Fig. 5: Orthoptera frequencies in the plots. The values are the average catch number per visit.

A small number of ***C. pullus*** was found in zone CP and a single specimen occurred in the adjacent area TA. It appeared from mid June to the end of July (Table 6). To compare the transects and plots, the numbers were calculated to an area size of 25 m^2 (factor 0.42 for the linear transects and factor 2 for SP3). Since the plots represented a habitat island within another habitat type, border effects could be neglected.

Table 6: *C. pullus* catches, the numbers in brackets are calculated to an area of 25 m^2.

transects	**June 1**	**June 2**	**July 1**	**July 2**	**Aug 1**	**Aug 2**	**total**
TA		1 (0.4)					1 (0.4)
CP			4 (1.7)	1 (0.4)			5 (2.1)
total	**0**	**1 (0.4)**	**4 (1.7)**	**1 (0.4)**	**0**	**0**	**6 (2.5)**

The most abundant *Chorthippus* species was ***C. vagans*** with a total of 54 catches. It was found in 11 transects or plots. TA contained more than twice the amount of the other transects. With one exception, no *C. vagans* were found in SP1 - 3. The first adults occurred in July, the maximum of the catches was counted in the second half of August. In the largest zone MS only 5 *C. vagans* were found, but approaching the forest (represented by the position of the additional transect MS*) twice the number could be recorded. The sex ratio of *Chorthippus vagans* was male dominated (2:1). ***Chorthippus brunneus*** was found in 9 of 13 transects and plots. The maximum was reached in the second half of August. Most of them occurred in transect TA. 188 ***O. caerulescens*** were found in total. In June only singular specimens were found, the maximum of the catches was reached in the second half of August. The sex ratio was male dominated (3:2). Transects CP and TA included very large numbers of *O. caerulescens*, transects SM, MS, GA and GR contained less catches. ***Sphingonotus caerulans*** reached its maximum in the first half on June and then decreased slightly from mid July to the end of August. Transect GA contained 20 catches, by far the largest number. Most of ***P. albopunctata*** counted at the site were found in transects MS, GM and GR. More than half of them occurred in June. In July only a few specimens were seen but in August again more *P. albopunctata* occurred. More females than males were found (8:1).

Chorthippus mollis, ***Oedipoda germanica***, ***Tettigonia viridissima*** and ***Leptophyes punctatissima*** were recorded only as single specimens; therefore they were omitted from further analyses.

Fig. 6 presents the diversity indices of the transects. The Shannon index Hs indicates the diversity with a combination of species number and frequency (MÜHLENBERG, 1993). The Evenness E (Simpson) is the degree of diversity in relation to the whole possible diversity (Appendix, Table 3). Fig. 11 (Appendix) represents an illustration with a gradation of the diversity values. The highest diversity was registered in GP2 and SP1, whereas SP2 and SP3 had the lowest.

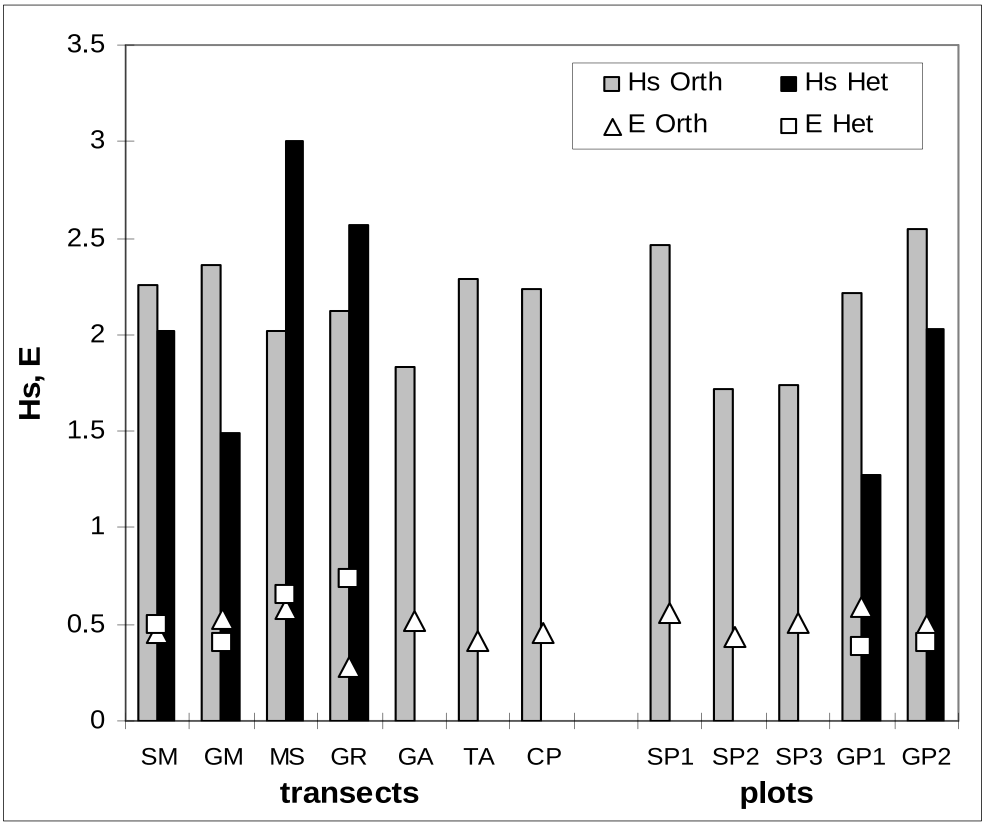


Fig. 6: Shannon's diversity index H_s (bars) and E (Simpson; symbols) for Orthoptera (grey, triangles) and Heteroptera (black, squares).

3.2.1.2 Relationship species – habitat parameters

The PCA in Fig. 7 shows the similarity of the transects and plots based on their composition of grasshoppers (based on Wainstein values in Appendix, Table 5a). The first and the second axis explain together 54 % of the variance of the data. GR and SP3 situated next to each other were very similar, and the same is true for TA and CP. GA, SM and MS form another group, in spite of their differences in abiotic and biotic parameters. The localisation of *C. pullus*, *O. caerulescens*, *C. vagans*, *C. brunneus* and *C. italicus* close to each other shows that these species can live under similar habitat conditions.

Ecological factors were included as supplementary variables (RDA). The number of plant species turned out to be a significant factor for the orthopteran distribution ($p = 0.0292$, $F = 2.304$) and the influence of woody plants showed a strong trend ($p = 0.0501$, $F = 1.999$). The fraction of bare soil or grasses had no influence.

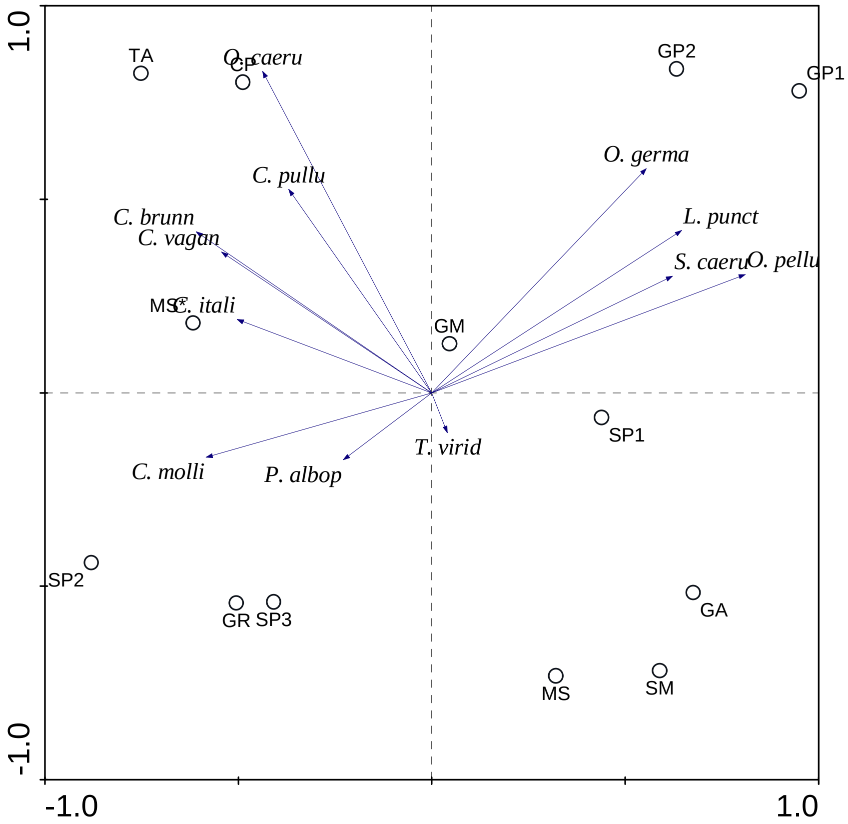


Fig. 7: PCA of the transects and plots for the orthopteran distribution.

Table 7: Spearman correlations of Orthoptera with ecological variables, plant species and *C. pullus*. Only significant values are given.

		ecological variables					plants				
		n plant species	bare soil	woody plants	herbs	grasses	*Calamagrostis epigejos*	*Hieracium piloselloides*	*Petrorhagia saxifraga*	*Salix elaeagnos*	*C. pullus*
Chorthippus brunneus	rho	-0.577									
	p	0.039									
Chorthippus pullus	rho			0.577							
	p			0.039							
Chorthippus vagans	rho		-0.715	0.673	0.659	0.648					
	p		0.006	0.012	0.014	0.017					
Oedipoda caerulescens	rho										
	p										
Sphingonotus caerulans	rho	0.556						0.798	0.854		0.878
	p	0.048						0.018	0.034		0.021
Platycleis albopunctata	rho				0.603	0.611	-0.949			-0.823	
	p				0.029	0.026	0.014			0.023	
Oecanthus pellucens	rho										
	p										

When looking at single parameters and species, the picture became more detailed, although it was not clear in all cases. The total orthopteran distribution was significantly influenced by the vegetation (= ‘number of plant species’) but the only positive correlation of plant diversity with a single species was found in *S. caerulans* (Table 7); a negative one was present with *C. brunneus*. *C. pullus* was correlated with woody plants, which seems to be contradictory; but as woody plants outside the forest are represented by saplings of pioneers on gravel like *P. sylvestris*, *Salix sp*. or *Populus sp*., this fact emphazises the pioneer character of *C. pullus.* As a typical inhabitant of grassy steppes, *P. albopunctata* correlated with ‘grasses’ and ‘herbs’.
C. vagans as another typical species of hot steppes with bushes shows a similar habitat preference, correlating negatively with the ‘fraction of bare soil’.
When considering plant species, a positive correlation of *S. caerulans* with *H. piloselloides* and *P. saxifraga*, both present as pioneers on gravelly surfaces, could be demonstrated. A negative correlation showed up between *P. albopunctata* and *C. epigeios* and *S. elaeagnos* being present in GP1 and 2, SM and GM.
Correlations within grasshoppers were a result of the common need of open ground and scarce vegetation, as it is known for *C. pullus*, *O. caerulescens* and *O. germanica*. *L. punctatissima* and *O. pellucens* joined this group, because of their preferred shrubby habitat structures which, within the investigated area, mainly occur in places with a low coverage of other vegetation. These facts are illustrated by the direction of the arrows in Fig. 7.

3.2.1.3 *Chorthippus pullus*: population size and dispersal

In zone CP 48 adults were found and individually marked (28 ♂♂, 20 ♀♀). Fig. 8 shows an overview about the 5 recordings at daytime. The maximum was found during the first search (n = 40), afterwards the number decreased rapidly. 13 of the marked animals were recaptured at least once (61.5 % ♀♀). In 31 cases only the marking flag was found (38.7 % ♀♀). The *C. pullus* population could be estimated to a size of ca. 73 individuals during the first recapture (Peterson-Lincoln-Index). For this calculation only the sightings at daytime were included. Figs. 12 to 15 (Appendix) show the distribution of *C. pullus* within CP. They stayed mainly in the central part. The aggregated distribution did not change much over time. Up to 7 specimens were found within one square.
No individuals were recorded on MS* using this passage to emigrate from CP.

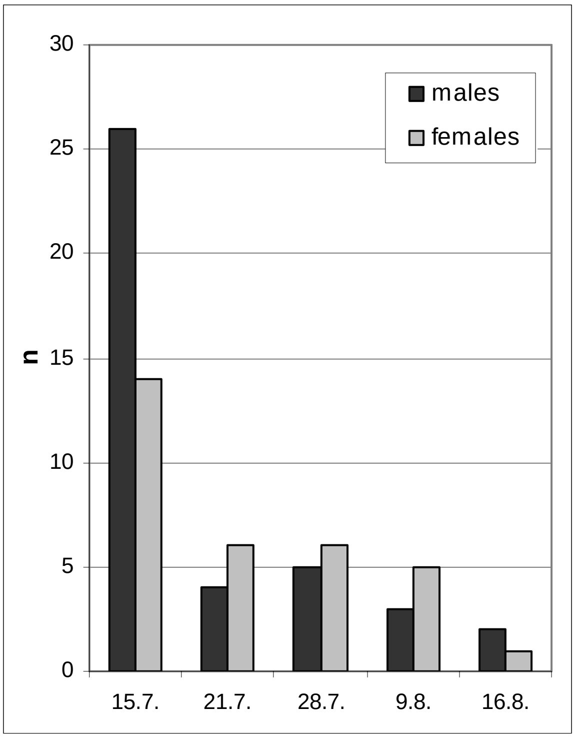
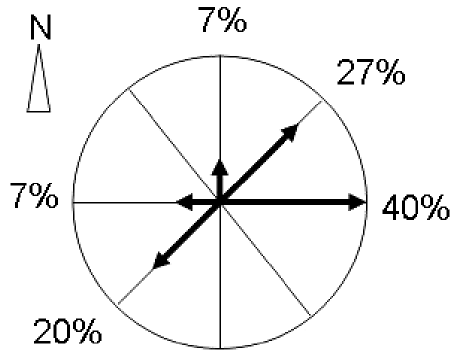


Fig. 8: *C. pullus* catches of five searchings, being carried out at favourable weather conditions in weekly intervals.

Three searchings were made at night. In the first night four *C. pullus* and 25 reflector foils were found, that had been stripped off. At the second searching 4 specimens and 5 flags were found and at the last searching three *C. pullus* and one foil. Afterwards the foil marking was omitted and we continued only with the colour markings and searchings at daytime.

The average moving speed of all *C. pullus* was 0.9 m per day (SD ± 0.6 m/d). The mean nightly distribution of the animals is shown in Appendix, Fig. 16. The males moved farther (1.1 m/d, SD ± 1.6 m/d) than the females (0.6 m/d, SD ± 0.6 m/d) but the difference is not sign.. The maximal distance covered by a male was 32 m within 12 days. The maximum for the females was 17 m within 14 days. 10 animals (5 ♂♂) remained within the same square, 11 animals moved to the next square only (8 ♂♂). Also the distribution maps (Appendix, Figs. 12-15) show a rather stable distribution pattern, with only little migration taking place.

The moving directions are shown in Figs. 9 and 10. The study area is orientated from NE to SW. Moving actions towards NE or SW should enable the largest distances possible. This was partly the case. 40 % of the animals did not move, 25 % moved north-eastwards and 15 % eastwards. The largest part of the mobile males went eastwards, most of the females moved north-eastwards. The two males covering the largest distances (32 m and 29 m) moved from NE to SW. The females with the largest distance (17 m and 11 m resp.) moved from SW to NE, and from NE to SW. But a few females remained nearly in the same area. No statistical tests were carried out, because the influences of the surrounding landscape could not be neglected.



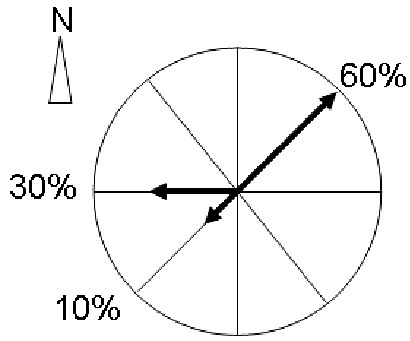


Fig. 9: Movement directions of *C. pullus* males in CP.

Fig. 10: Movement directions of *C. pullus* females in CP.

3.2.2 Heteroptera

3.2.2.1 Species spectrum and abundances

On average 30 Heteroptera were counted during one searching (n = 20 - 43), belonging to 19 species of 8 families. Table 8 summarizes the heteropteran fauna of the study site. Pentatomidae were the most frequent family with 65 specimens of 9 species, followed by 63 Miridae (2 spp.) and 28 Rhopalidae (4 spp.).

The most frequent species was ***Lygus gemellatus*** (62 catches in total); it occurred mainly in plots GP1 and GP2 and in transect GM (see Table 9). Also a few ***Chorosoma schillingi*** and ***Eurydema* sp**. were found, the former occurring mostly in GP1 and MS, the latter mostly in GP2. 11 species were found as single specimens only. About 3/4 of the true bugs were caught in August. Table 9 lists the most common species of the transects and plots.

MS and GR showed a very diverse heteropteran fauna, GP1 the lowest (see 3.2.1.1, Fig. 6). Transects with less than 10 catches were omitted from the calculations. The Evenness was high in GR and MS and low in GP1, GP2 and GM. Fig. 17 (Appendix) illustrates the diversity at the study site.

Table 8: Species list of Heteroptera at the 6 visits.

family	**species**	June 1	June 2	July 1	July 2	Aug 1	Aug 2	**Total**
Alydidae	*Alydus calcaratus*			2		2		**4**
	Camptopus lateralis				2			**2**
Coreidae	*Syromastes rhombeus*			1				**1**
Miridae	*Adelphocoris lineolatus*			1				**1**
	Lygus gemellatus			7	9	27	19	**62**
Pentatomidae	*Aelia acuminata*			4	1			**5**
	Carpocoris fuscipinus	1		1	1			**3**
	Carpocoris pudicus					1		**1**
	Dolycoris baccarum				1			**1**
	Eurydema oleracea		1	4	1			**6**
	Eurydema ornatum			1	1			**2**
	Eurydema larvae	23	8	9	3		1	**44**
	Neottiglossa larva		1					**1**
	Piezodorus lituratus		1					**1**
	Stagonomus bipunctatus		1					**1**
Reduviidae	*Rhinocoris iracundus*	6		1	1			**8**
Rhopalidae	*Chorosoma schillingi*	1	1	8	7		4	**21**
	Rhopalus distinctus		1					**1**
	Rhopalus parumpunctatus		2		1	1	1	**5**
	Stictopleurus punctatonervosus	1						**1**
Scutelleridae	*Eurygaster maura*		1	1				**2**
	Odontotarsus purpureolineatus		2	3	1			**6**
Stenocephalidae	*Dicranocephalus agilis*				1			**1**
	Dicranocephalus albipes		1					**1**
Total		**32**	**20**	**43**	**30**	**31**	**25**	**181**

Table 9: Heteroptera in transects and plots and species numbers.

transects	*Alydus calcaratus*	*Camptopus lateralis*	*Syromastes rhombeus*	*Adelphocoris lineolatus*	*Lygus gemellatus*	*Aelia acuminata*	*Carpocoris fuscipinus*	*Carpocoris pudicus*	*Dolycoris baccarum*	*Eurydema oleracea*	*Eurydema ornatum*	*Eurydema sp.*	*Neottiglossa sp.*	*Piezodorus lituratus*	*Stagonomus bipunctatus*	*Rhinocoris iracundus*	*Chorosoma schillingi*	*Rhopalus distinctus*	*Rhopalus parumpunctatus*	*Stictopleurus punctatonervosus*	*Eurygaster maura*	*Odontotarsus purpureolineatus*	*Dicranocephalus agilis*	*Dircanocephalus albipes*	**n toal**	**n / 25m²**	**n species**	**n species / 25m²**
SM		1		1	6			1											1		1				11	4.6	6	2.5
GM	1				11	1						2							1			2			18	7.5	6	2.5
MS	2		1		3	3	1		1			1				2	7		1			3			25	10.4	11	4.6
GR		1				1	1			4		7			1	2	2								19	7.9	7	2.9
GA																								1	1	0.4	1	0.4
TA	1											4													5	2.1	2	0.7
CP											1								1						2	0.7	2	0.7
SP1													1				1				1	1			4	4	4	4
SP2					2									1											3	3	2	2
SP3												1													1	2	1	2
GP1					26							1					9	1	1	1					39	39	6	6
GP2					14		1			2	1	28				4	2						1		53	53	7	7
Total	**4**	**2**	**1**	**1**	**62**	**4**	**3**	**1**	**1**	**6**	**2**	**44**	**1**	**1**	**1**	**8**	**21**	**1**	**5**	**1**	**2**	**6**	**1**	**1**	18 1	134.6	22	35,3

3.2.2.2 Relationship species – habitat parameters

Fig. 18 (Appendix; Wainstein values in Appendix, Table 5b) represents the similarities of the transects based on the heteropteran occurrence. 73 % of the variance could be explained by the first and the second axis. GP1, GP2, GR and MS are separated from the other transects, the remaining ones were clustering together. The investigated ecological variables (plant groups, plant diversity and frequency of bare soil) had no significant influence on the distribution of Heteroptera at the study site (RDA).

True bugs are very dependent on plant species and were exclusively found in the vegetation in this study. Table 6 (Appendix) lists the Spearman correlations. *Rhopalus parumpunctatus* was significantly correlated with the plant diversity (p = 0.008, rho = 0.700). *E. oleracea* was highly correlated with *Carpocoris fuscipinus* (p = 0.001, rho = 0.817) and with *Rhinocoris iracundus* (p = 0.001, rho = 0.817). Table 7 (Appendix) shows the Spearman's indices of the correlations of plants with Heteroptera. There was a highly significant correlation of *L. gemellatus* with *Salix purpurea* (p = 0.007, rho = 0.993) and of *C. schillingi* with *Berberis vulgaris* (p = 0.005, rho = 0.975).

3.2.3 Sphecidae

3.2.3.1 Species spectrum and abundances

Table 10: Numbers of Sphecidae found during the observation periods. * The total includes Sphecidae sp., which escaped before identification was possible.

species	June 1	June 2	July 1	July 2	Aug 1	Aug 2	Total
Ammophila apicalis	3	1	4				**8**
Ammophila sabulosa		2	1				**3**
Bembecinus tridens	25	32	6	1			**64**
Podalonia affinis			3				**3**
Prionyx kirbii	1	9	23	3		2	**38**
Tachysphex helveticus	1						**1**
Total	**30**	**44**	**37**	**4**	**0**	**2**	**121***

Out of the 56 species recorded by ZEHNDER & ZETTEL (1999) in 1994/95, 6 larger species were selected for the present survey. On average 20 Sphecidae were recorded at each visit (Table 10). 64 ***B. tridens*** were counted in total, being the most abundant digger wasp at the study site. With one exception, all of them occurred in a colony in SP2. They were found in June and July, and their maximum was reached in the second half of June. 38 ***Prionyx kirbii*** were found, with a maximal abundance in the first half of July. Almost half of the total number occurred in GA, 6 in SM. SP3 and SP2 contained both large amounts of *P. kirbii* (6 and 4 individuals per 25 m^2), while in contrast the other areas did not, except MA and SM (2.4 individuals per 25 m^2 or less). 8 specimens of ***Ammophila apicalis*** were found from June to mid-July. Because of the very low catch numbers, no data analyses could be made.

3.2.3.2 Relationship species – habitat parameters

The RDA of the Specidae is presented in Fig. 19 (Appendix; Wainstein values in Appendix, Table 5c). 94 % of the variation was explained by the axes 1 and 2. Due to its *Bembecinus* colony, transect SP2 lied apart from the others. All other surfaces were similar in their digger wasp communities. None of the included ecological parameters had a significant influence (fraction of bare soil, herbs, woody plants, grasses), but the diversity of plants might have affected the distribution ($p = 0.065$, $F = 4.269$).

Table 11 lists the Spearman correlations of the Sphecidae. *Podalonia affinis* was highly positively correlated with plant diversity, but negatively with the herbs *A. campestris* and *Centaurea vallesiaca*. No correlation with the fraction of bare soil could be found.

Table 11: Significant correlations of Sphecidae with ecological variables and plant species.

		ecological variables		plant species		
		n plant species	woody plants	*Centaurea vallesiaca*	*Artemisia campestris*	*Hippophaë rhamnoides*
Ammophila sabulosa	rho		0.634			-0.899
	p		0.020			0.044
Podalonia affinis	rho	0.735	0.586	-0.905	-0.635	
	p	0.004	0.036	0.013	0.020	
Prionyx kirbii	rho		-0.573			
	p		0.041			

3.2.4 Coleoptera

3.2.4.1 Species spectrum and abundances

At the study site a mean of 21 Coleoptera was found at each visit, representing 11 families and at least 24 species. Table 12 presents the diversity of the transects and plots. Table 13 lists the beetle species. Too small numbers of catches were excluded from the analysis and no statistical comparison was done. The most diverse transect was GM, having a high Hs value, followed by SM and GP1 (see also Appendix, Fig. 20). Fig. 21 (Appendix) shows an illustration of the coleopteran diversity.

Table 12: Coleoptera catches in the transects and plots and their diversity: Hs Shannon-Index, E Evenness (Simpson).

transects	GM	SM	GP1	CP	GR	SP2	GP2	GA	MS	TA	SP1	SP3	**Total**
Total	16	6	7	5	13	23	14	6	33	3	3	1	**130**
Hs	2.74	2.58	2.47	2.32	2.30	2.16	2.14	1.81	1.65	1.59			
E	0.70		0.81		0.69	0.35	0.68	0.75	0.48				

Table 13: Coleoptera species and their abundances during the 6 searchings.

family	**species**	June 1	June 2	July 1	July 2	Aug 1	Aug 2	**sum**	Total
Alleculidae	*Cteniopus flavus*		3	1				**4**	**4**
Buprestidae	*Buprestis octoguttata*			1				**1**	**1**
Cerambycidae	*Chlorophorus varius*	1		2				**3**	**4**
	Strangalia melanura			1				**1**	
Chrysomelidae	*Aphtona sp.*						1	**1**	**28**
	Cryptocephalus services	1						**1**	
	Exosoma lusitanica	6	18					**24**	
	Pachybrachis hieroglyphicus	1		1				**2**	
Cicindelidae	*Cicindela hybrida*			7	5	4	2	**18**	**18**
Coccinellidae	*Coccidula quatuordecimpustulata*			2				**2**	**19**
	Coccinella quinquepunctata		6	1	1			**8**	
	Coccinella septempunctata	4		5				**9**	
Curculionidae	*Sibinia tibialis*	3						**3**	**9**
	Mogulones geographicus		2					**2**	
	Sitona tenuis				1			**1**	
	Sitona discoideus			1				**1**	
	Tychius tridentinus			1				**1**	
	Brachyderes incanus					1		**1**	
Meloidae	*Mylabris variabilis*		6	2	3			**11**	**11**
Mordellidae	*Mordellistena sp.*		1	1				**2**	**2**
Oedemeridae	*Oedemera flavipes*	9	12	1				**22**	**26**
	Chrysanthia viridissima	1	3					**4**	
Scarabaeidae	*Blitopertha campestris*	5						**5**	**8**
	Chaetopteroplia segetum	3						**3**	
Total		**34**	**51**	**27**	**10**	**5**	**3**	**130**	**130**

Exosoma lusitanica was the dominant beetle over the whole study site. It was only found during June. In March and April a lot of ***Cicindela hybrida*** were seen, particularly in the sandy areas such as SM and SP. In the middle of June they disappeared for a period of some weeks, but from the beginning of July their number increased again. ***Oedemera flavipes*** was common at the site, mainly in June.

3.2.4.2 Relationship species – habitat parameters

The first and the second axis of the PCA of the Coleoptera data explained 62 % of the variance (Appendix, Fig. 22). The inclusion of the supplementary variables showed an influence of the number of plant species ($p = 0.025$, $F = 2.428$; Wainstein values in Appendix, Table 5d). This implies that the diversity of plants explains a part of the coleopteran distribution over the transects.

The Spearman correlations are given in Table 14. *C. hybrida* correlated highly with the plants *A. campestris* and *Populus nigra*. *O. flavipes* correlated with *P. nigra* and *E. lusitanica* correlated with *H. piloselloides*. A highly significant correlation of *Coccinella septempunctata* with *C. hybrida* and with *Coccinella quinquepunctata* was found. *Chrysanthia viridissima* correlated highly with *Cteniopus flavus*.

Table 14: Significant correlations of Coleoptera with ecological variables, Coleoptera and plant species. Percentage of bare soil = sand, gravel, open soil. Insignificant values are not shown.

		ecol. variable	Coleoptera				plant species					
		bare soil	*Cicindela hybrida*	*Coccinella quinquepunctata*	*Exosoma lusitanica*	*Cteniopus flavus*	*Populus nigra*	*Stipa pennata*	*Artemisia campestris*	*Pinus sylvestris*	*Hieracium piloselloides*	*Calamagrostis epigejos*
Coccinella quinquepunctata	rho	0.581										
	p	0.037										
Coccinella septempunctata	rho	0.574	0.730	0.726								
	p	0.040	0.005	0.005								
Oedemera flavipes	rho			0.640	0.651		-0.853			-0.750		
	p			0.019	0.016		0.003			0.032		
Chrysanthia viridissima	rho					0.851						
	p					<0.000						
Cicindela hybrida	rho						0.810	-0.594	0.741			
	p						0.008	0.042	0.004			
Exosoma lusitanica	rho									0.746	-0.992	
	p									0.034	0.001	
Mylabris variabilis	rho											-0.884
	p											0.047

3.2.5 Myrmeleonidae

Mymeleonidae, represented only by ***Myrmeleon bore*** larvae, were the most abundant insect family at the site. An average of 253 individuals was counted at each visit, the number decreasing from 388 in early June to 144 in late August. *M. bore* was present in loose sandy soil, even if the sandy plot measured only a few square metres. Most of the 160 funnels were counted in SP2. Also SM and SP1 contained a lot of *M. bore*, with 48 and 35 funnels, respectively. Its presence was highly correlated with bare soil (e.g. sand; $p = 0.005$, rho = 0.728). *M. bore* correlated also with *B. tridens* ($p = 0.010$, rho = 0.684) and with *C. hybrida* ($p = 0.012$, rho = 0.673), all three species occurring mainly in SP2.

4. DISCUSSION

4.1 Study site

Dividing the heterogeneous study site into zones was a good method for the recording and classification of insects. Not all investigated plots had the same shape and size. This could not be avoided because the investigation concerned the diversity of the site, including given natural formations and mixture of soil structures. A transect in the pine forest was not considered, as on a larger scale, the whole corridor area is situated within the forest.

The difference of soil types and unequal water access lead to a vegetation with mosaic character. The zones with a mixed character of soil types and heterogeneous vegetation contained the largest number of plant species (namely MS, SM and GM), whereas sandy soil had a low diversity. Generally many pioneer plants occurred at the site, the three most common being *A. campestris* (common in dry steppes of the Central Valais; it was predominant at the study site, mainly in areas with a large proportion of bare soil), *A. onobrychis* (on alluvial soils with sandy patches) and *S. pennata* (on sandy soil of later successional stages and steppes, TA and CP).

4.2 Insects: Biodiversity and abundance

The special climatic situation provided an optimal habitat for insects depending on high temperature and aridity. As expected, Orthoptera represented a large proportion of the entire fauna at the site. Heteroptera and Coleoptera were recorded in moderate numbers. This was predictable, because no search on selected plant species was carried out and no pitfall traps were used. A small number of the selected Sphecidae was recorded, because they have a larger home range than sessile species. The open soil of the transects represented simply their nesting sites and they searched for food elsewhere.

Generally the presence at the site represented (1) a habitat for less mobile species, such as Orthoptera and Heteroptera. More mobile insects (2), such as Sphecidae, were recorded whilst feeding or nesting. Groups like Coleoptera (3), whose larvae differed totally from the adults in their biology and habitat. When larvae can be found and identified, such species (e.g. grasshoppers, true bugs) provide more data over their whole developmental time than those with hidden larvae and a short presence as adults (e.g. digger wasps, wild bees).

4.2.1 Sampling methods

Visual search and sweep-netting was an appropriate combination for this survey. With the visual search most of the insects were discovered, but in transects with diverse and high vegetation the netting was also important. The two sampling methods were not compared statistically, because the main differences would lie in the behaviour of each species and its habitat.

With the used methods it was impossible to cover the whole insect fauna. Some families, especially ground-dwelling taxa and the short time available may be underestimated in heterogeneous areas, namely Lygaeidae and Cydnidae or Carabidae, which were lacking at all. We have three explanations:

1. We did not use pitfall traps because the number of species sampled by this method is low compared to the captured non-target organisms. Moreover the research area is under natural protection. It must be taken into consideration that pitfall traps capture a different selection of animals compared with the sweep-net (CHERILL *et al*., 1994 in STANDEN, 2000; DANAHAR, 1998 in STANDEN, 2000).
2. The visual search depends strongly on the searchers skills. Small, cryptic and agile species are easily missed, especially in dense vegetation.
3. Only few individuals per species were killed and identified. All the other individuals were compared to these specimens and identified on-site. Therefore it is likely that similar species could have been missed.

4.2.2 Orthoptera

Grasshoppers are known as bioindicators for habitat quality because of their strong dependence on microclimate (mainly humidity and temperature) and vegetation structures (REICH, 1991). Habitat changes always go along with a change of these parameters (INGRISCH & KÖHLER, 1998).

At the beginning of June, almost no adults were found at the study site. Compared to other summers the adults appeared later than expected, possibly due to the cold and rainy spring.

Generally speaking the number of plant species and the factor of woody plants were influencing factors of the distribution of Orthoptera. Both underlined the stages of succession, ranging from recently eroded areas to pine forest. The variety and structure of the site implicated a broad spectrum of grasshoppers.

C. pullus is flightless and thus very philopatric. It needs gravelly or sandy riverbanks covered with sparse vegetation and it avoids shaded localities (MAAS *et al*., 2002; THORENS & NADIG, 1997; FREIVOGEL, 2003). Oviposition takes place in the substrates sand or moss (SCHWARZ-WAUBKE, 2001; UVAROV, 1966). The correlation of *C. pullus* with woody plants does not imply an occurrence in the forest, since it was found only in CP, where numerous saplings of woody plants occurred. In 2000 WUNDER (2001) had found very few *C. pullus* in GA, emigrating from CP. FREIVOGEL (2003) showed that a cover of herbs larger than 35 % or a cover of woody plants exceeding 8 % lead to a decrease of population density.
C. pullus correlated with *C. vagans* and *O. caerulescens*, which were all frequent in CP. As these are typical for later successional stages, together with *C. italicus*, CP has to be considered no longer as an optimal habitat for *C. pullus*.
C. vagans favoured older succession stages than *C. pullus*; the greater abundance of the former indicates the better habitat conditions for it than for *C. pullus*.
WALTHER (2006) found the following species accompanying *C. pullus* at Russenbrunnen: *C. italicus*, *C. vagans*, *O. caerulescens*, *C. brunneus*, *C. mollis* and *O. germanica*. In the present study most of them were approved for Rottensand, too. However *C. mollis* and *O. germanica* had more different habitats than the other mentioned species. According to the habitat demands also *S. caerulans*, *Tetrix tuerki* and *C. brunneus* were expected to correlate with *C. pullus* (BAUR *et al*., 2006). But actually, the only positive correlations with *C. pullus* were found with *C. vagans* or *O. caerulescens*.
P. albopunctata and *O. pellucens* were expected to correlate negatively with *C. pullus*, because of different habitat needs. This was not the case, possibly because today CP represents successional stages beyond the optimum for *C. pullus*.

C. italicus prefers open vegetation and avoids shade of forest or bushes (BELLMANN, 2006), BAUR *et al*. (2006) described *C. italicus* as thermophilic with high demands on the habitat. Its frequent distribution over the whole study site refers to a large habitat acceptance in the range of the site. Though it was mostly found in the grass, it occurred in every transect. No correlation of *C. italicus* could be made out, neither with ecological variables nor with other grasshoppers nor with plant species. WUNDER (2001) and URECH (2003) were able to demonstrate an avoidance of trees and bushes, referring to associated shadow.

O. caerulescens occurred in a wide range at the site, but favoured CP and the adjacent TA. It inhabited open soil patches, even if they were adjacent to forest or bush stands. Stony meadows, gravel pits and gravel banks are preferred and *O. caerulescens* can occur locally frequent (BAUR *et* *al*., 2006; BELLMANN, 2006; KÜCHENHOFF, 1994). DETZEL (1998) mentions a pronounced local stenotopy. *O. caerulescens* did not correlate with any ecological variable or plants. The sex ratio during the observation period was slightly male biased; the maximum of the males was reached at the beginning of August, while the number of females was still increasing, due to an additional larval instar (shown for Pfynwald by MÜHLHEIM, 2002).

P. albopunctata prefers meadows, steppes and mosaic areas poor in vegetation (BAUR *et al*., 2006; BELLMANN). At the site many larvae were recorded, but later on only a small number of adults was found. This might originate from the clumped occurrence of young larvae and the dispersal as very mobile adults. Possibly *P. albopunctata* was reduced by numerous predators, such as lizards or spiders (early instars only; DETZEL, 1998). It is possible that special microhabitats were used for oviposition (like URECH, 2003, showed for *C. italicus*). There were not enough records to establish a skewed sex ratio. *P. albopunctata* increased with grasses and herbs, but not when the pioneers *C. epigejos* or *S. elaeagnos* were present.

C. vagans is very abundant in Valais and in the South of the Alps. The correlations showed an avoidance of a large coverage of bare soil and a preference for any type of vegetation (woody plants, herbs, grasses). The most suitable habitat of *C. vagans* was TA. BELLMANN (2006) and BAUR *et al*. (2006) described *C. vagans* as xero-thermophilic and as an inhabitant of rocky steppes and open woods. WUNDER (2001) could show an avoidance of areas with a large fraction of gravel. DETZEL (1998) described the preferred habitat as low vegetation with little spatial resistance containing moderate gaps.

The differing behaviour of both sexes explains the seemingly unbalanced sex ratio. Males bounce through the vegetation and stridulate, whereas females behave cryptical, staying rather quiet and being less active (BAUR *et al*., 2006).

O. pellucens is thermophilic and is bound to sunny habitats, dry meadows rich in shrubs and rocky steppes (BAUR *et al*., 2006; DETZEL, 1998). It is predominantly nocturnal and hides during the daytime on branches, flowers or on rolled-up leaves.

At first ***S. caerulans*** larvae were not frequent, maybe because the egg deposition had taken place in areas outside the investigated transect. DETZEL (1998) described the egg laying on the surface or in bare soil, in favour fine gravel or sand. As a typical pioneer, it is a good flyer and inhabits sparse areas and very open patches with a large fraction of bare soil.

Only a small number of *S. caerulans* and *O. germanica* appeared in some areas at the site (the former mainly in GA, the latter in GP1 and GP2) as it was the case in 2000 (WUNDER, 2001).

A positive correlation of *S. caerulans* with plant diversity was shown. It involves characters of the zones, as *S. caerulans* was found in open areas in early successional stages, with a diverse flora. This was also proved with the positive correlations of *S. caerulans* with *H. piloselloides*, *P. saxifraga* and *S. purpurea*.

C. brunneus inhabits a broad spectrum of arid and hot areas with open vegetation, such as meadows and neglected grasslands as well as pioneer habitats, such as gravel banks or embankments along traffic routes (BAUR et al., 2006). Preferring open soil, it correlated negatively with plant diversity.

O. germanica has not been found regularly at Rottensand during the last few years, in all probability due to microclimatic circumstances, as it is very sentitive to late frost (BAUR *et al*., 2006; DETZEL, 1998). It occurrs more frequently on vineyard hills on the other side of the Rhone. As a more demanding species than *O. caerulescens* it inhabits dryer and warmer sites, such as rocky heathland, bare and sun exposed areas and gravel or stone pits. At the study site it was found in the same zones as *L. punctatissima* and *O. pellucens*.

4.2.2.1 *C. pullus*: population size and dispersal

Compared to other years, the adults of *C. pullus* appeared very late and the population was small. At the first search in in mid-July the population had already reached its maximum and by end of August no *C. pullus* were found anymore. FREIVOGEL (2003) estimated the maximum of the same population in July 2002 to 180 individuals, which is 2.5 times more than in the present study. WALTHER (2006) found the maximum of two different *C. pullus* populations at the middle or the end of June, respectively. As the populations at Pfynwald live at a very low altitude, their maximum is earlier than presented by THORENS & NADIG (1997). Changes in population size can be caused by changes in habitat quality – which may be at least part of the reasons for the decline at our site (SANDER, 1995). But they can also be caused by population dynamics and climate variations, leading to density variations of a factor 2 to 10 for Acrididae (KÖHLER, 1996 and 1999). In spite of changes in abundance and distribution, the main part of the population stayed in the same place as in 2002 (FREIVOGEL, 2003). In 2002 the animals were relatively resident compared to a second population of *C. pullus* in Pfynwald, investigated by FREIVOGEL (2003).
In the present study, no big change in the distribution during time was recorded. Although the most moving animals went north-eastwards, the largest distances were covered into the opposite direction.

The average speed of the females was less than 1 m per day, some females covered distances larger than 10 m within 2 weeks.
The migration potential of single individuals over large distances was found by WALTHER (2006), CARRON (1999) and Zettel (pers. comm.). Compared to other species, the flightlessness has a strong impact on the spreading ability of *C. pullus*. In the present study most of the animals did not move far, since the small habitat did not offer great chances to migrate. In the first instance migration and establishing of a new population depends on females and where they lay the eggs. In the present study there was no difference in the average moving distance and speed of males and females observed.
No *C. pullus* were recorded in the control transect MS*, which provides a narrow pathway for leaving CP. The dense vegetation must have hindered the animals from emigrating only. A single animal was found in the adjacent area TA, which contained already more shrubs than CP.
Compared to the widely distributed *C. vagans*, FREIVOGEL (2003) mentioned an uneven distribution of *C. pullus* at Rottensand. During the hottest period of the day, the animals retreated to shaded places and plants above the soil surface, thus avoiding temperatures above a threshold which seems to be lower than in other grasshoppers.

The foil used to mark *C. pullus* with reflecting flags proved to be inappropriate: the material (Scotchlite 3290) was too stiff and the glue loosened, maybe under high temperatures, leading to a loss of the flags. Therefore this methods was abandoned and markings were done further on with colour dots on the pronotum only. Later on, a test of another, much thinner foil (Scotchlite 8850) gave much better results.
Drawbacks of the flag-methods are, that obstacles like large stones, shrubs or dense vegetation reduce the visibility of the markings and the animals may become entangled in the vegetation. It may also be that the predation risk was increased: once a reflector foil was found in a lizards excrement, which had been observed by HOLDEREGGER (1999) in earlier studies, too.

Endangering of the population

KÖHLER (1999) described grasshoppers as mainly vulnerable to demographic extinction and fragmentation. The minimal viable population size of 500 individuals for grasshoppers was proposed by THOMAS (1990) and by KÖHLER (1999), based exclusively on genetic considerations, not including catastrophes and habitat changes in the models. The population at Rottensand lies far below this threshold. Supposably the estimation for a minimal viable population of 500 individuals is too high, as only a small population of less than 40 animals had been observed for a long time before 1997 (pers. comm. G. Carron and P. Werner). Nevertheless the estimated population size of 180 individuals in 2002 was still much higher than the population size in the present study (FREIVOGEL, 2003).

4.2.3 Heteroptera

Generally the distribution of Heteroptera is strongly influenced by climate and vegetation (DOLLING, 1991; CURRY, 1994). The composition of a local heteropteran community seems to depend upon five main characteristics: (1) the micro-climatic characteristics of the site, (2) the vegetation type (3) the season, (4) the presence of prey for predatory species and (5) the influence of human practices (FAUVEL, 1999; CURRY, 1994).
GP1, GP2 and GR differed from the other transects in their true bug composition, however the ecological variables did not have a significant influence on this distribution. The large frequency of species and species numbers in the gravelly plots and grass separated them from the other transects.
Steppes were the habitat for xerophilic true bugs that are adapted to dry and warm places, namley *L. gemellatus*, *R. parumpunctatus* and *C. pudicus*. In the grassland the xero-thermophilic species dominated, e.g. *A. calcaratus*, *A. acuminata* and *S. rhombeus*.
Pentatomidae and Miridae were the most frequent families at the study site. The former were generally most common in semi-natural grasslands, but in the present study they were frequently found in GP2. Miridae prefer herbage as habitat (DOLLING, 1991) and they were mostly observed in the gravelly plots GP1 and GP2, in which most of the true bugs were found. Unlike GA and CP, they contained only a few specimens, maybe because the areas did not contain higher flowering plants.
As for Orthoptera, the habitat requirements of larvae and adults do not differ much. The main season for true bugs is late summer, when they reach the highest number of individuals and species. This peak is connected with the food supply of the host plants. A difference between the maxima might depend on the ripening of seeds of a specific plant and therefore individuals aggregate on the plants, e.g. *E. ornatum* on *E. nasturtiifolium*, which was most frequently found in GP2 and GM.

L. gemellatus belongs to the mediterranean fauna and is generally adapted to dry and warm places. It was very frequent and present in several transects with gravelly soil. A correlation with *S. purpurea* was shown, which grows as a pioneer on gravel. JORIS (2002) and WITSCHI (2001) found *L. gemellatus* only on *C. vallesiaca*, *Artemisia vallesiaca* and *Odontites luteus*.

C. schillingi, a grass-dwelling species, was correlated with *B. vulgaris*. The correlation might be caused by a preference of both organisms for dense grass. *C. schillingi* was frequent in GP1 and in MS. *C. schillingi* correlated positively with the grass *B. erectus*; which had in these two areas its greatest abundance. Surprisingly we found a smaller number of *C. schillingi* in GP2 and GR. Possibly the main population lived in an area next to the transect and the home range overlapped with it. Since no other accordant correlations with specific grasses or the 'proportion of grass' were found, we assume that grass density is of lower importance. WITSCHI (2001) found *C. schillingii* on *C. vallesiaca* and *A. campestris*. A large number of ***Eurydema*** spp. (= larvae) was counted, mostly on Brassicaceae in GP2, especially on *Erysimum rhaeticum* and *E. nasturtiifolium*. WITSCHI (2001) found it on the same plants and also on *Euphorbia sp.*. ***Eurydema oleracea*** was primarily found in the grass. JORIS (2002) found it on the host plants *Peucedanum oreoselinum* and *Brassica sp.*. It was correlated with *R. iracundus* and *C. fuscipinus*. All three species were partly found in the grass.
R. parumpunctatus was highly connected with the plant diversity. WITSCHI (2001) found it on *C. vallesiaca*, *Euphorbia sp*. and on *O. luteus*, JORIS (2002) on *Achillea millefolium* and *Stipa capillata*.

4.2.4 Sphecidae

The occurrence of Spehcidae is restricted to warm summer months (BLÖSCH, 2000) and is determined by the presence of flowers as food source for the imagines and prey as food for the larvae. In addition, appropriate soil conditions for soil-breeders must be available. JÄGER (1995) and ZEHNDER (1996) investigated the digger wasp fauna at Rottensand.
With the exception of a *B. tridens* colony and a number of *P. kirbii*, not many Sphecidae were found at the site. Their presence was rather erratic and the study is merely snap-shot of the digger wasp fauna. Compared to other taxa like true bugs or grasshoppers, Sphecidae are more mobile and have a larger home range. They only appeared in transects and plots for digging nests or feeding their larvae, which happens during a very low percentage of time. Only little seems to be known about the occurrence of multiple generations per year. In species with one generation in this latitude and two in the south, a beginning of a second generation can be observed, if the weather is favourable. This was described for *P. affinis* by FIELD (1993) and it was assumed for *Ammophila sabulosa* by OLBERG (1959); ZEHNDER (1996) could observe a second generation of *A. apicalis* at Rottensand.
All of the recorded species were sand breeders. ***B. tridens***, breeding in loose sand, was the most abundant digger wasp at the site but occurred almost exclusively in a colony in SP2. It has a low

ability to spread, but is frequent in the Rhone valley and in the South of the Alps (BLÖSCH, 2000; DE BEAUMONT, 1964). It did not correlate with 'bare soil', maybe due to the fact that soil types were not distinguished and 'bare soil' comprised sand as well as gravel, blocks or earthy ground**.** It was also recorded at Rottensand by JÄGER in 1994 and by ZEHNDER in 1995. The possibility of a translocation of *B. tridens* is difficult to evaluate, because no studies about this matter are known yet.

P. kirbii had its population maximum in the first half of July. Areas with compact soil were preferred, but on the other hand it was also found at sandy surfaces.

P. affinis occurred where a high plant diversity prevailed. The significance of the negative correlation with *A. campestris* and *C. vallesiaca* remains unclear, as these plants were distributed more or less over the whole site.

4.2.5 Coleoptera

2/3 of the Coleoptera recorded during the observation period were recorded in June. In August only singular specimens were sighted. ***E. lusitanica*** and ***O. flavipes*** were the most frequent beetles at the site. The leaf beetle *E. lusitanica* is univoltine, polyphagous and is known as an occasional pest of grapes (OCETE *et al*., 1996). It feeds on grape mainly of old or abandoned vineyards, especially regrowth after hail or frost damage. Adults emerge in late May and reach peak populations in mid-June.

C. hybrida was seen in spring, disappeared then for some weeks and emerged again in July, in spite of this disjunct appearance in the year of our survey, only one generation per year is known (W. Marggi, pers. comm.). The correlation with of *C. hybrida* with *A. campestris* and *P. nigra* confirmed its preference for sandy areas with pioneer plants. REITTER (1908) described its main habitat as gravel banks on both sides of the Alps. MARGGI (1992) described it as a frequent species in Switzerland.

The blister beetle ***Mylabris variabilis*** occurred at the site from mid-June to July. It was found in heterogeneously structured areas, such as MS, GM, MA and GR. The adults feed on flowers, but their early larvae (triungulins) predate on grasshoppers eggs (NIKBAKHTZADEH, 2004; GREATHAED *et al*., 1994). GREATHEAD *et al*. (1994) considered it as a predator with possibly large impact on grasshoppers.

4.2.6 Myrmeleonidae

The larvae of *M. bore* were found frequently at the site, especially in SP2, where also *B. tridens* and *C. hybrida* were recorded numerously. Its funnels are built in extreme habitats, such as open sandy soils in exposed positions. In Middle Europe *M. bore* inhabits light pine forests (GEPP & HÖLZEL, 1989). The adults are nocturnal and approach light sources. Being a Siberian fauna element, it is thinly distributed over Middle- and Northern Europe; in Switzerland *M. bore* has been detected only in Ticino (pers. comm. C. Monnerat).

4.3 Insects - conservational aspects, conclusions

Because the Pfynwald is a hotspot of biodiversity, a conservation of the whole area, as well as a conservation of rare habitat types (steppes, dynamic river corridor, riverine landscape) is needed. Further, the conservation of rare species is important e.g. xylophagous or steppe insects and pioneers on gravel islands. The most valuable aspects must be priotitised, e.g. species, which are endangered by extinction or those, who are flightless. *C. pullus* is given top priority in protection, as habitat degradation caused its endangering. Three possibilities would enable its survival: (1) habitat management, with constantly improving the habitat quality of the occupied sites, (2) translocation of the population to a new site (gravel plain) or (3) creating a migration corridor to enable *C. pullus* to move itself to the new site. Habitat management (1) includes high costs repeatedly, as it represents a constant battle against the habitat degradation. Translocation (2) bears the risk of extinction at the new site, in case of dispersal of the animals. The migration corridor (3) has a local impact on the surroundings. As the most natural possibility, we suggest the migration corridor. The best solution for its position is an old side channel of the Rhone, which is at the same time also a measure for improving runoff possibilities during future inundations. But the risk must be accepted, that positive measures for *C. pullus* may have negative influence on other rare species. The present investigation aimed at doing an insect inventory along the most probable corridor.
The whole transect revealed to be of high value; thus, where to put the priorities?

Orthoptera 83% of the species at the study site are mentioned in the Red List of Switzerland (THORENS *et al*., 1994), 8 species are threatened by extinction: *C. italicus*, *C. mollis*, *C. vagans*, *O. caerulescens*, *O. germanica*, *P. albopunctata*, *L. punctatissima*, *O. pellucens*. Two species are endangered - *C. pullus* and *S. caerulans*.

The areas GP2, SP1, GM and TA showed a high grasshopper diversity. TA represents a barrier and must be removed in order to open the corridor for *C. pullus*, but in a few years the same zone structure will be reestablished.

Heteroptera For Switzerland no Red List of the true bugs is available yet, but according to the Red List of Germany (JEDICKE, 1997) *Carpocoris pudicus*, *Odontotarsus purpureolineatus, E. ornatum, C. schillingi, R. iracundus* and *Syromastes rhombeus* are endangered. *Rhopalus distinctus* is even highly endangered and *Dicranocephalus agilis* went extinct in parts of Germany. The diversity of true bugs was high in MS and GR, the endangered species occurred mainly in GP1, GP2, MS, GR and SP1 and the most threatened *D. agilis* was also found in GA.

Sphecidae *A. sabulosa* and *T. helveticus* are widespread in whole Switzerland, *P. affinis* in the region of the Alps, *P. kirbii* and *A. apicalis* are common in the Rhone valley and *B. tridens* is prevalent in the Rhone valley, but rare in the Midlands (DE BEAUMONT, 1964). Most digger wasps taken into account were found in SP2, represented by a *B. tridens* colony. Also in MS, SM and CP endangered species were recorded.

Coleoptera According to the Red List of Germany (JEDICKE, 1997) *B. octoguttata* and *Mogulones geographicus* are endangered. *C. varius*, *P. hieroglyphicus* and *Sibinia tibialis* went extinct in some parts of Germany. A high diversity of beetles and some threatened species were found in GM, SM and GR.

Myrmeleonidae In Switzerland only one finding of *M. bore* is known yet. After JEDICKE (1997) *M. bore* went extinct in some parts of Germany or is highly endangered. High numbers of *M. bore* were found in SP2, SP1 and SM.

Summing up these results, is the whole area of high value. Now where to set priorities? Which of the rare species are common at Pfynwald? Which are of high faunistic value and need a protection in similar priority as *C. pullus*?

Orthoptera Steppe species do not represent a problem, as they were all abundant. *S. caerulans* is very mobile and abundant on the near gravel plain. It appears on all suitable sufaces within a short time. *O. germanica* is very rare at Rottensand for microclimatic reasons, but is abundant on the surrounding sunny hills and slopes. But this is all much less important than the protection of *C. pullus*.

Heteroptera The rare true bugs are steppe species and are regularly found in other parts of Rottensand. No special measures need to be carried out to protect them in the corridor track.

Sphecidae The Pfynwald contains a rich digger wasp fauna and the linear structure of the corridor is of neglectable importance for them. Good nesting grounds are available in vicinity, e.g. for *B. tridens*, which is common in colonies over all Rottensand. The loss of the colonies found can be compensated by opening some sandy areas nearby; an artificial translocation of the colonies is not needed. Concerning Sphecidae, there are no reasons forbidding the corridor.

Coleoptera Beetles were found in low numbers and no important parts of populations were recorded. Similar habitats are available at Rottensand.

Myrmeleonidae Several species of Myrmeleonidae are present at Pfynwald (J. Zettel, pers. comm.). No inventory has been carried out so far. Considering the data of CSCF (one entry for Ticino), these colonies have a very high importance, but a very easy solution: translocation of the larvae to nearby sandy places.

Taking all this into account, the corridor track can be accepted, from the point of view of nature conservation (Fig. 11). Technical measure has to be discussed with specialists in the administration of the canton.

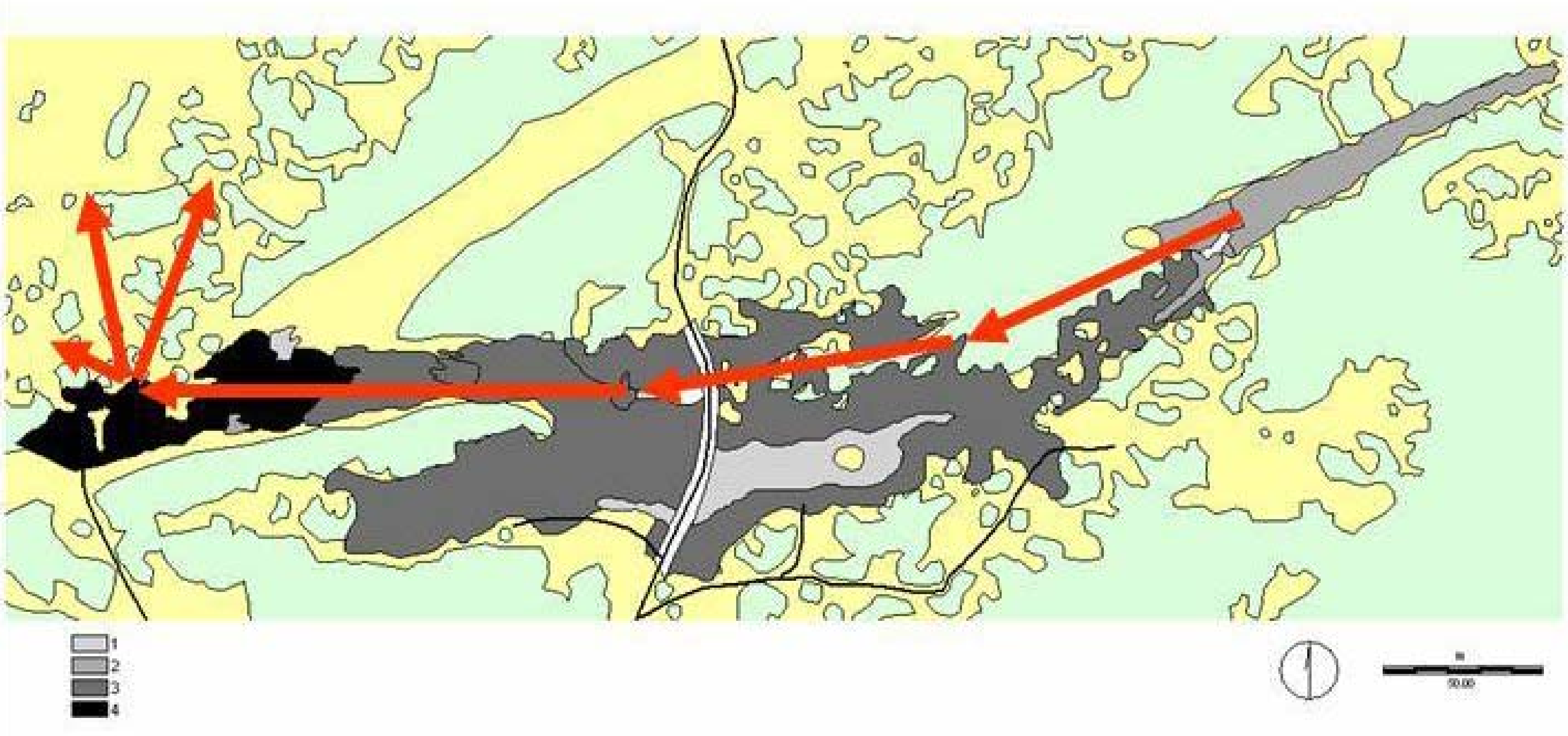


Fig. 11 : Optimal position of the migration corridor and combined diversities of Orthoptera, Heteroptera, Coleoptera and Sphecidae. The basis is the sum of ranks concerning Shannon's (Hs) diversity values and Simpson's Evenness (E). The darker the colour on the map, the higher is the entomological value.

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7. APPENDIX: TABLES

Table 1: Characterization of the zones at the study site.

zone		characteristics	soil					vegetation				
			bare soil (%)	**fine gravel (%)**	**coarse gravel (%)**	**blocks (%)**	**litter (%)**	**moss (%)**	**herbs (%)**	**grass (%)**	**shrubs (%)**	**trees (%)**
sandy patches	**SP**	loose sand patch (grain size < 2 mm), scattered shrubs, trees	0-20	0-20	0	0-20	80-100	0-20	0-20	0-20	0-20	0
gravelly patches	**GP**	fine gravel (0.2- 5 cm) and coarse gravel (5- 50 cm) mixed, area-wide, grass, scattered shrubs and trees	40-80	40-80	0	0	80-100	0	0-20	0-20	0	0
area occupied by *C. pullus*	**CP**	coarse gravel, scattered blocks, mosaic structure, **dense moss cover**, herbs, *Artemisia campestris*	0-20	20-60	20-60	0-20	40-60	40-80	0-20	0-40	0-20	0
gravel with anthropogenic influence	**GA**	compacted gravel, moss, herbs, all < 30 cm height	40-60	20-40	0	0-20	40-80	0-20	40-60	0-20	0	0
forest	**-**	mosaic of moss, blocks, a lot of dead plant material, grass, dense **trees** (> 1,50 m), *Pinus sylvestris*	0	0-40	0-20	40-60	0-20	0-20	0-20	20-60	0-20	80-100
transition area	**TA**	some blocks, coarse gravel, mosaic, partly moss cover, **shrubs**	0-20	20-60	0-20	0-20	40-60	40-60	0-20	20-60	20-60	0-20
grass dominated area	**GR**	dense **grass** cover	0-20	0-20	0	40-60	0-20	0-20	0-20	80-100	20	0
mosaic with shrubs	**MS**	coarse gravel, partly moss, herbs, grass, shrubs, scattered trees	0-20	0-20	0	20-40	0-20	0-20	0-20	80-100	20	0-20
gravelly mosaic	**GM**	mosaic of gravel patches, shrubs, grass and herbs	60-80	0-20	0	20	40-80	0-20	20-40	0-40	0-20	0-20
sandy mosaic	**SM**	gravel mixed with sandy patches, scattered trees, shrubs	40-60	0-20	0	20	60-80	0-20	0-20	0-20	20	0-20
floodplain	**-**	mixed gravel sizes, sandy areas; no grass, but shrubs, scattered trees, only few herbs	40-80	20-60	0-20	0-20	60-80	0-20	0-20	0	20	0-20

Table 2: Mean values of the plant cover in the transects and plots, using classes 1 - 4. Class 0- 1 = 1- 5 % plant cover (white), class 1- 2 = 6- 25 % plant cover (light grey), class 2- 3= 26- 50 % plant cover (dark grey) and class 3- 4= 51- 75 % plant cover (black). Values higher than 75 % were not reached. MS* was not taken into account for comparisons of transects. The species numbers of SP1- 3 and GP1- 2 were averaged to obtain comparable values for the sandy and gravelly zones SP and GP, respectively.

	SM	**GM**	**MS**	**GR**	**GA**	**TA**	**CP**	**MS***	**SP1**	**SP2**	**SP3**	**GP1**	**GP2**
woody plants													
Berberis vulgaris	0.1	0.3	0.5						0.4			0.8	
Betula pendula		0.1		0.4		0.3	0.1		0.3		0.2	0.8	
Hippophaë rhamnoides	0.3	0.2	0.8			0.1							0.8
Juniperus communis			0.3	0.2									
Ligustrum vulgare			0.2										
Pinus sylvestris		0.3			0.4	0.1		0.4	0.8	0.3	0.2		0.8
Populus alba						0.8	0.4					0.2	
Populus nigra	1.3	0.3			0.8	0.8	0.8	0.8		0.4		0.3	1.8
Quercus pubescens			0.1										
Salix elaeagnos	0.8	0.1				0.3	0.8				0.2	0.8	0.4
Salix purpurea	0.8	0.8				0.3	0.3				0.3		0.8
Sorbus aria			0.1										
herbs													
Acinos arvensis	0.8	0.8											0.3
Artemisa campestris	1.6	2.2	1.2	1.4	1.9	1.5	2.8	1.8	2.3	3.3	2.0	3.0	2.0
Artemisia vallesiaca	0.8												
Astragalus onobrychis	0.8	1.2	1.3	1.8	1.9	1.8	1.4	2.0	1.5	2.3	2.3	0.2	0.8
Centaurea vallesiaca	0.3		0.3	0.8		0.1		0.8	1.0				
Cirsium arvense	0.1												
Echium vulgare	0.1	0.4											0.3
Epilobium dodonaei		0.3	0.8	0.4									
Epilobium fleischeri			0.4										
Erucastrum nasturtiifolium		0.8	0.4									0.2	0.9
Erysimum rhaeticum			0.4	0.4	0.1	0.1	0.2						0.2
Euphorbia cyparissias				0.4				0.4					
Euphorbia seguieriana	0.2	0.3	0.9	0.6	0.3	1.4	0.5	0.5	0.7			0.3	0.9
Galium mollugo		0.4	0.4	0.4			0.2		0.5				0.8
Gypsophila repens	0.4		0.8			0.8	0.8	0.8					
Helianthemum nummularium		0.4	0.3	0.6	0.6	0.8		0.5				0.8	
Hepatica triloba					0.8								
Hieracium piloselloides		0.8	0.1		0.6	0.2		0.4			0.2	0.2	0.8
Hippocrepis comosa									0.8				0.2
Melampyrum pratense						0.8							
Odontites lutea			0.1		0.3		0.8						
Petrorhagia saxifraga	0.4				0.5	0.3	0.3	0.3				0.3	
Peucedanum oreoselinum	0.8				0.4								0.8
Potentilla pusilla					0.4							0.8	
Scabiosa triandra	0.4		0.4	0.3			0.8		0.7				

Senecio sp.						0.4							
Silene otites				0.4	0.8						0.5		
Solidago virgaurea		0.4										0.3	0.8
Teucrium montanum					0.1							0.3	0.2
Thymus serpyllum	0.2		0.8		0.5	1.3	1.1	0.3				0.4	
Thymus sp.			0.8		0.3	1.0	0.8	0.3					
Verbascum thapsus	0.3												
Viola sp.												0.8	
grasses													
Agropyron pungens										0.3			
Bromus erectus	0.6	0.6	1.7	0.5	0.4	0.4	0.2	0.8	0.8	0.4	0.8	1.0	0.5
Calamagrostis epigejos	0.8	0.3	0.3									0.5	0.5
Festuca ovina	0.2	0.3		0.8									
Festuca valesiaca	0.4		0.4	0.1	0.1	0.3	0.4	0.1			0.3	0.3	0.2
Koeleria vallesiana	0.4	0.4	0.2	0.4	0.3	0.3	1.0	0.5	0.8	0.2	0.8		0.2
Stipa pennata	0.8	0.5	0.9	3.5	0.3	1.9	1.0	2.9		0.8	3.7	0.2	0.9
number of species	**22**	**21**	**24**	**17**	**17**	**20**	**17**	**14**	**12**	**7**	**11**	**16**	**20**
										10		**18**	
fraction of bare soil	**80**	**52**	**23**	**23**	**79**	**42**	**36**	**21**	**82**	**93**	**88**	**92**	**93**

Table 3: Diversity of Orthoptera; Hs= Shannon-Index, E= Evenness (Simpson) and D= dominance (frequency of the dominant species in a community). The dominant species in all transects and plots was *C. italicus*.

	n species	H_s	E_s	D
GP2	9	2.551	1.03	0.33
SP1	8	2.461	0.99	0.31
GM	8	2.362	0.95	0.41
TA	9	2.292	0.92	0.41
SM	8	2.256	0.91	0.39
CP	8	2.237	0.90	0.37
GP1	7	2.212	0.89	0.32
GR	7	2.125	0.86	0.69
MS	6	2.020	0.81	0.42
GA	7	1.828	0.74	0.41
SP3	5	1.736	0.70	0.59
SP2	6	1.717	0.69	0.50

Table 4: Abundance of *C. italicus* at the 6 visits, with numbers of individuals calculated for 25 m^2. The maximal abundance was found in GR, followed by TA and SP3.

transects	**June 1**	**June 2**	**July 1**	**July 2**	**Aug 1**	**Aug 2**	**Total**
SM		2.5		2.9	0.4	2.5	8.3
GM		5.0	4.2	4.2	2.9	0.8	17.1
MS	0.4	3.3	1.7	2.9	5.8	0.4	14.6
GR		13.3	9.2	7.5	5.8	0.8	36.6
GA	2.1	7.5		2.1	1.3		12.9
TA	1.3	7.5	4.6	6.3	0.4	2.9	23.0
CP	0.8	7.5	2.5	3.8	2.5	0.8	18.0
MS*	0.4	4.6	6.3	2.5	1.3	2.1	17.2
SP1		2.0	4.0		3.0		9.0
SP2	2.0	4.0	1.0		3.0	4.0	14.0
SP3	4.0	4.0	2.0	2.0	4.0	4.0	20.0
GP1	1.0	2.0	4.0	6.0		4.0	17.0
GP2	1.0	4.0	8.0	4.0			17.0
total	**13.0**	**67.2**	**47.5**	**44.2**	**30.4**	**22.4**	**224.7**

Table 5a: Wainstein indices of Orthoptera in transects. Comparisons of plots were omitted, because of different shapes and sizes.

	SM	GM	MS	GR	GA	TA	CP
SM		44.8	39.2	32.2	**60.3**	34.9	39.8
GM			46.2	42.8	39.3	**53.4**	**51.5**
MS				46.0	49.3	31.3	37.5
GR					49.8	**51.6**	46.7
GA						47.8	42.6
TA							**77.6**
CP							

Table 5b: Wainstein indices of Heteroptera in transects. Comparisons of plots were omitted.

	SM	GM	MS	GR	GA	TA	CP
SM		13.6	2.4	0.7	0.0	0.0	1.3
GM			20.9	0.6	0.0	1.3	1.1
MS				11.5	0.0	0.8	0.4
GR					0.0	0.0	0.0
GA						0.0	0.0
TA							0.0
CP							

Table 5c: Wainstein indices of Sphecidae in transects. Comparisons of plots were omitted.

	SM	GM	MS	GR	GA	TA	CP
SM		5.0	**36.2**	25.0	18.8	12.5	22.9
GM			22.5	8.3	24.5	**33.3**	25.0
MS				20.0	**47.9**	12.5	26.7
GR					**44.1**	25.0	11.1
GA						16.7	8.3
TA							**44.4**
CP							

Table 5d: Wainstein indices of Coleoptera in transects. Comparisons of plots were omitted.

	SM	GM	MS	GR	GA	TA	CP
SM		3.8	5.0	0.7	8.3	9.5	1.7
GM			5.5	2.6	1.5	3.1	5.9
MS				3.4	8.2	2.6	9.6
GR					3.9	1.0	0.8
GA						13.3	2.1
TA							2.9
CP							

Table 6: Spearman correlation coefficients (rho) and significance (p) of Heteroptera with ecological variables and reciprocal Heteroptera species. Percentages of ecological variables = coverage of the according variable. Insignificant values are not shown.

		ecological variables				Heteroptera										
		n plant species	**bare soil**	**woody plants**	**herbs**	*Adelphocoris lineolatus*	*Lygus gemellatus*	*Aelia acuminata*	*Carpocoris fuscispinus*	*Carpocoris pudicus*	*Dolycoris baccarum*	*Rhynocoris iracundus*	*Neottiglossa sp.*	*Stagonomus bipunctatus*	*Alydus calcaratus*	*Odontotarsus purpureolineatus*
Aelia acuminata	rho				0.581											
	p				0.037											
Dolycoris baccarum	rho							0.628								
	p							0.022								
Eurydema oleracea	rho								0.817			0.817		0.613		
	p								0.001			0.001		0.026		
Alydus calcaratus	rho		-0.566	0.592				0.636			0.628					
	p		0.044	0.033				0.019			0.022					
Camptopus lateralis	rho					0.677				0.677				0.677		
	p					0.011				0.011				0.011		
Chorosoma schillingi	rho								0.612			0.612				
	p								0.026			0.026				
Rhopalus parumpunctatus	rho	0.700					0.562									
	p	0.008					0.046									
Odontotarsus purpureolineatus	rho							0.605			0.626				0.605	
	p							0.029			0.022				0.029	
Eurygaster maura	rho					0.613				0.613			0.736			
	p					0.026				0.026			0.004			
Syromastes rhombeus	rho							0.628							0.628	0.626
	p							0.022							0.022	0.022

Table 7: Spearman correlation coefficients (rho) and significance (p) of Heteroptera with plants. Insignificant values are not shown.

		Berberis vulgaris	*Betula pendula*	*Pinus sylvestris*	*Salix purpurea*	*Centaurea vallesiaca*	*Erysimum rhaeticum*	*Euphorbia seguieriana*	*Bromus erectus*	*Thymus serpyllum*
Koeleria vallesiana	rho					0.836				
	p					0.038				
Thymus serpyllum	rho							0.782		
	p							0.038		
Thymus sp.	rho									0.949
	p									0.014
Lygus gemellatus	rho				0.933					
	p				0.007					
Aelia acuminata	rho						0.849			
	p						0.033			
Chorosoma schillingi	rho	0.975	0.813	0.666					0.556	
	p	0.005	0.026	0.044					0.049	

<u>8. APPENDIX: FIGURES</u>

Fig. 1: Floodplain, representing an optimal habitat for *C. pullus*.

Fig. 2: *Chorthippus pullus* male marked with a reflective flag at the hind femur and with a colour dot on the pronotum.

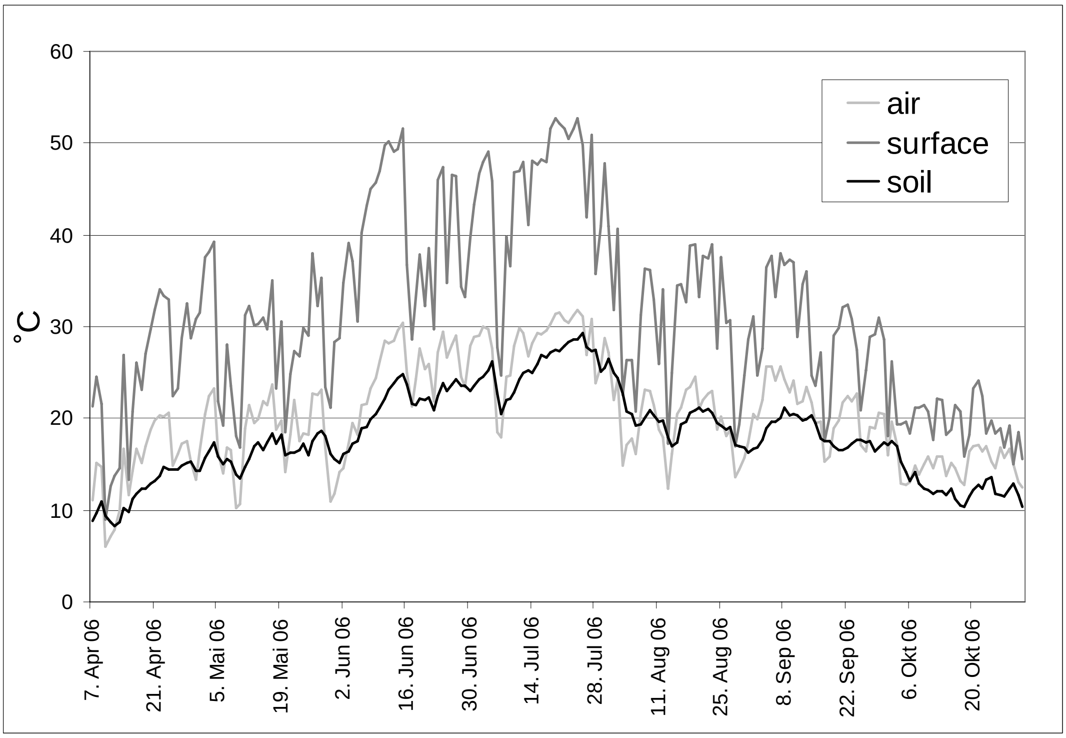

Fig. 3: Daily means of temperature (7 a.m. to 7 p.m.) at Rottensand, Pfynwald: air (2 m above surface), surface and soil (5 cm below surface).

Fig. 4: CP, habitat of the relic population of *C. pullus*.


Fig. 5a: SM, mosaic structure with sandy soil.


Fig. 5b: GA, gravelly soil with anthropogenic influence.


Fig. 5c: GM, mosaic structure with gravelly soil.


Fig. 5d: GR, dense grass.


Fig. 5e: MS, mosaic structure with grass and shrubs .


Fig. 5f: TA, transition area between CP and forest. Intermediate density of vegetation.

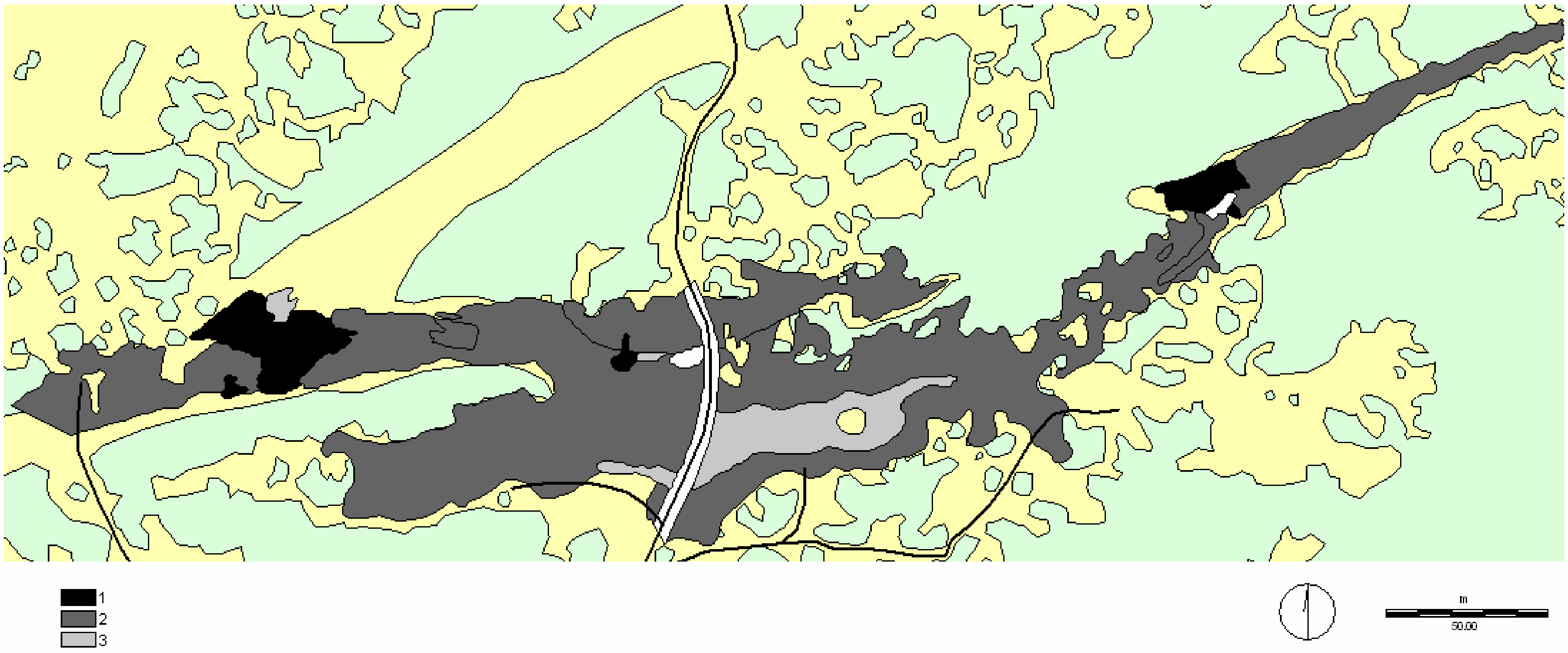

Fig. 11: Orthoptera diversities at the study site. The diversity index of Shannon (Hs) was used. The darker the zone, the more diverse the grasshopper fauna. The lowest diversity (3) Hs ranged from 1.7 - 2.0, the middle Hs (2) from 2.0 – 2.3 and the highest (3) from 2.3 – 2.6.

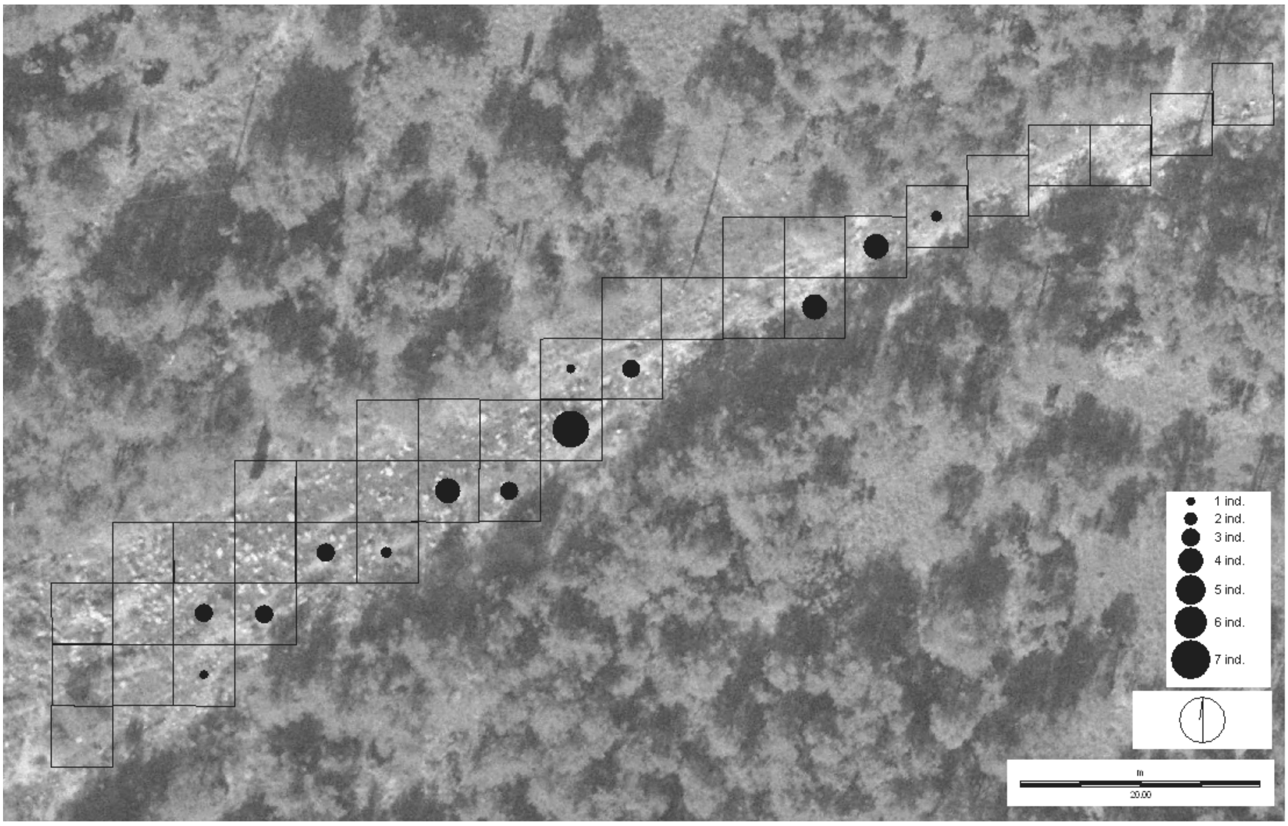

Fig. 12: Distribution of *C. pullus* in CP at the first searching during the day (15.7.2006; n = 40).

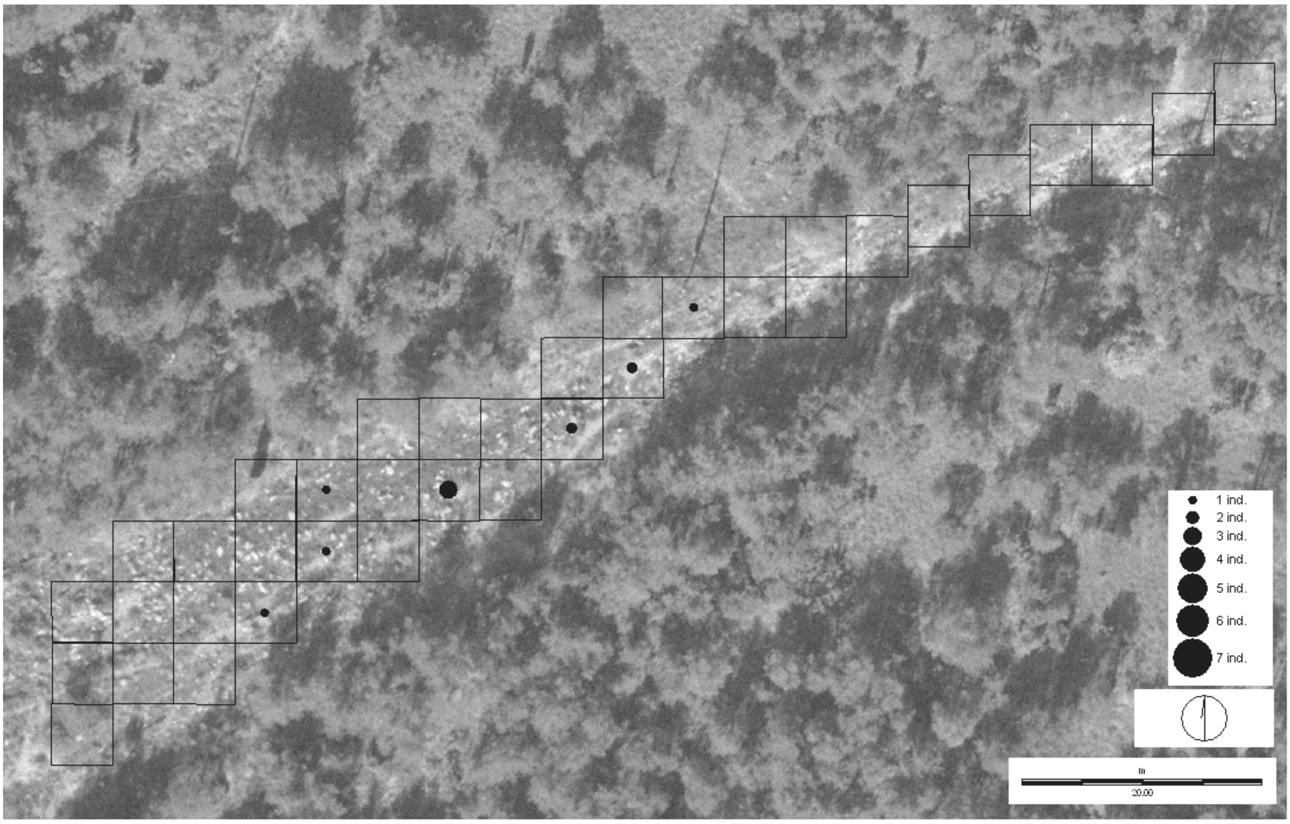

Fig. 13: Distribution of *C. pullus* in CP at the second searching during the day (21.7.2006; n = 11).

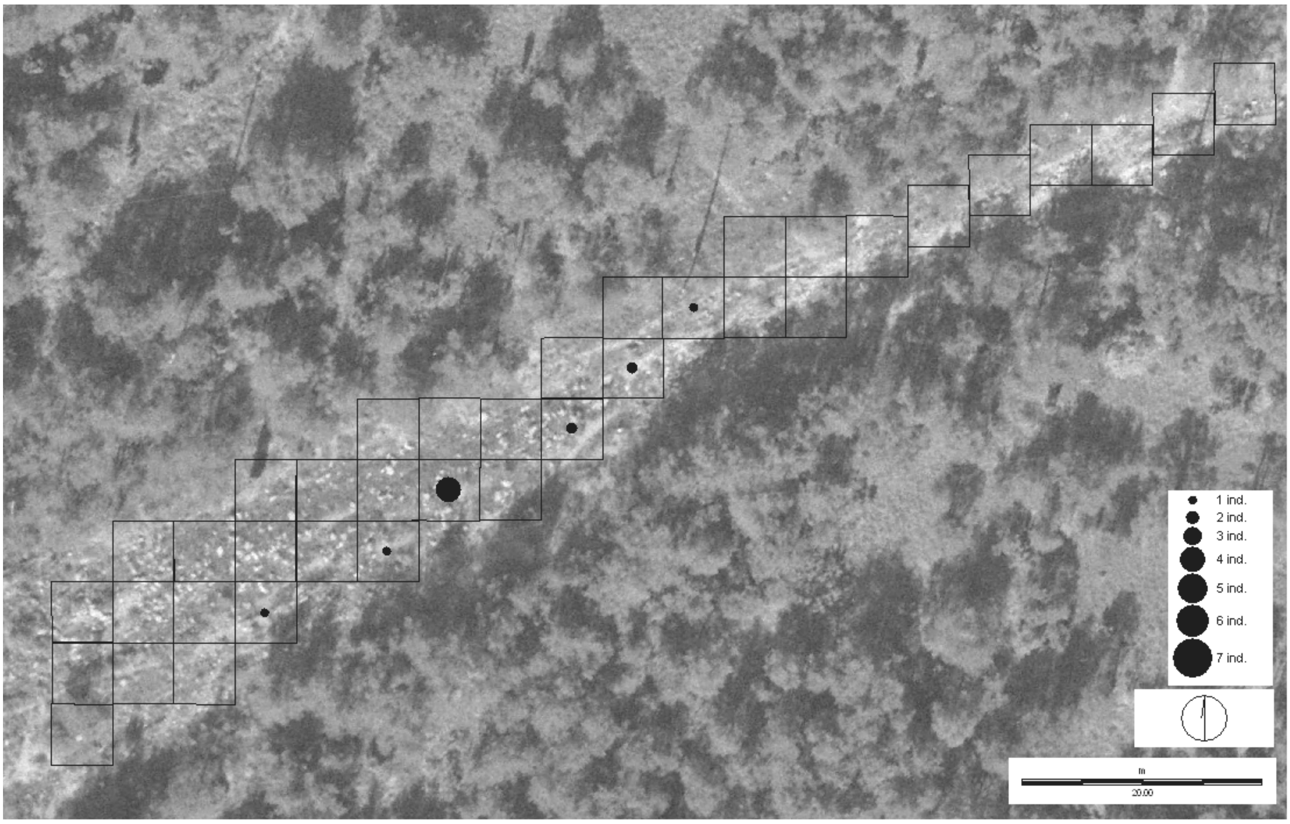

Fig. 14: Distribution of *C. pullus* in CP at the third searching during the day (28.7.2006; n = 11).

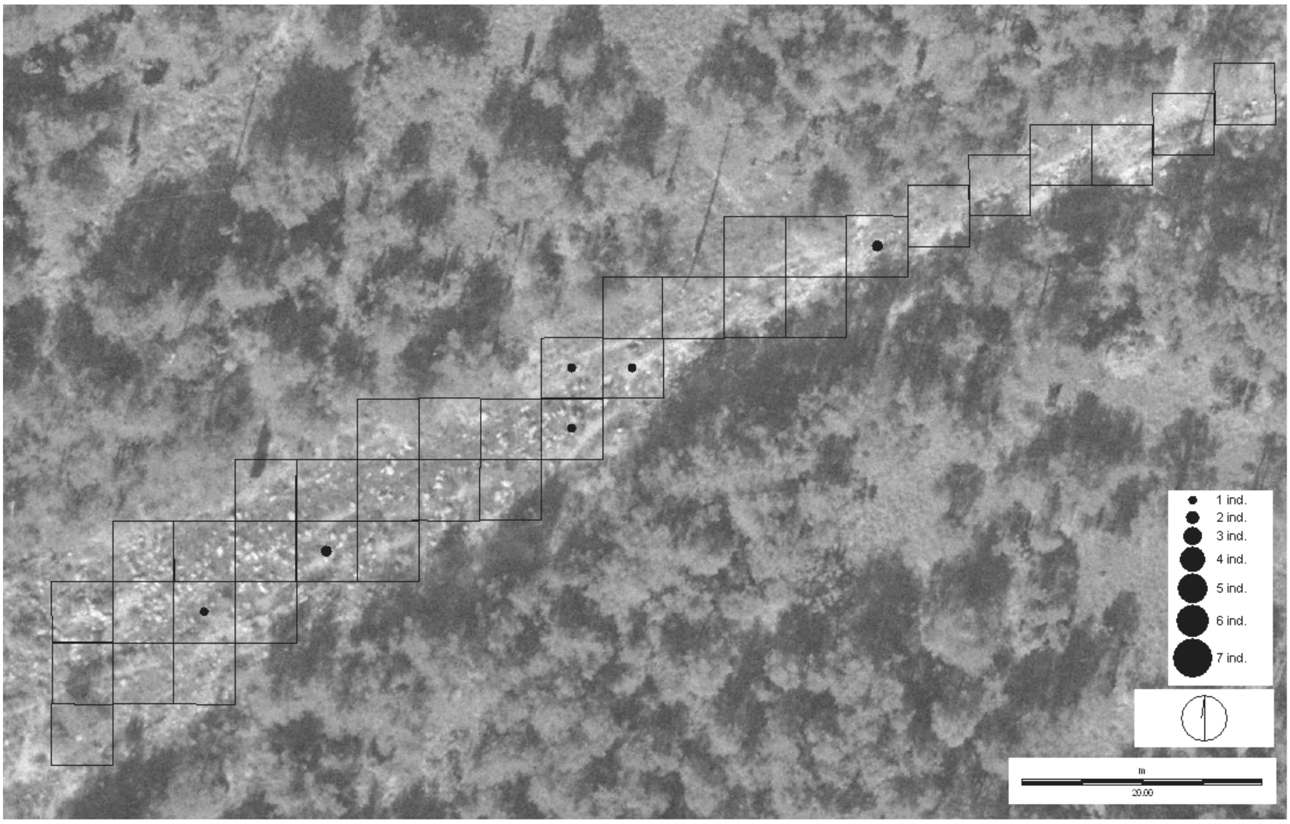

Fig. 15: Distribution of *C. pullus* in CP at the fourth searching during the day (9./ 10.8.2006; n = 8).

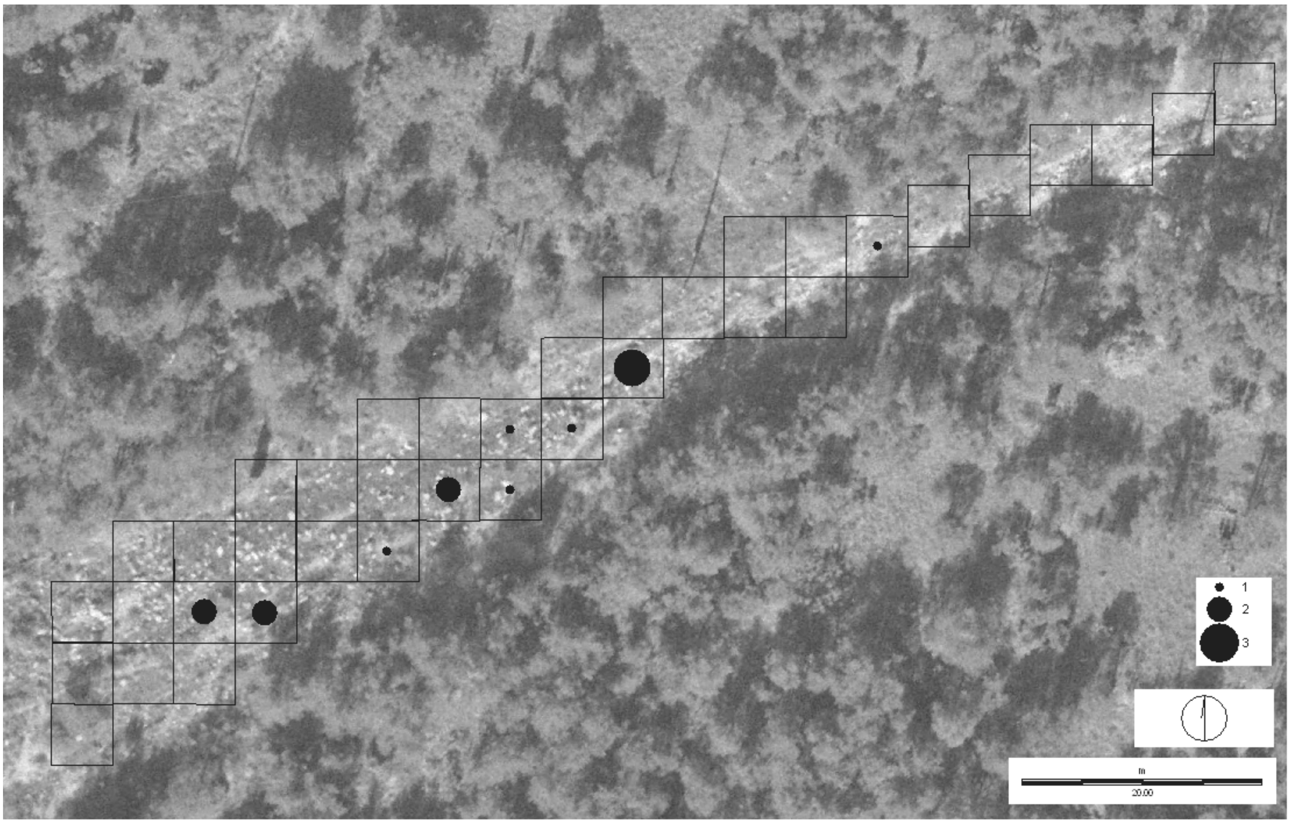

Fig. 16: Mean distribution of *C. pullus* in CP at the night searchings from 20.7.2006 to 4.8.2006.

Fig. 17: Heteroptera diversities at the study site. The diversity index of Shannon (Hs) was used. The darker the zone, the more diverse the true bug fauna. The lowest diversity (3) contained Hs from 1.2 – 1.8, the middle Hs (2) ranged from 1.8 – 2.4 and the highest (3) from 2.4 – 3.0. No Hs was calculated for the white coloured zones, since the catch numbers were to low to estimate the diversity.

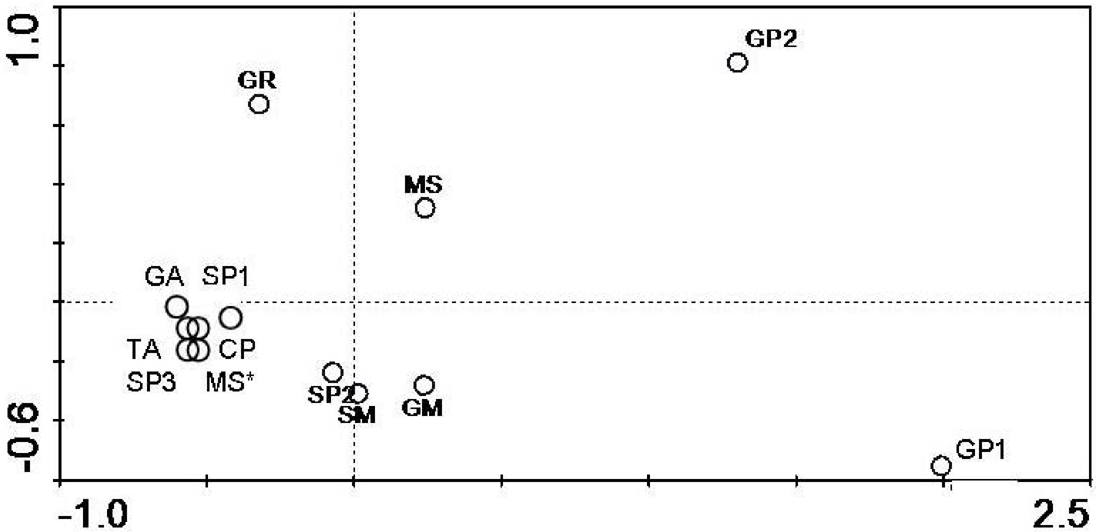

Fig. 18: PCA; similarity of the transects concerning species composition and abundance of Heteroptera (axes: 0.601; 0.137). The two axes together explain 73 % of the variance of the data.

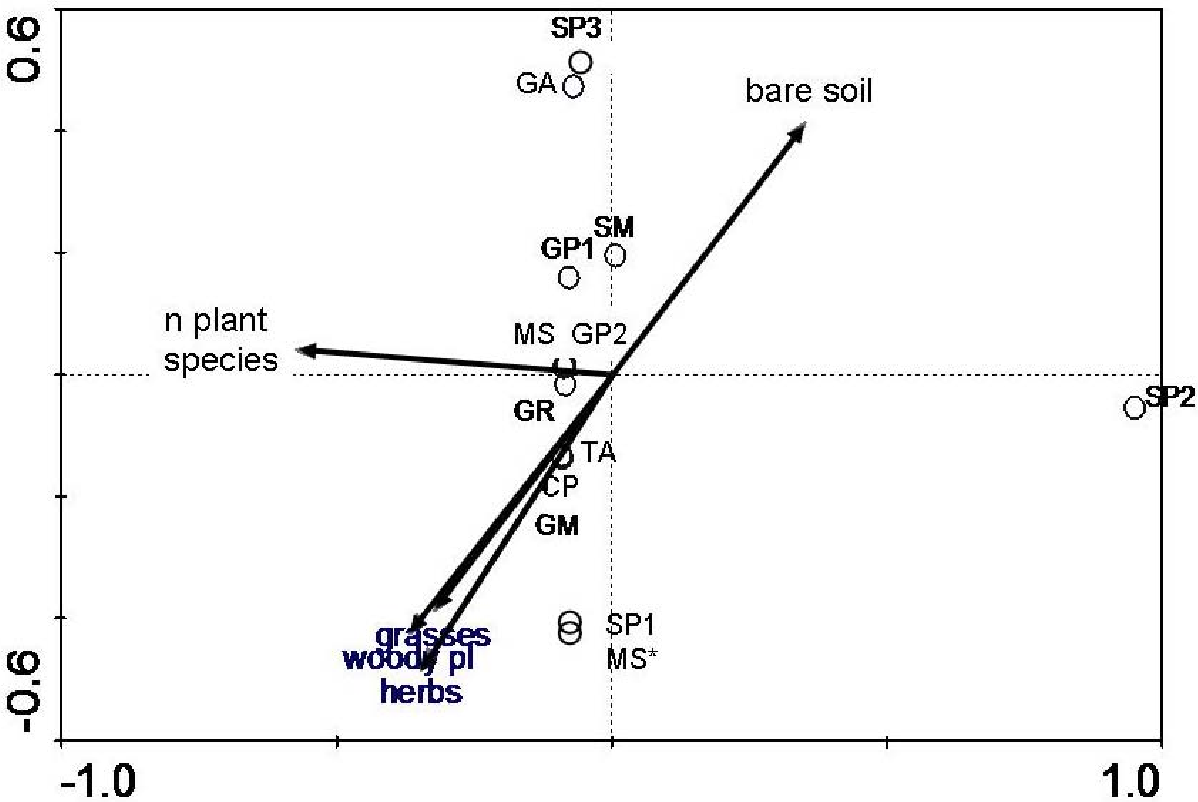

Fig. 19: RDA; similarity of the transects concerning species composition and abundance of Sphecidae (axes: 0.834; 0.106). The two axes together explain 94 % of the variance of the data. The supplementary variables 'bare soil', 'number of plant species', 'grasses', 'woody plants' and 'herbs' were included.

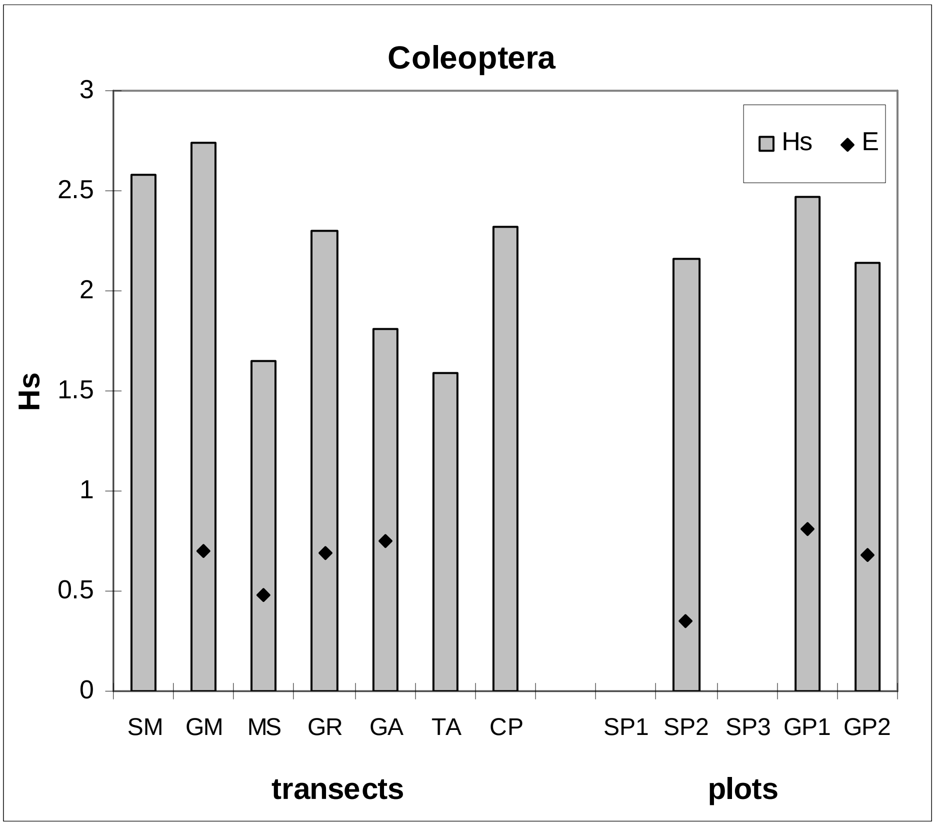

Fig. 20: Shannon's diversity indices Hs and Evenness E (Simpson) for Coleoptera. Hs or E were omitted in some transects or plots, because only a small catch number was recorded.

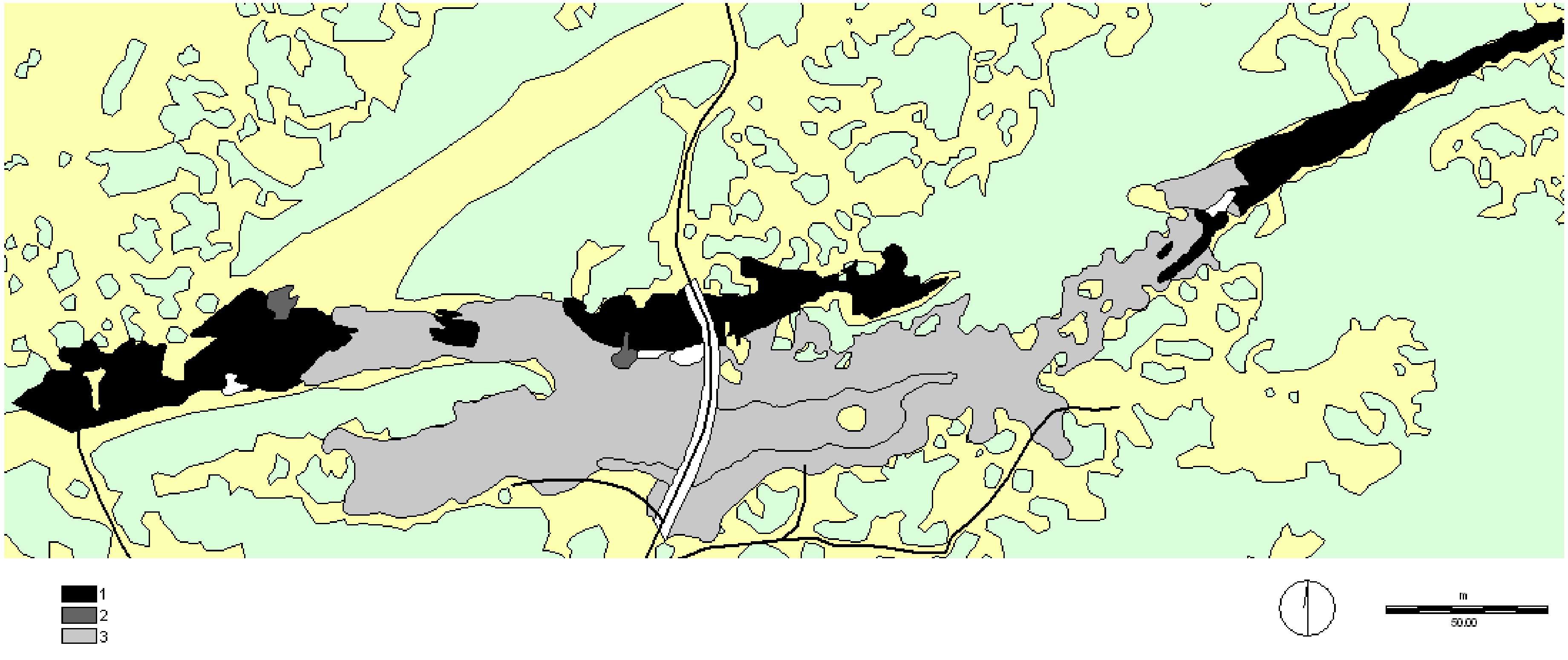

Fig. 21: Coleoptera diversities at the study site. The diversity index of Shannon (Hs) was used. The darker the zone, the more diverse the beetle fauna. The lowest diversity (3) contained Hs from 1.5 – 1.9, the middle Hs (2) ranged from 1.9 – 2.3 and the highest (3) from 2.3 – 2.7. No Hs was calculated for the white coloured zones, since the catch numbers were to low to estimate the diversity.

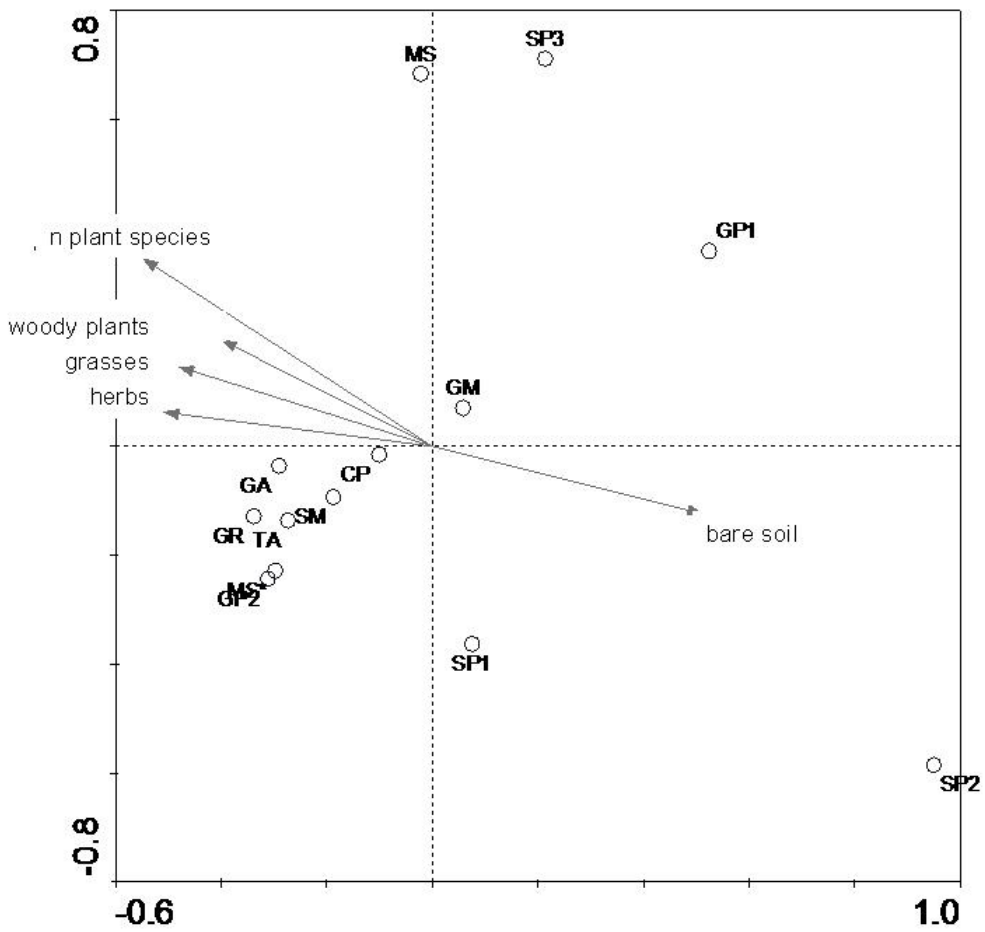

Fig. 22: RDA; similarity of the transects concerning species composition and abundance of Coleoptera (axes: 0.356; 0.260). The two axes explain together 62 % of the variance of the data.