Habitat management in the xeric steppes of Pfynwald (VS, CH): What will be the influence of grazing on insects (Sphecidae, Orthoptera and Heteroptera)?

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Zusammenfassung

Das Ziel dieser Studie war die Erfassung des momentanen Zustandes eines ausgewählten Gebietes im Rottensand, Pfynwald (VS, Schweiz), welches in einem zukünftigen Beweidungsexperiment mit Rindern verwendet werden soll.

Es wurden in einer Trockensteppe zwei nebeneinander liegende Flächen definiert und jede in Quadrate à 5x5 Meter unterteilt. Die Pflanzendeckung war auf beiden Flächen ähnlich, wobei Moos auf Fläche B signifikant häufiger vorkam als auf Fläche A (29% zu 11%), jedoch auf Fläche A mehr mineralische Bodenoberfläche vorhanden war als auf Fläche B (46% zu 12%).

Die Erfassung der ausgewählten Indikatorarten (Sphecidae, Orthoptera und Heteroptera) erfolgte zwischen Ende Juni und Anfang September 2004.

In Bezug auf die Sphecidae wurden 3 Taxa erfasst (*Ammophila*, *Prionyx* und *Sphex*), welche für den Nestbau auf kompakten Sand angewiesen sind. Alle vorkommenden Orthoptera (4 Ensifera, 7 Caelifera und 1 *Mantis* Art) wurden mit Bezug auf die verschiedenen Oberflächenparameter aufgenommen. Von den Heteroptera wurden insgesamt 40 Arten beobachtet und als Indikatorarten für die Vegetationszusammensetzung verwendet.

Entgegen der Erwartungen wurden die Sphecidae individuenmässig zahlreicher und der Nestbau häufiger auf Fläche B als auf Fläche A beobachtet (insbesondere gültig für *Prionyx kirbii*), obwohl signifikant weniger sandige Bodenoberfläche vorhanden war (2% zu 14%). Die wichtigsten Blütenpflanzen stellten *Thymus praecox* und *Asperula aristata* dar.

Von den Orthoptera wurden auf Fläche A mehr Individuen beobachtet als auf Fläche B. Anhand einer durchgeführten Canonical Correspondence Analysis (CCA) konnte auf Fläche A im Gegensatz zu Fläche B eine klare Auftrennung der Arten auf ihre bevorzugten Oberflächenparameter aufgezeigt werden. Die Anwesenheit der Arten wird beeinflusst von der Struktur und der Dichte der Vegetationsdeckung sowie dem Vorhandensein von mineralischer Bodenoberfläche, welche eine wichtige Rolle für seltene und xero-thermophile Arten spielt (z.B. *Sphingonotus caerulans*).

Insgesamt mehr Heteroptera-Arten und -Individuen wurden auf Fläche B vorgefunden. Die am häufigsten vertretenen Familien waren die Pentatomidae und Lygaeidae. 40% der Individuen wurden auf der für sie wichtigsten Wirtspflanze *Centaurea vallesiaca* beobachtet.

Zum Schutz der Artenvielfalt sowie des Artenreichtums der Pflanzen und Insekten und zur Erhaltung des Steppenhabitates (Gefahr der Verbuschung und das Überwachsen der ehemals sandigen Flächen mit einer Moosschicht), werden Beweidungsexperimente als Pflegemassnahme in Betracht gezogen.

Summary

The aim of this study was to characterize the present state of a defined area in the Rottensand, Pfynwald (VS, Switzerland), which will be used in a planned grazing experiment with cattle.

Two adjacent sites of dry steppe were chosen, each being subdivided into 30 plots of 5x5 metres. The vegetation, its abundance and the composition of the soil surface were recorded. The plant cover was similar on both sites; moss was significantly more abundant on site B than on A (29% and 11%, resp.), mineral soil covered more surfaces on site A than on site B (46% and 12%, resp.).

Sampling of selected indicator species (Sphecidae, Orthoptera and Heteroptera) was carried out between end of June and beginning of September 2004.

From the Sphecidae 3 of the taxa depending on compacted sand soil for nesting were monitored (*Ammophila*, *Prionyx* and *Sphex*). All occurring Orthoptera (4 Ensifera, 7 Caelifera and 1 Mantid species) were recorded according to the different soil surface parameters. From the Heteroptera, 40 species were observed and used as indicator species for vegetation composition.

In contrast to the expectation, the Sphecidae were more numerous and nesting behaviour was more frequently observed on site B than A (mainly true for *Prionyx kirbii*), in spite of the significantly smaller sand surface available (2% and 14%, resp.). The most important flowering plants were *Thymus praecox* and *Asperula aristata*.

From the Orthoptera more individuals were monitored on site A than B. A Canonical Correspondence Analysis (CCA) showed a clear correlation of the species with their preferred soil surface parameters. The presence of the species is influenced by the structure and density of the vegetation cover as well as the occurrence of mineral soil surface, which is important for some rare and xero-thermophilic species (e.g. *Sphingonotus caerulans*).

More Heteroptera species and individuals were collected on site B. Most abundant families were the Pentatomidae and the Lygaeidae. 40% of the individuals were observed on *Centaurea vallesiaca,* the most important host plant.

In order to maintain the open steppe habitat (reducing the growth of woody plants and removing the moss cover on the former sandy soil surface) grazing experiments will be carried out in the near future.

1. Introduction

Numerous species, which disappeared from the other parts in Switzerland at the end of the last concise climate change, have survived in the Valais (Switzerland) due to its continental climate. Until today, the arid local climate has enabled the survival of the typical flora of xeric steppe habitats in the driest areas (BILLE & WERNER, 1986). Therefore the xeric steppes of the Valais show a kind of a relict-flora (WERNER, 1994), resulting in a high richness in special forms (BILLE & WERNER, 1986).

The value of such areas lies in the characteristic of the mediterranean elements of flora and fauna as well as offering a habitat for many rare and endangered species (BRECHTEL *et al.*, 1995).

The Rottensand, which is part of the nature reserve Pfynwald, is situated between Susten/Leuk and Sierre. It is a region with a unique character in Switzerland consisting of different succession stages and zonation types (e.g. pine forests, xeric steppes).

In earlier times, an important side arm of the Rhone was flowing through the Rottensand. After a severe flood in 1860, constructions of dams along the river began (BILLE & WERNER, 1986; WERNER, 1985). As a result of these dam constructions, the Rottensand was separated from the Rhone and the pine forest started to extend. The former dominant steppe areas were reduced and are suffering nowadays from bush encroachment and a dense moss layer covering the former sandy soils. To conserve these special habitats, grazing is one of the options of a habitat management.

The aim of this study was to collect data as a basis for comparisons after grazing experiments with different domestic animals.

In a defined area in the Rottensand the present state of two adjacent xeric steppe sites was investigated. Selected indicator species (Sphecidae, Orthoptera and Heteroptera) were sampled, the composition of the vegetation (species and abundance) and the soil surface were recorded.

Each of the selected insect group was chosen as an indicator for specific habitat parameters:

Sphecidae: for the soil surface parameter sand. Especially with regard to the taxa *Ammophila* and *Prionyx*, which are known to prefer compact sand as nesting places (BROCKMANN, 1985; HAGER & KURCZEWSKI, 1986; JÄGER, 1995; OLBERG, 1959).

In addition, many digger wasp species are specialized with regard to prey for their larvae. Therefore they are good indicators for open soil combined with vegetation as food source of their prey species (BLÖSCH, 2000; ZEHNDER & ZETTEL, 1999).

Orthoptera: for soil surface parameters. They have – apart from some vagile species or those with a wider habitat preference – a large indicator value for special habitats. As numerically small group they are good manageable and most species (e.g. rare and the sporadically occurring species) can be determined easily (HARZ, 1980).

Heteroptera: were chosen in connection with the vegetation composition. They live in many different habitats and are relatively easy to sample. Many of the mostly phytophagous species are bound to specific host plants. Some are generalists, with an ability to shift from one feeding type to another (in particular from zoophagy to phytophagy), while others are specialists (e.g. monophagous) (FAUVEL, 1999). Thus their occurrence is correlated with diverse and highly structured vegetation (OTTO, 1991). The larval stages and the adults live in the same habitat (MORRIS, 1979), and both show a sensitive reaction to habitat changes (OTTO, 1996). The richness of the bug fauna strongly correlates with the total insect diversity, showing that they are good indicators for the whole biodiversity of a certain habitat (DUELLI & OBRIST, 1998).

In regard to future grazing experiments, numerous aspects should be considered. Grazing can be realized by various herbivores (e.g. sheep, goats, donkeys, horses, llamas, different breeds of cattle), in different seasons, for different duration, with different numbers of animals, resulting in different impacts on plants and insects.

2. Material and methods

2.1 Research area and study sites

The research area was located at the Rottensand in the nature reserve of the Pfynwald. This area is situated between Susten/Leuk and Sierre in central Valais (Switzerland).

The region is characterized by its continental-central alpine climate and dryness. Summer months are hot; the period with lowest rainfall is from March through July. Winter months are cold, and a large part of the left riverside remains in the shadow of the Gorwetsch mountain. There exist great daily and annual temperature fluctuations, and regular westerly winds intensify the effect of aridity (BILLE & WERNER, 1986; WERNER, 1985).

In the Rottensand different habitats are present, especially the xeric steppes. WERNER (1985) described the vegetation of the xeric steppes as Stipo–Poion carniolicae, which is dominated by the Poaceae *Stipa pennata* and *Stipa capillata*.

The steppes are a habitat for many rare and endangered species. Different plant species (e.g. *Centaurea vallesiaca*, *Ephedra helvetica*, *Telephium imperati*) are present, which are rarely found outside the central Valais, many of them with mediterranean characteristics (BRECHTEL *et al*., 1995; WERNER, 1985).

The selection of the two study sites was made using aerial photographs (Fig. 1). Important characteristics were the presence of sand and gravel on site A, and the presence of a dense moss cover on site B. The sites where subdivided into 30 plots of 5x5m.

2.2 Habitat parameters

2.2.1 Vegetation

From May 10th to 19th, all herbs and shrubs were determined after HESS *et al*. (1991), LAUBER & WAGNER (1998a & b) and SCHAUER & CASPARI (1993) (Tab. 2a and 2b) the nomenclature followed LAUBER & WAGNER (1998a). From the grasses only *Stipa pennata* was identified, the others were specified as grasses sp. Moss was not considered as vegetation, but used as a surface parameter. In each plot the percentage of the cover of each plant species was estimated and transformed into classes (12 total) (Tab. 1), which followed the method of BRAUN-BLANQUET (1964) but with an expansion in order to realize more details.

During the whole sampling season, the flowering period was monitored for all plant species (Tab. 3).

2.2.2 Surface parameters

The percentage of the different surface parameters was estimated for each plot (Tab. 4a and 4b): moss, blocks (>30cm), stones (5-30cm), gravel (coarse (1-5cm) and fine (1mm-1cm)), sand, litter, dead wood and vegetation. The vegetation was subdivided into grass, dicotyledonous herbs, shrubs (<1m) and shrubs (>1m).

2.3 Sampling methods

Each site was sampled five times between June 25th and September 2nd 2004 (Tab. 5). In general sampling took 3 days per site, with intervals of one week and was carried out under good weather conditions only (minimal air temperature 10°C, no rain and no strong wind).
Sampling was done during morning and afternoon, with a break during the hot noon, sites A and B being sampled on alternating days. The number of sampled insects was influenced by the pronounced daily temperature fluctuations (surface temperatures up to 60°C over noon). To minimize this problem, plots were sampled in reverse order during consecutive series.
The search method consisted of visual search; scanning the plots while slowly walking a line (in the shape of a W) from one corner to the opposite one. In addition the vegetation (especially flowering plants) was screened for cryptic individuals.
For digger wasps activities as flying, flower visits, nest digging and provisioning the nest with prey were recorded. Unknown Orthoptera and Heteroptera were collected, and transferred to perspex tubes for later determination; to prevent repeated counting they were released at the place they had been collected after finishing the sampling of that day. For all heteropteran specimens the host plant was recorded.

2.4 Species identification

As the study was carried out in a nature reserve and many rare or endangered species were concerned, as few individuals as possible were killed for later determination.

2.4.1 Sphecidae

Observations were concentrated on the taxa *Prionyx* and *Ammophila*. Specimens were determined after BEAUMONT (1964), BELLMANN (1995) and WITT (1998). The nomenclature followed DOLLFUSS (1991) (Tab. 6). Due to determination problems at the beginning of the study most of the *Ammophila*-individuals were pooled as *Ammophila sp.* for analysis. All *Ammophila*-individuals observed later were determined as *Ammophila terminata*, assuming that *Ammophila sp.* individuals were mainly *A. terminata*.

2.4.2 Orthoptera

Individuals (adults and larvae) were determined to species level in the field, using BELLMANN (1985), BELLMAN & LUQUET (1995) and DETZEL (1998) (Tab. 7). Nomenclature followed CORAY & THORENS (2001). Information on ecology and habitat preferences were taken from DETZEL (1998), INGRISCH & KÖHLER (1998) and THORENS & NADIG (1997). Remarks on the red list concern the southern part of Switzerland (THORENS & NADIG, 1997).

Of the *Chorthippus*-species only *Chorthippus vagans* could be determined by sight. *Chorthippus brunneus* and *Chorthippus mollis* males were determined acoustically using the CD by BONNET (1995). Females of *Ch. brunneus*, *Ch. mollis* and Chorthippus-larvae were pooled as *Chorthippus sp.* For analysis larvae were pooled with the corresponding adults.

2.4.3 Heteroptera

Most adult specimens were determined in the field to species level, larvae to family level after SAUER (1996), WACHMANN (1989) and the comprehensive reference collection of the Zoological Institute University of Berne (collected by F. WITSCHI and C. JORIS) (Tab. 8). Several individuals were killed and determined later on in the laboratory after WAGNER (1952, 1966 & 1967) and were used as an additional reference collection. The nomenclature followed GÜNTHER & SCHUSTER (2000) and WAGNER (1952, 1966 & 1967). As there is no red list for Switzerland available yet, information was taken from the red list of Germany (GÜNTHER *et al*., 1998).

Some species can only be identified under the microscope or by dissecting the genitalia. Therefore for time reasons some species were pooled as genera: *Nysius sp.* (c.f. *Nysius ericae*) and *Lygus sp.* (c.f. *Lygus gemellatus*) (possibly containing *N. graminicola*, *N. thymi*, *N. senecionis* and *N. cymoides*; *L. pratensis* and *L. wagneri,* which were found by WITSCHI (2001)). Larvae were not included in analyses.

2.5 Statistical analysis

For most of the data analyses, all five series of samples were pooled, resulting in one sample per site. When using numbers of individuals, the average over the five sampling series was calculated.

For the description of the vegetation cover median values were used, because the values showed a great deviation.

Dominance D_i was calculated using the formula in MÜHLENBERG (1993), with the definitions: Eudominant (>10%), dominant (5-10%), subdominant (2-5%), recedent (1-2%) and subrecedent (<1%).

To study the influence of surface parameters on Orthoptera, a Canonical Correspondence Analysis (CCA) was performed (MVSP, version 3.13l). Species represented by only 1-2 individuals were omitted from analysis (*Ch. mollis*, *Oedipoda germanica* and *Tettigonia viridissima*). Some environmental parameters were pooled for the CCA: blocks and stones as stones, coarse- and fine gravel as gravel and shrubs >1 and shrubs < 1 as shrubs. For site B, the parameter shrubs was omitted from analysis due to the large number of blank values. A CCA of the heteropteran resulted in no viable results.

The relation between Saltatoria and specific environmental variables were calculated using Pearson- (normal data distribution) or Spearman rank correlation (non-normal data distribution) (SPSS version 12.0.1 for Windows).

3. Results

3.1 Habitat parameters

3.1.1 Vegetation

41 plant species out of 23 families were recorded on the two sites. 10 species were found only on site A and 9 species only on site B (Tab. 2a and 2b).

On both sites grasses sp. and *Stipa pennata* were present on almost every plot (A: 30 and 25 plots; B: 27 and 29 plots, resp.) with an average cover of 3.5% (median over all plots A and B: both species). The common dicotyledonous herbs on both sites and in every plot were *Artemisia campestris* and *Astragalus onobrychis* (median over all plots, A and B: both species 12.5%). *Centaurea vallesiaca*, *Euphorbia seguieriana*, *Odontites luteus* and *Silene otites* were present on both sites on average in 23 plots (median over all plots, A: 25 plots; B: 21 plots, resp.), but with a lower cover than *A. campestris* and *A. onobrychis* (median over all plots A: 0.5, 3.5, 0.5 and 1.0%; B: 0.5, 3.5, 0.5 and 3.5%, resp.).

3.1.2 Surface parameters

On site A, pooled over all plots, moss was present with 11.4%, vegetation with 23.4%, mineral soil surface with 45.2% and litter and dead wood together with 20% (Tab. 4a and 4b). On site B moss was present with 29.4%, vegetation with 24.3%, mineral soil surface with 12.2% and litter and dead wood together with 34.1%.

On both sites and pooled over all plots, litter reached the highest cover percentage (A: 15%; B: 32%, resp.), followed on site A by sand (14%) and on site B by moss (29%) (Fig. 2a and 2b). With the third highest percentage followed the dicotyledonous herbs on both sites (both 13%). Moss on site A (11%) and grass on site B (10%) were found in the fourth place. All other parameters were present with less than 10%. For details see Tab. 4a and 4b.

3.2 Species spectrum and abundance

3.2.1 Sphecidae

513 observations covering 4 species were made (Tab. 6). 398 observations (77.6%) were made of *Prionyx kirbii*, followed by *Ammophila terminata* and *Ammophila sp*. together with a total of 109 observations (21.2%). *Sphex rufocinctus* and *Ammophila sabulosa* were observed 3 times each.

Overall more Sphecidae were recorded on site B than A (63% and 37%, resp.). More individuals of *P. kirbii* and *Ammophila sp.* were observed on site B than on site A (62.8% and 36.1%, resp.) (Tab. 9).

Fig. 3a and 3b show the phenology of *P. kirbii* and *Ammophila sp.* On site B the increase of *P. kirbii* occurred earlier than on site A, and the maximum abundance was reached earlier as well. On site A, a slight decrease of *P. kirbii* was found at the beginning of the sampling season. The curve of *Ammophila sp.* was similar on both sites with the maximum density of individuals at the end of July. On site A a slight increase between the last two sampling series occurred.

Concerning the different activities of *P. kirbii* and *Ammophila sp.* over all sampling series, the largest part of individuals was recorded in flight (*P. kirbii* 46.6%, *Ammophila sp.* 60.0%) (Fig. 4 and Tab. 9). The activity "flower visits" was ca. 32% for both species. Less than 5% of *Ammophila sp.* individuals were observed digging a nest, while *P. kirbii* was represented with 18.0% of digging individuals. In both species only few individuals (3.4% and 2.9%, resp.) were observed provisioning the nest with prey (Tab. 9).

3.2.2 Orthoptera

12 Orthoptera species out of 5 families, including the family Mantidae with the only species *Mantis religiosa*, were recorded (Tab. 7). On site A twice as much individuals were observed than on site B (66.7% and 33.3%, resp.). *Oedipoda caerulescens* was the most abundant species (41%), followed by *Calliptamus italicus* with 33% and *Platycleis albopunctata* and *Chorthippus sp*. with ca. 10%. With a lower number of individuals (1-5%) *Chorthippus vagans*, *M. religiosa* and *Sphingonotus caerulans* were represented. *Phaneroptera falcata*, *Tettigonia viridissima* and *Oedipoda germanica* were observed as single specimens.

Regarding the percentage of six species on site A (Fig. 5a and 5b), most recordings were made of *O. caerulescens* (56%), followed by *C. italicus* (30%) and *P. albopunctata* (7%). On site B *C. italicus* was the most frequent species (53%), followed by *O. caerulescens* (24%) and *P. albopunctata* (19%). *Ch. vagans*, *S. caerulans* and *Oecanthus pellucens* were represented on both sites with less than 5% each.

On site A *O. caerulescens* and *C. italicus* were eudominant, followed by the dominant *P. albopunctata* (Fig. 6a and 6b). On site B *C. italicus*, *O. caerulescens* and *P. albopunctata* were eudominant. *O. pellucens* was subrecedent on site A and recedent on site B. *S. caerulans* was subrecedent on both sites.

Fig. 7a and 7b shows the phenology for the larvae and Fig. 8a and 8b for the adult grasshoppers. At the beginning of sampling season mainly larvae occurred, the last ones being found at the end of July, except for 3 individuals of *O. caerulescens* on site A in mid of August. The maximum density of adult individuals was reached for *C. italicus* at the end of July and for *O. caerulescens* and *P. albopunctata* at the end of August.

3.2.3 Heteroptera

40 Heteroptera species out of 9 families were recorded (Tab. 8). Seven species were found only on site A and 13 species only on site B.

On site A, the Pentatomidae were the most common family represented by 8 species, followed by Coreidae and Lygaeidae (both 4 species) (Fig. 9). Most represented on site B were the Lygaeidae with 9 species, followed by Pentatomidae with 8 species and Reduviidae and Rhopalidae with 4 species both.

66.8% of all individuals were observed on site B and 33.2% on site A (Tab. 8). Fig. 10 shows, that on site A and B, the families of Lygaeidae was represented with 29.1% and 21.8% of the individuals and Pentatomidae with 26.5% and 21.6%. Between 10 and 20% belonged to the families of Alydidae (A: 18.5%; B: 20.1%, resp.) and Miridae (A: 10.6%; B: 12.1%, resp.). The families Reduviidae and Scutelleridae were represented on site B with ca. 10% (9.5% and 9.2%, resp.) and with less than 5% on site A (4.8% and 2.6%, resp.). The families Rhopalidae, Coreidae and Stenocephalidae were represented with less than 5% on both sites (A: 4.2, 3.7 and 0%; B: 3.4, 1.8 and 0.5%, resp.).

Dominance: On both sites c.f. *Nysius ericae* was the eudominant species followed on site A by *Alydus calcaratus* and c.f. *Lygus gemellatus* and on site B by *Carpocoris fuscispinus*, c.f. *L. gemellatus* and *Camptopus lateralis* (Fig. 11a and 11b). The dominant species on site A were *C. lateralis* and *C. fuscispinus*, on site B *A. calcaratus*, *Eurygaster maura* and *Rhynocoris iracundus*. Recedent and subrecedent species were omitted from the diagram.

Fig. 12a and 12b shows the phenology of Heteroptera species and individuals. The species number reached the maximum on both sites at the end of July. The maximum density of individuals occurred on site B at the end of July and on site A at the beginning of August.

3.3 Relation between species and habitat parameter

3.3.1 Sphecidae

A total of 162 individuals (31.6%) were observed while visiting flowers on a total of 11 flowering plant species. Fig. 13 shows the percentage cover of the most visited plants and the total number of observed individuals per plant on both sites. *A. onobrychis* dominated with 12.5% on sites A and B. On site A *Thymus praecox* was represented with 3.5% and on site B *Teucrium montanum* with 12.5% and *Allium sphaerocephalon* with 5%. All other plants were represented with two or less percent of cover. 64.9% of the individuals on site A were recorded on *T. praecox*, whereas on site B 63.6% on *Asperula aristata*. *O. luteus* was the second most visited plant on both sites (A: 20.3%; B: 18.2%, resp.), followed on site A by *A. aristata* (6.8%) and on site B by *Epilobium dodonaei* and *T. montanum* (both 4.5%).

P. kirbii was recorded on site A on 6 and on site B on 8 plant species, respectively (Fig. 14). *Ammophila sp.* individuals were observed on site A on 5 and on site B on 3 plant species, respectively.

3.3.2 Orthoptera

Fig. 15a and 15b show the CCA ordination biplot for site A and B, representing the two main axes, the species (triangles) and the environmental variables (arrows). The axes of the final ordination are restricted to be linear combinations of the environmental variables and the species data. The arrows (environmental variables) indicate the direction of maximum change of that variable across the diagram and their length is proportional to the rate of change. Therefore a long arrow indicates a large change and indicates that the change is strongly correlated with the ordination axes and thus with the community variation. The position of a species in relation to the arrows indicates the environmental preference of that species (MVSP, user's manual).

The two biplots show a different distribution of the environmental variables and the species. On site A the two main axes explain 36.9% and 70.2% of the total variance, respectively. When including the third axes (not mapped), 89.1% of the total variance is explained. The most important environmental parameters for the species are dicotyledonous herbs, gravel, stones, litter and sand. Shrubs, dead wood and grass are less important and moss is represented with the shortest arrow.

On site B 84.4% of the total variance is explained with all three axes, thereof the two main axes explain 41.2% and 64.6%, respectively. The environmental variables grass and litter are most important. All the others are less important, except for deadwood, which is represented only with a short arrow. 7 out of 9 species cluster in the middle of the biplot and their preference for certain habitat parameters are less evident than on site A.

A significant correlation exists between *O. caerulescens* and the habitat parameter sand on site A ($r = 0.652$; $N = 30$; $p < 0.0001$ (r significant at the 1% level)) but not on site B ($r_s = -0.069$; $N = 30$; $p < 0.716$) (Fig. 16a and 16b). Between *O. caerulescens* and the habitat

parameter moss, a significant correlation exists on site B (r_s = 0.690; N = 30; p < 0.0001 (r significant at the 1% level)), but not so on site A (r = 0.131; N = 30; p < 0.491) (Fig. 17a and 17b). The combination of the surface parameter gravel-sand and the abundance of *O. caerulescens*, shows a positive correlation trend on site A (r = 0.347; N = 30; p < 0.060) and a significant correlation on site B (r_s = 0.582; N = 30; p < 0.001 (r significant at the 1% level)) (Fig. 18a and 18b). These results are illustrated spatially in Fig. 19: The cover of gravel-sand was higher on site A than B (30% and 8%, resp.) and more plots with a high percentage (25.1-55%) of gravel-sand were present on site A than on B (15 plots and 1 plot, resp.). On site A *O. caerulescens* was present on all plots, with highest numbers (mean 4- > 6 individuals) on plots with a high gravel-sand cover (25.1-55%). On site B the mean cover of gravel-sand was low (0-25%), and also the presence of *O. caerulescens* was low (mean 0-3 individuals).
A significant correlation was found between the pooled variables grass and dicotyledonous herbs and the abundance of *P. albopunctata* on site A (r = 0.399; N = 30; p < 0.029 (r significant at the 5% level)), and as well on site B (r = 0.567; N = 30; p < 0.001 (r significant at the 1% level)) (Fig. 20a and 20b). These results are illustrated spatially in Fig. 21: The mean coverage of the pooled parameters grass and dicotyledonous herbs was higher on site B than on A (23% and 19%, resp.). More plots with a high percentage (20.1-40%) of this combination were present on site B than on A (13 plots and 10 plots, resp.), but *P. albopunctata* was evenly distributed over all plots on both sites (on 58 out of 60 plots).
The mean cover of gravel was higher on site A than on B (16% and 6%, resp.), and more plots with a high percentage (17.6-35%) of gravel surface were present on site A than on B (12 plots and 4 plots, resp.) (Fig. 22). *S. caerulans* individuals were found on site A on 17 plots and on site B on 4 plots.
With a higher percentage of cover over all plots was the parameter grass on site B present (B: 10%; A: 6%, resp.) (Fig. 23). Grass was represented with a high percentage (10.1%-25%) of cover on more plots on site B than on A (9 plots and 4 plots, resp.). *C. italicus* was evenly distributed over all plots of both sites (> 1 ind./plot, except 4 plots with less than 1 ind./plot).

3.3.3 Heteroptera

A total of 504 individuals representing 29 species were recorded on 13 different host plants (Tab. 10a and 10b): 358 on 12 species of herbs and grass on site B and 146 on 9 herbaceous plants on site A. On site A nine and on site B eight true bug species, with at least two individuals, were observed on a single host-plant species only. Three Heteroptera species were found with a high preference of one single host plant: On site A and B c.f. *N. ericae* on *C. vallesiaca* (41 individuals and 51 individuals, resp.), on site A *Eurydema ornatum* on

Erucastrum nasturtiifolium (28 individuals) and on site B *E. maura* on *C. vallesiaca* (17 individuals). *C. fuscispinus*, although observed on other host plants, was mainly found on *C. vallesiaca* (A: 9 individuals; B: 30 individuals, resp.).

Fig. 24 shows a comparison of the coverage of plant species and the sum of true bugs being present. On both sites *A. campestris* and *A. onobrychis* were most abundant (12.5% cover), and on site B in addition to last-named, *T. montanum* was present with the same amount of cover. All other plants were present with five or less percent. Around 40% of the Heteroptera were observed on *C. vallesiaca* (site A & B), ca. 20% on *E. nasturtiifolium* (site A) and ca. 20% on *A. onobrychis* (site B). Numerous individuals were observed on *A. campestris* (A: 15.1%; B: 13.7%, resp.), on grass (A: 12.3%; B: 11.5%, resp.) and on *S. otites* (B: 10.3%).

Fig. 25 shows the presence of *C. vallesiaca* and the number of Heteroptera observed. *C. vallesiaca* was more abundant on site A (A: 25 plots; B: 18 plots, resp.), but on site B more plots showed a high cover of *C. vallesiaca* (> 2%) compared to site A (7 and 5 plots, resp.). On the plots with the highest percentage of *C. vallesiaca*, the highest number of true bugs was found. A larger amount of individuals was observed on site B (B: 70.9%; A: 29.1%, resp.).

4. Discussion

4.1 Sampling methods

Visual search was chosen because it was possible to record the insects together with their host plants. It was resigned to use pitfall traps as too many rare non-target organisms would have been captured, and our emphasis was laid on insects (especially Heteroptera) in the upper part of the vegetation. DECKERT & HOFFMANN (1993) considered hand collection the most efficient method to investigate true bugs together with sweep-net-, beating method and sieving.

For terricolous grasshoppers like *Oedipoda caerulescens* and *Sphingonotus caerulans*, which cannot be recorded acoustically, visual abundance determinations by slow pacing off the site and to startle the individuals are the best method (HEMPEL & SCHIEMENZ, 1963). Sweep-netting was not necessary as the abundances were low.

With visual search the problem of the dependence on the searchers skills may exist. In dense vegetation, cryptic, agile and small specimens could easily be missed. Almost all individuals of the three insect groups could be identified in the field with books and the reference collection. As only very few Heteroptera were killed for later identification, it is likely that some species were missed, because they were not discerned from abundant sister species (e.g. c.f *Nysius ericae*).

We cannot exclude, that larger and very mobile individuals (e.g. grasshoppers and digger wasps) were counted more than once when moving from one plot to the next, but we tried to prevent this by moving around very carefully.

Temperature and insolation influence the behaviour of insects. Maximum values of the soil surface exceed regularly 60° C (J. ZETTEL, pers. comm.), and therefore individuals hiding in shady places or in the upper part of the vegetation could have been missed.

4.2 Species spectrum and abundance

4.2.1 Sphecidae

Prionyx kirbii was the most common species found on both sites, followed by *Ammophila terminata* and *Ammophila sp.*, respectively, which is in accordance with earlier studies on other sites in the Rottensand, where *P. kirbii* and *A. terminata* individuals were the most abundant species (JÄGER, 1995; ZEHNDER, 1996).

For the **phenology**, the maximum of individuals was recorded during end of July, except for *P. kirbii* on site A. The slight decrease of observations between the first and third sampling series could be due to the fact that the availability of flowering plants was suboptimal during this time period on this site (see 4.3.1). The late slight increase at the end of the *Ammophila sp.* curve on site A probably indicates a second generation, which is assumed by BLÖSCH (2000) for most of the *Ammophila*-species and for *A. terminata* by ZEHNDER (1996).

The question arises why more individuals were observed on site B. The occurrence of digger wasps is determined by the presence of appropriate substrate for nesting, food resources for adults and specific food for larvae (e.g. BLÖSCH, 2000).

Although more open sand patches were available on site A than on B (14% and 2%, resp.), more digging individuals as well as more nests were observed on site B (B: 10 plots with 0 up to > 20 nests; A: 3 plots with 0 up to > 20 nests, resp.), even though much of the open soil surface of site B was covered by moss (mean: 29%). In opposition to our expectation already a small surface of sand ($1cm^2$) is sufficient for a digger wasp to dig its nest. We assume that it is also important for females to find flowers as nectar sources and food plants of their prey in the close vicinity of their nests. HAGER & KURCZEWSKI (1986) recorded that most digger wasps concentrated their nests within a $4m^2$ area and only a few distributed their nests over a greater area.

A crucial prerequisite for nesting is the presence of small stones, since they are used to close nest entrance (HAGER & KURCZEWSKI, 1986). There was no shortage of such stones on both sites (fine gravel, mean: A: 6%; on B: 5%, resp.).

Generally, *Ammophila* and *Prionyx* are known to prefer compact sand soil for digging their nests (BROCKMANN, 1985; HAGER & KURCZEWSKI, 1986; JÄGER, 1995; OLBERG, 1959). An explanation for this choice is given by HAGER & KURCZEWSKI (1986): if the first 1-3 millimetres of the sand cover are compacted enough, a collapsing of the nest entrance is prevented. Beneath such a layer, favourable microclimatic conditions prevail: Despite high insolation and heat the evaporation is reduced due to this protective layer, and the soil offers enough humidity for the larvae.

The compact and thick moss layer becomes very hard when drying out, which makes it impenetrable for digging species. If there are gaps in the moss cover or when it is only thin, digger wasps are not prevented from nesting (as for site B, under the moss mainly sand was found).

Only a very few *Ammophila sp.* were observed during digging their nest. JÄGER (1995) made the same observation. The reason could be that *Ammophila* prefer to nest in bare soil surrounded by vegetation (HAGER & KURCZEWSKI, 1986), and thereby were more difficult to observe. In our study 60% of the *Ammophila*-individuals were digging close to a tuft of grass, while most of the recorded *P. kirbii* individuals (ca. 90%) were recorded digging on an open ground patch.

OLBERG (1959) and ZEHNDER (1996) described interactions between ants and digger wasps, the latter being attacked by foraging ants while digging their nest. After my own observations this disturbance seems to be rather irrelevant, at least on this two sites. Ants were observed on both sites on the open sand patches and in a greater number on site A. But no negative correlation between the presence of ants and the number of digger wasp nests seems to exist.

4.2.2 Orthoptera

Out of the 12 species found on both sites, 11 are mentioned on the red list of Switzerland (southern part) (THORENS & NADIG, 1997). *S. caerulans* is threatened by extinction and 5 species are mentioned as endangered. 50% of the species are mentioned as stenotopic and 58.3% as xerophilic; the xeric steppe represents an important habitat for these species.

The **phenology** curves show their maxima at the beginning of September (*O. caerulescens*) and the highest peak at the end of July (*Calliptamus italicus*), which is matching with data given by THORENS & NADIG (1997) and MÜLLER (1998) (Fig. 8a and 8b). There is no obvious reason for the decrease of individual number and a new increase at the end of July for *C. italicus* on site A and *O. caerulescens* on site B. It cannot be explained by remarkable weather changes; no heavy rain or temperature drop was registered between the third and fourth sampling series; only on August 10^{th} and 12^{th} the weather was rather suboptimal, i.e. sunny during the day and rainfall in the evening. Nevertheless, the same pattern should be seen in all species or at least within the same species at both sites.

For ***Chorthippus* species** females and larvae were pooled into *Chorthippus sp.*, as *Chorthippus brunneus* and *Chorthippus mollis* can only be determinated acoustically. This explains the high number of individuals in this group. The second highest number of individuals was represented by *Chorthippus vagans*. This corresponds to results from earlier studies at the Pfynwald on other sites (MÜHLHEIM, 2002; MÜLLER, 1998; WUNDER, 2001). *Ch. brunneus* was recorded in a smaller amount (0.8% of the individuals) and only one single stridulating male of *Ch. mollis* was found. Both species are later in the phenology than *Ch. vagans* (THORENS & NADIG, 1997), and it seems that my sites were not suitable for these two species. According to INGRISCH & KÖHLER (1998) the vegetation structure (hight, density as coverage percentage) is probably the most important habitat parameter. It can be assumed that on sites A and B the vegetation was too scarce for *Ch. brunneus* and *Ch. mollis*.

4.2.3 Heteroptera

The distribution of Heteroptera is strongly influenced by vegetation and climate (CURRY, 1994; DOLLING, 1991). The composition of a local heteropteran fauna is determined by five main characteristics of their habitat: 1) the climatic area and the microclimatic characteristics of the site, 2) the type of vegetation (trees, bushes, annual or long-lived low-growing plants), 3) the season, 4) the presence of prey for predatory species and 5) the influence of human practices (FAUVEL, 1999). On our plots the heterogeneity of the vegetation structure and groundcover as well as the plant species richness provide a great number of niches for Heteroptera.

40 species out of 10 families were collected during the sampling period. In other studies on true bugs carried out on other sites at the Pfynwald much higher numbers were recorded: 144 and 105 species, respectively (JORIS, 2002 (only her data for steppe habitats considered); WITSCHI, 2001). This could be probably due to the sampling methods used or the consequences of last year's hot and dry summer.

The **species number per family** was highest in the Pentatomidae and the Lygaeidae, 9 and 8 species, respectively. Compared to the results of WITSCHI (2001) with the Miridae being the most common family, they were represented with only 2 species in this study. This could be due to the sampling method (no sweep-netting) and probably more extreme climatic conditions (dry and hot) on my study sites, which could influence the vegetation composition.

In the study of WITSCHI (2001) next to the Miridae the Lygaeidae and Pentatomidae were the second most common families. Lygaeidae (often terricolous) prefer steppes with open ground patches, while Pentatomidae are dependent on the presence of certain herbs or grasses (especially in the semi-natural grassland). PÉRICART (1987) (in FAUVEL, 1999) reports vertical migrations, some species being found on soil only during the day, but are collected from the plants at night. But it is also well known that many invertebrates avoid hot surface temperatures (during day time) and climb onto the plants, where they can be observed more easily.

The presence of an indicator species is strongly correlated with habitat parameters, either biotic (e.g. food) or abiotic (e.g. humidity, temperature) (MARCHAND, 1953). Indicator species for steppes are generally adapted to dry and warm areas. More than ten of the species (14 out of 40) found on my study sites are known to be xero-thermophilic (Tab. 8).

Dominance: On both sites the eudominant species was c.f. *Nysius ericae*. The same result was found by WITSCHI & ZETTEL (2002) and concerning the steppes by JORIS (2002). MARCHAND (1953) describes as preferred habitat a clear and open plant stand with sandy soil surface plus the corresponding temperature- and humidity conditions; after WAGNER (1966) the species needs sandy soil surface and sufficient insolation. These conditions correspond to the ones at our sites. Eudominant were also *Alydus calcaratus*, *Camptopus lateralis*, c.f. *Lygus gemellatus* and *Carpocoris fuscispinus*. All of them except c.f. *L. gemellatus* are xero-thermophilic and prefer arid and warm habitats.

Phenology: Larvae and adults are present together at any time during summer. The main season for true bugs is late summer, when they reached the highest number of individuals and species. This peak is probably connected with the food supply of the host plants (see 4.3.3). The maximum number of individuals occurred ca. 10 days later on site A compared to site B. One reason could be that the seeds of a specific host plant were mature and therefore many individuals aggregated on this plant, e.g. *Eurydema ornatum* on *Erucastrum nasturtiifolium*. This plant was found more frequent on site A than B, especially one large specimen (median over all plots, 0.5% and 0.375%, resp.).

4.3 Relation between species and habitat parameters

The vegetation survey was made early in the growing season (beginning of May). Many species, for example *Centaurea vallesiaca*, were not yet fully developed. Later in the season the cover of grasses and dicotyledonous herbs increased (Appendix 1 - 4). A second plant cover estimation was not carried out.

4.3.1 Sphecidae

Most of the digger wasps are euryanth, visiting different flowers for nectar uptake. But they are restricted to flowers, which are available spatially and by time as well as to those with a flower structure enabling the use of their nectar (OLBERG, 1959).

According to the phenology and the blooming period of the most visited flowers, the highest number of digger wasps was reached at the same time when *Asperula aristata* and *Odontites luteus* started flowering (Tab. 3; Fig. 3a and 3b) but *A. aristata* was less visited than *O. luteus*. At the beginning of sampling season individuals were mainly recorded on *Thymus praecox*, whereas towards the end on *O. luteus*, representing the different phenology of these species.

According to OLBERG (1959) *Ammophila* and *Prionyx* belong to the Sphecidae species, which are able to gain nectar even from specialised flowers, thanks to their long tongues. Also JÄGER (1995) recorded only *Prionyx* and *Ammophila* during flower visits, *P. kirbii* using a larger plant spectrum than the *Ammophila*-species (A: 6 and 5 plant species; B: 8 and 3 plant species, resp., Fig. 14). This corresponds to data from JÄGER (1995) and ZEHNDER (1996):

P. kirbii was observed on 7 and 9 different plant species, respectively and *A. terminata* on 4 and 8 different plant species, respectively.

4.3.2 Orthoptera

According to JOERN (1982) the following parameters have been shown to influence microhabitat utilization: vegetation structure, number of plant species, availability of food plants, soil characteristics, availability of suitable oviposition sites and substrate characteristics which render an individual cryptic. For xero-thermophilic species the microclimate plays a central role.

The microclimate close to the soil is important for inhabitancy of the grasshoppers. Base soil heats up much more than soil with a plant cover, but at night it radiates more heat energy and as a result shows more extreme temperature fluctuations (FRANZ, 1931 in DETZEL, 1998).

A soil covered by moss shows on average a higher surface temperature compared to a sandy soil. This rise in temperature can be explained with the dark colour of the moss. It could be that the thermal conductance into the soil is reduced and the moss remains warmer.

The CCA biplot (Fig. 15a and 15b) shows for site A an even distribution of the 9 species over the whole diagram, while on site B the species cluster in the centre, and the preference for habitat parameters is not so apparent as on site A. The reason could be that on site A the cover percentage is more evenly distributed among all habitat parameters, thus no parameter is dominating. On site B two parameters dominate distinct and therefore reduce the impact of the others. Another possibility is that the number of species showing a strong preference for a specific habitat parameter (e. g. *O. caerulescens*) is larger on site A and therefore more clearly assigned to this parameter.

Sphingonotus caerulans is a pioneer species and occurs in the Pfynwald on gravel bars along the river Rhône and on more or less bare gravel sites in the Rottensand. As a secondary habitat, the species prefers man-made open surfaces, consisting of a gravel-sand mixture with sparse vegetation (0-10% according to HOLDEREGGER, 1999). Many individuals were observed on the near gravel road as well as on gravel-sand patches next to the sites, assuming that the individuals found on my sites immigrated from there.

Oedipoda caerulescens preferred patches with open vegetation and a high percentage of sand-gravel mixture (ca. 25-55% per plot). WANCURA (1996) (in DETZEL, 1998) describes for *O. caerulescens* the preference for a plant cover of ca. 50%; in habitats with less than 30% vegetation cover the species was not found. According to HOLDEREGGER (1999) the species occurred at her sites in the Pfynwald in habitats with a vegetation cover of 30 to 80%.

For ***Platycleis albopunctata*** grass, dicotyledonous herbs and shrubs seem to play an important role, especially for males, which were often found stridulating hidden in a bush or shrub. A mosaic of open ground patches, open vegetation and some shrubs and bushes is the preferred habitat (DETZEL, 1998). According to GOTTSCHALK (1997) open and highly structured vegetation is a key factor for the habitat preference. Different structures are used during the day depending on temperature.

Calliptamus italicus preferred patches with grass and open soil, especially covered with moss. In the CCA biplot it is located in the centre, closest to the parameter dicotyledonous herbs although no specific habitat parameter influenced its presence. It was found evenly distributed over all plots on both sites (Fig. 23). According to results of URECH (2003) and WUNDER (2001) the preferred percentage of steppe vegetation is 50-75% and 40-100%, respectively. DETZEL (1998) describes the species as a colonizer of a broad spectrum of habitats, and BRANDT (1996) (in DETZEL, 1998) mentions a small-scaled mosaic of patches with sparse as well as dense vegetation to be especially favourable.

Chorthippus vagans occurrs only in the southern parts of Switzerland and is mainly common in the Valais (THORENS & NADIG, 1997). The fact that more individuals were found on site A could be explained by the higher tolerance of the species to the presence of shrubs compared to other grasshoppers (J. ZETTEL, pers. comm.). According to (DETZEL, 1998) it shows a preference for habitats with low vegetation in the transition zone between edges of shrubs and open grassland.

The occurrence of ***O. caerulescens*** is limited by the presence of a minimal percentage of sand and a maximum of vegetation (Fig. 15-19). On site A these specifications are realized, but apparently not on site B. However it is assumed that open surface can include moss and that the vegetation density has a larger impact on the presence of the species than sand. On the CCA biplot of site A *O. caerulescens* is located between the environmental variables gravel and sand, and on site B close to the environmental variables gravel, stones and moss.

4.3.3 Heteroptera

88.6% of the species were recorded on 13 herbaceous plants including grass. The remaining 11.4% where observed on other habitat elements (e.g. soil surface, shrubs).

A few species were recorded on a specific plant only once; these recordings may be accidental. Polyphagous species can be found on a number of host plants but not necessarily in high abundances (MARCHAND, 1953). The same applies to predators e.g. *Rhynocoris iracundus*, which was often observed on *Silene otites* (B: 14 individuals).

Within a genus some species are restricted to herbs and others are found on any type of vegetation. Pentatomidae, for example are often ubiquitous, with some species (e.g. *Dolycoris baccarum*, *Palomena prasina*) inhabiting herbs as well as fruit trees. Lygaeidae and Coreidae, in particular the Pseudophloeinae, living at the base of plants, seem more linked to low-growing vegetation, although some species are commonly found on bushes (FAUVEL, 1999).
The most common phytophagous heteropterans are polyphagous although some species show well-known preferences: e.g. Pentatomidae of the genus *Eurydema* seem to prefer crucifers. Scutelleridae (e.g. *Eurygaster*, *Aelia*) live mainly on Poaceae and particularly on crop (FAUVEL, 1999).
Different factors may be involved in the link between a heteropteran species and a particular host plant. Floral attraction may help the adult insects to find pollen or nectar and to satisfy specific food requirements (e.g. proteins, amino acids) (FAUVEL, 1999 without giving any details). Many species profit from ripening ovules and seeds, which are rich in proteins and carbohydrates. *C. vallesiaca* was observed to be the plant with the highest number of Heteroptera found on it on both sites (A and B: ca. 40% of the individuals) (Tab. 10a and 10b). This corresponds to results of the study by WITSCHI & ZETTEL (2002), where most of the species and individuals (22 species out of 6 families) had been observed on *C. vallesiaca*. Most of the individuals were monitored especially on flower heads, which were in the phase of seed maturation. From the end of June till the beginning of September flowering as well as ripening flower heads were observed (Tab. 3).

4.5 Conservation and management of steppe habitats by grazing

In order to preserve the steppes at Rottensand, measures of habitat management are needed. Increasing woody vegetation and the sealing of the soil surface by the compact moss cover are a danger for the existence of many rare insect species. Vertebrate herbivores would be a „natural disturbing factor“ which could affect the composition and the structure of the ecosystem in a positive way and enhance the biodiversity (e.g. WHITE & PICKETT, 1985; HOBBS & HUENNECKE, 1992 in HOLTMEIER, 2002).
Heterogeneous vegetation can be maintained by grazing in contrast to homogeneous vegetation, which results by mowing. Grazed surfaces show a higher floral and faunal diversity than mowed ones (DEMARMELS, 1990).
More open and scarce vegetation, as a result of grazing, will affect the existence of xero-thermophilic insects in a positive way (MORRIS, 1979).

What will be the impact of grazing for the Rottensand?

The steppe area would remain open and be protected against invasion by bushes. By trampling the soil surface would be “damaged”, which means that the moss cover will be partly destroyed.

For most herbivore insects it would be important to maintain or create heterogeneity in vegetation and habitat structures, for this is a key to maximizing biodiversity (ROOK *et al.,* 2004).

Perhaps the most important mechanism by which grazing animals create plant heterogeneity is selective feeding, which alters the competitive advantage of plant species (BULLOCK & MARRIOTT, 2000 in ROOK *et al.,* 2004). A second mechanism is treading which opens regeneration niches for gap-colonizing species. A third mechanism is nutrient cycling. This has the effect of concentrating nutrients at dung and urine patches and again may alter the competition between species, both directly and by feedback effects on dietary choice of the grazing animals (BOKDAM, 2001 in ROOK *et al.,* 2004). Grazing mammals also play a role in propagule dispersal. This may be either endozoochorous (i.e. by seeds passing through the animal’s digestive system) or exozoochorous (i.e. by seeds attaching to the animal’s coat) dispersal (BAKKER, 1998 in ROOK *et al.,* 2004).

Concerning the insect species, different effects would occur:

Sphecidae: The flowering plants play an important role as nectar source as well as for the availability of prey. Therefore they should not be reduced too much. The tearing up of the moss would lead to an increase of open soil surface, which is a positive effect. But at the same time, the sand is loosened, which is not favourable for all digger wasps. Especially *P. kirbii* preferred to dig their nests on site B on patches with a mossy surrounding, because the sand surface is compacted in such spots.

Orthoptera: According to KÖHLER & BRODHUN (1987) (in INGRISCH & KÖHLER, 1998) during a short term grazing a displacement of the grasshoppers occurred at first, followed by a rapid recolonization from the periphery. Extensive grazing (e.g. with cattle) may have a neutral or even positive effect on populations (WINGERDEN *et al*., 1991 in INGRISCH & KÖHLER, 1998).

For species preferring open ground patches with sand and gravel (e.g. *S. caerulans*, *O. caerulescens*) the removal of the moss will lead to an improvement of their habitat.

Heteroptera: As herbivores true bugs are directly dependent on the presence of their food plants. According to MORRIS (1979) (in OTTO, 1996), Heteroptera are affected stronger by grazing during spring and summer than in autumn and winter, due to the fact that many species complete their development already in late summer or in autumn.

Several mammal species could be used for grazing:

Sheep & goats: Wandering sheep herds are effective distributor of diasporas and small animals (especially grasshoppers, but also slugs, spiders, bugs, *et al*.) and they contribute to the exchange of plants and animals between isolated areas as well as to the conservation of the species diversity (FISCHER *et al*., 1996 in HOLTMEIER, 2002).

While sheep can easily be fenced in, it needs great efforts to erect goat-proof fences. According to WALLIS DE VRIES (1995) (in PYKÄLÄ, 2000) freely moving livestock resemble more natural herbivore patterns than fenced livestock, partly because of the dispersal mode of plant propagules by freely moving animals (FISCHER *et al*., 1996 in HOLTMEIER, 2002). And in addition they will not concentrate their activities along the fences and next to gates. Sheep and goats are more selective in browsing plant than cattle, because of their greater ability to select high quality plant parts such as flowers, pods and young shoots. These species effects on selectivity and thus on biodiversity are of great importance (e.g. OLIVAN & OSORO. 1996; CELAYA et al., 2003 in ROOK *et al.,* 2004). As sheep show a distinct flocking behaviour, their effects on a vulnerable habitat like the steppes are much more pronounced than with goats.

Donkeys & horses: These animals are maybe useful for cracking up the soil with their hooves. Especially donkies prefer to roll in the sand (sand bathing) from time to time, thereby creating vegetationless sandy depressions in the soil. Horses with top and bottom incisors can graze much closer to the ground than cattle and thus produce a quite different vegetation structure (ROOK *et al.,* 2004).

Cattle: Cattle grazing is considered more suitable for plant diversity than sheep or horse grazing (e.g. JOHANSSON & HEDIN, 1991 in PYKÄLÄ, 2003). This is mainly due to the fact that cattle graze less selectively (PYKÄLÄ, 2000 in PYKÄLÄ, 2003). Nonselective feeding behaviour leads to the suppression of large and abundant plants, which in turn increases plant diversity (HULME, 1996 in PYKÄLÄ, 2000).

Llamas: According to HOLTMEIER (2002) they would not be able to crack the soil surface with their cushioned hooves. They are known to avoid resinoid plants like conifers (pines!) (J. ZETTEL, pers. comm.).

Seasonal grazing: Vegetation varies seasonally in composition and biomass. Selective grazing of certain plants in summer could decrease the grazing pressure on other species (GALLET & ROZE, 2001). During summer grazing many of the flowering plants would probably affected in a way that they lose their importance for insects. Sphecids and Heteroptera need flowers or ripening seeds, which will not be produced after a late grazing. Grazing not only has an immediate effect, but also can weaken plants and decrease their ability to survive winter cold (BAYFIELD, 1979 in GALLET & ROZE, 2001). GRANT *et al*. (1982) (in GALLET & ROZE, 2001) suggested that grazing towards the end of summer causes a reduction in carbohydrate reserves, which could have detrimental effects on the regrowth of plants in the next spring. An additional feeding of the grazing mammals has to be made during all seasons, because the steppes do not offer enough food.

Considering the facts mentioned habitat management by grazing should take place mainly in winter, early spring or late autumn.

Duration of grazing: Duration of grazing depends on the grazing pressure realized by the livestock used. The vegetation can sustain a heavy grazing if it is of short duration (GRANT *et al*., 1982 in GALLET & ROZE, 2001). At moderate grazing pressure animals are more able to express their dietary preferences and thus this mechanism can be more important and can lead to high biodiversity levels (MILNE & OSORO, 1997 in ROOK *et al.,* 2004). Deer and other wild mammals (e.g. hares) are already grazing on the two sites, thus a minimal grazing pressure is already existent. Single horse tracks demonstrate, that already a singular trampling event may destroy the moss cover sufficiently for the use of the place as a nesting site by specific digger wasps.

Rotational grazing could also be considered. Each species has different requirements, and rotational management allows for the conservation of a maximum range of invertebrate and plant species (CHAMBERS & SAMWAYS, 1998 in GEBEYEHU & SAMWAYS, 2003). In the study by GALLET & ROZE (2001) rotationally grazed sites had significantly higher grass species richness and abundance compared to seasonally grazed sites, resulting in a higher grasshopper diversity.

According to PYKÄLÄ (2000) the optimal grazing management system for biodiversity is maybe a complicated combination both of continuity (similar grazing pressure over a long time) and stochasticities (variation in grazing pressure, rotational grazing, abandonment and resumption of grazing) and the use of different grazing animals over a variety of spatial and temporal scales.

4.6 Erhaltung und Bewirtschaftung von Steppenhabitaten anhand von Beweidung

Zur Erhaltung der Steppenhabitate im Rottensand werden Massnahmen in Bezug auf die Bewirtschaftung des Habitates benötigt. Zunehmende Verbuschung und der Verlust der sandigen Bodenoberfläche aufgrund einer kompakten Moosschicht sind eine Bedrohung für die Existenz von vielen seltenen Insektenarten. Pflanzenfresser wären „natürliche Störfaktoren“, die die Zusammensetzung und Strukturen des Ökosystems beeinflussen und die Biodiversität erhöhen würden (u.a. WHITE & PICKETT, 1985; HOBBS & HUENNECKE, 1992 in HOLTMEIER, 2002).

Im Gegensatz zu einer homogenen Pflanzenstruktur, welche durch mähen entsteht, wird eine heterogene Pflanzenstruktur durch Beweidung aufrecht erhalten. Beweidete Oberflächen weisen im Gegensatz zu gemähten eine höhere Diversität in Bezug auf Flora und Fauna auf (DEMARMELS, 1990). Eine durch Beweidung spärliche und vermehrt offen gehaltene Vegetation, wirkt sich positiv auf die Existenz von xero-thermophilen Insekten aus (MORRIS, 1979).

Was wären die Auswirkung einer Beweidung im Rottensand?

Das Steppengebiet würde offen gehalten und vor Verbuschung bewahrt. Durch Trittschäden würde die Bodenoberfläche „beschädigt“, was ein Aufreissen der Moosdecke bedeuten würde.

Für die meisten pflanzenfressenden Insekten wäre es von Bedeutung, bezüglich der Vegetation und der Habitat-Struktur Heterogenität zu erhalten oder zu erschaffen, da dies ein Schlüssel zur Erhöhung der Biodiversität wäre (ROOK *et al.,* 2004).

Der vielleicht wichtigste Mechanismus, durch den weidende Tiere Heterogenität in der Vegetation herbeiführen, ist das selektive Fressen, welches die Konkurrenz zwischen Pflanzenarten verändert (BULLOCK & MARRIOTT, 2000 in ROOK *et al.,* 2004). Ein zweiter Mechanismus betrifft die Trittschäden, welche Nischen für Lücken besiedelnde Arten eröffnen. Ein dritter Mechanismus ist der Nährstoffkreislauf. Ein Effekt hierbei ist die Anreicherung von Nährstoffen in Kot- und Harn-Flecken, dies beeinflusst den Konkurrenzkampf zwischen Arten, sowohl direkt als auch durch einen Rückkopplungseffekt in Bezug auf die Nahrungswahl der Säuger (BOKDAM, 2001 in ROOK *et al.,* 2004). Weidende Säuger spielen auch eine Rolle bei der Verbreitung von Pflanzen durch Sporen und Samen. Die Verbreitung kann entweder endozoochor (d.h. Samen, welche das Verdauungssystem des Tieres passieren) oder exozoochor (d.h. Samen, welche sich im Pelz des Tieres verfangen) erfolgen (BAKKER, 1998 in ROOK *et al.,* 2004).

In Bezug auf die Insektenarten könnten verschiedene Auswirkungen eintreten:

Grabwespen: Blütenpflanzen spielen sowohl als Nektarquelle, als auch für das Vorhandensein von Beutetieren (Larvennahrung) eine wichtige Rolle. Aus diesem Grund sollten sie nicht zu sehr reduziert werden. Das Aufreissen der Moosdecke würde zu einer Vergrösserung der offenen Bodenoberfläche führen, was ein positiver Aspekt wäre. Eine Auflockerung des Sandes ist nicht für alle Grabwespenarten von Vorteil. Speziell *P. kirbii* bevorzugte für das Graben ihrer Nester Stellen auf Fläche B, die weitgehend mit Moos überwachsen waren, weil da der Sand kompakter war.

Heuschrecken: Gemäss KÖHLER & BRODHUN (1987) (in INGRISCH & KÖHLER, 1998), erfolgte bei einer kurzzeitigen Beweidung durch Rinder zunächst eine Verdrängung der Heuschrecken, gefolgt von einer raschen Wiederbesiedlung, vermutlich von den Randbereichen aus. Extensive Beweidung (z.B. mit Rindern) kann sich sowohl neutral als auch positiv auf die Populationen auswirken (WINGERDEN *et al*., 1991 in INGRISCH & KÖHLER, 1998). Für Arten, welche offene Bodenstellen mit Sand und Kies bevorzugen (z.B. *S. caerulans*, *O. caerulescens*) würde eine Reduktion des Moosbewuchses zu einer Verbesserung ihres Habitats führen.

Wanzen: Als Pflanzenfresser sind Wanzen direkt abhängig von der Präsenz ihrer Futterpflanzen. Gemäss MORRIS (1979) (in OTTO, 1996) sind Heteroptera stärker beeinflusst durch Beweidung, wenn diese in der Vegetationsperiode stattfindet, dies aufgrund der Tatsache, dass viele Arten ihre Entwicklung bereits im späten Sommer oder im Herbst abschliessen.

Verschiedene Säugetiere können zur Beweidung eingesetzt werden:

Schafe & Ziegen: Wandernde Schafherden sind effektive Verbreiter von Samen und auch von kleinen Tieren (vor allem Heuschrecken, aber auch Schnecken, Spinnen, Käfer u.a.) und sie tragen zum Austausch von Pflanzen und Tieren zwischen isolierten Flächen, sowie zur Erhaltung der Biodiversität bei (FISCHER *et al*., 1996 in HOLTMEIER, 2002).

Während die Einzäunung von Schafen leicht erfolgen kann, braucht es einen wesentlich grösseren Aufwand um Ziegen-sichere Zäune aufzustellen. Gemäss WALLIS DE VRIES (1995) (in PYKÄLÄ, 2000) ähnelt der Einfluss von Vieh, welches sich im Gegensatz zu eingezäuntem frei bewegen kann, mehr dem natürlichen Muster von Pflanzenfressern. Zum Teil ist dies wegen der Samenverbreitung durch sich frei bewegende Tiere der Fall (FISCHER *et al*., 1996 in HOLTMEIER, 2002). Hinzu kommt, dass sie ihre Aktivitäten nicht nur entlang des Zaunes oder in der Nähe des Tores konzentrieren würden. Schafe und Ziegen fressen Pflanzen viel selektiver als Rinder. Diese Selektivität und ihr Einfluss auf die Biodiversität sind von grösster Wichtigkeit (z.B. OLIVAN & OSORO, 1996; CELAYA et al., 2003 in ROOK *et al.,* 2004). Weil Schafe ein deutliches Herdenverhalten zeigen, wären ihre Auswirkungen auf die Steppen viel augeprägter als diejenigen von Ziegen.

Esel & Pferde: Pferde, welche im Ober- und Unterkiefer Schneidezähne besitzen, können Pflanzen viel näher am Grund abweiden als Rinder und dadurch eine andere Vegetationsstruktur erzeugen (ROOK *et al.,* 2004). Nebst ihren Trittspuren sind Pferdeartige besonders interessant, weil sie gerne Sandbaden, wobei sie vegetationslose, sandige Mulden im Boden erschaffen.

Rinder: Das Beweiden mit Rindern wird, in Bezug auf pflanzliche Biodiversität, als geeigneter erachtet als dasjenige mit Schafen oder Pferden (z.B. JOHANSSON & HEDIN, 1991 in PYKÄLÄ, 2003). Dies hauptsächlich aus dem Grund, dass Rinder weniger selektiv weiden (PYKÄLÄ, 2000 in PYKÄLÄ, 2003). Nicht selektives Nahrungsverhalten führt zu einer Verdrängung von grossen und häufigen Pflanzen, was wiederum die Pflanzendiversität erhöht (HULME, 1996 in PYKÄLÄ, 2000).

Lamas: Gemäss HOLTMEIER (2002) würden Lamas, aufgrund ihrer gepolsterten Hufe, die Bodenoberfläche nicht aufreissen. Sie sind auch bekannt dafür, dass sie harzhaltige Pflanzen wie Koniferen (Kiefer!) meiden (J. ZETTEL, pers. Mitt.).

Saisonale Beweidung: Die Vegetation variiert je nach Jahreszeit in Zusammensetzung und Biomasse. Selektive Beweidung von bestimmten Pflanzen im Sommer könnte den Beweidungsdruck auf andere Arten herabsetzten (GALLET & ROZE, 2001). Während einer Beweidung im Sommer würden viele Blütenpflanzen derart beeinträchtigt, dass sie ihre Bedeutung für Insekten verlieren würden. Grabwespen und Wanzen sind auf Blüten oder reifende Samen angewiesen, welche nach einer späten Beweidung nicht produziert würden. Die Beweidung hat nicht nur einen sofortigen Einfluss zur Folge, sondern kann Pflanzen auch schwächen und so ihre Überwinterungsfähigkeit herabsetzten (BAYFIELD, 1979 in GALLET & ROZE, 2001). GRANT *et al*. (1982) (in GALLET & ROZE, 2001) deutet darauf hin, dass eine Beweidung, welche gegen Ende des Sommers durchgeführt wird, eine Reduktion der Kohlehydratreserven verursachen könnte, was im nächsten Frühling eine negative Auswirkung auf das Wachstum der Pflanze hätte. Eine zusätzliche Fütterung der weidenden Säugetiere müsste zu jeder Jahreszeit erfolgen, da allgemein in den Steppen zu wenig Futter vorhanden ist.

Betrachtet man die zuvor genannten Fakten, sollte die Bewirtschaftung des Habitates durch Beweidung hauptsächlich im Winter, früh im Frühling oder im Spätherbst erfolgen.

Dauer der Beweidung: Die Dauer der Beweidung hängt vom Beweidungsdruck ab, der je nach eingesetztem Vieh variieren kann. Die Vegetation kann eine starke Beweidung ertragen, wenn sie von kurzer Dauer ist (GRANT *et al*., 1982 in GALLET & ROZE, 2001). Bei einem mittleren Beweidungsdruck sind die Tiere eher im Stande, bevorzugte Pflanzen zu wählen, was zu einer erhöhten Biodiversität führen kann (MILNE & OSORO, 1997 in ROOK *et al.*, 2004). Die zwei Flächen A und B werden auch von Rothirschen und anderen wilden Säugetieren (z.B. Feldhasen) beweidet, somit existiert bereits ein minimaler Beweidungsdruck. Einzelne Pferdespuren veranschaulichen, dass schon ein einmaliges Durchqueren genügen kann, um die Moosdecke ausreichend zu zerstören, um den Standort für bestimmte Grabwespen wieder attraktiv zu machen.

Eine rotierende Beweidungsform kann auch in Betracht gezogen werden. Jede Art hat verschiedene Ansprüche und eine rotierende Bewirtschaftungsform erlaubt die Erhaltung der maximalen Gesamtheit von Invertebraten und Pflanzenarten (CHAMBERS & SAMWAYS, 1998 in GEBEYEHU & SAMWAYS, 2003). In der Studie von GALLET & ROZE (2001) wiesen solche Flächen, verglichen mit saisonaler Beweidung, eine signifikant höhere Reichhaltigkeit und Abundanz der Gräser auf, was zu einer höheren Diversität der Heuschrecken führte.

Gemäss PYKÄLÄ (2000) beinhaltet das optimale Bewirtschaftungssystem durch Beweidung zur Erhaltung der Biodiversität eine schwierige Kombination von Fortbestand (ähnlicher Beweidungsdruck während längerer Zeit) wie auch Stochastizität (Veränderungen im Beweidungsdruck, rotierende Beweidung, Abbruch und Wiederaufnahme der Beweidung) und die Verwendung von verschiedenen Weidegängern über eine Vielfalt von räumlichen und zeitlichen Massstäben.

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7. Tables

Tab. 1: Conversion and extension of BRAUN-BLANQUET (1964) scale of coverage to percentage and classes.

Class	Cover in %	Braun-Blanquet
1	1 specimen	r
2	< 1%	+
3	1	
4	2	1
5	3-4	
6	5	
7	5-10	
8	10-15	2
9	15-20	
10	20-25	
11	25-50	3
12	50	
	50-75	4
	75-100	5

Tab. 2a: Plant cover per plot in site A. Key to numbers see Tab. 1.

= species recorded only on site A

= most common dicotyledonous herbs

Family	Species/plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	median
Poaceae	Grasses sp.	5	8	7	5	8	8	5	7	8	8	2	8	5	2	5	5	5	5	6	5	5	5	5	5	6	5	8	9	8	4	3.5
	Stipa pennata	5	5	5	2	5	5	5	2				5	2	2	2	5	2	2	5	5	5	4	8	8	6	5	5		5		3.5
Asteraceae	*Artemisia campestris*	8	9	8	7	8	8	8	8	8	8	7	8	7	7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	12.5
	Centaurea vallesiaca	2	2	2			2	2	5	4	2	2		2	2	2	2	2		2	2	2	2	1	4		2	2	2	5	5	0.5
	Hieracium piloselloides										2	2		2		2								2					2	2	5	0.5
	Hieracium staticifolium																								2							0.5
	Scorzonera austriaca																															0
Berberidaceae	*Berberis vulgaris*																															0
Boraginaceae	*Echium vulgare*											2																				0.5
Brassicaceae	*Erucastrum nasturtiifolium*			1			5					4					2						2	2	2					2		0.5
	Erysimum rhaeticum	2		6	2				1								2															0.5
Caryophyllaceae	*Arenaria leptoclados*										2			2																		0.5
	Gypsophila repens			2					5			2	2	5	5		2	2	5	8	5	4	5	8	10	8	8	8	5			3.5
	Herniaria glabra																															0
	Petrorhagia saxifraga						1	2								2	2	2		2	1	1		2	2			2			2	0.5
	Saponaria ocymoides																													3		1
	Silene otites	2		5	2	5	5	5		2			5	4		2	5	2		2	4	5			3	2	2	3		5	2	1
Cistaceae	*Helianthemum nummularium*	7	5	5	4	5	2			2	5	2	2	2		5	1	2		2	2	2	2	1		2		5	5		5	0.5
Crassulaceae	*Sedum album*																										4					2
	Sedum montanum						2	5																								2
Euphorbiaceae	*Euphorbia seguieriana*	4	5	2	2		2			5	2	4	4		5	5	4	2	5	6	5	5	5	5	5	5	5	5	7	5	7	3.5
Fabaceae	*Astragalus monspessulanus*		2								2																		5			2
	Astragalus onobrychis	8	9	9	7	8	7	7	9	9	8	7	8	8	8	8	8	8	8	8	8	8	8	5	7	8	8	8	9	9	9	12.5
Globulariaceae	*Globularia punctata*																															0
Lamiaceae	*Teucrium montanum*																															0
	Thymus praecox		7	7	4		2	6	2			4		8	8	4	2		5	5	5	5	2		2	5	5	6	2	2	5	3.5
Liliaceae	*Allium sphaerocephalon*																															0
	Muscari comosum																															0
Onagraceae	*Epilobium dodonaei*	2	2					4	4	5		2																				2
Orchidaceae	*Orchis morio*																															0
Rosaceae	*Potentilla pusilla*																															0
Rubiaceae	*Asperula aristata*												2								1		3	2	2	2	2				2	0.5
	Galium lucidum				2															2					2	2						0.5
Scrophulariaceae	*Odontites luteus*	2	2	2	2	2	2	2	2	2	2		2	2		2	2		5	2	2	2	5	2	2	2	2	5	2	5		0.5
Betulaceae	*Betula pendula*																			8												12.5
Cupressaceae	*Juniperus communis*												5																			3.5
Fagaceae	*Quercus pubescens*					8																										12.5
Pinaceae	*Pinus sylvestris*					5									5				5				9									3.5
Salicaceae	*Populus nigra*	7	2	2	5	8			8	10	6	6	8	2	6		5	5	5	2	4		2					2			5	3.5
	Salix alba													2	5								2					5				2
	Salix purpurea														2																	0.5

Tab. 2b: Plant cover per plot in site B. Key to numbers see Tab. 1.

(dark grey) = species recorded only on site B

(light grey) = most common dicotyledonous herbs

Family	Species/plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	median
Poaceae	Grasses sp.	5	6	5	5	5	5	3	8	5	5	8	8	8	2	5	11	10	12	5	5	5	5			11	9	8	8	4		3.5
	Stipa pennata	5	2	5	2	8	5	5	5	2	5	8	5	3	5	5	8	8		2	5	8	5	8	8	5	5	2	2	5	5	3.5
Asteraceae	*Artemisia campestris*	8	8	8	6	8	8	8	8	9	8	9	9	9	8	9	8	8	8	9	9	11	8	8	8	10	11	8	8	9	9	12.5
	Centaurea vallesiaca	5	5	3	2	6	6	2	5	2	2		2				5		1	1	1			1	5			2				0.5
	Hieracium piloselloides	2	2		2	5	3		2		3		2		2	2			2	2	2	2	5	1	1		2	5			2	0.5
	Hieracium staticifolium																															0
	Scorzonera austriaca																5	5														3.5
Berberidaceae	*Berberis vulgaris*																8															12.5
Boraginaceae	*Echium vulgare*					5			1													5								5		3.5
Brassicaceae	*Erucastrum nasturtiifolium*			2	5			1	1		1												2									0.375
	Erysimum rhaeticum							2															2		1					2		0.5
Caryophyllaceae	*Arenaria leptoclados*																					5	2	2	5					2	5	2
	Gypsophila repens																															0
	Herniaria glabra																						1	1							1	0.25
	Petrorhagia saxifraga	2		2	2	2	2	2		2	5	2		4	5	4	2	1	2	4	4	5	4	4	5	1	1	4	2	5	5	0.5
	Saponaria ocymoides																															0
	Silene otites	6	2	2	5	2	5	2	5	5	5		2	2	5	5		5		5	5	5	5	8	1		2	5	5	5	2	3.5
Cistaceae	*Helianthemum nummularium*			2		5	2	6	2	2		2					5	5				2		1	1	2	2					0.5
Crassulaceae	*Sedum album*																						2	5								2
	Sedum montanum																															0
Euphorbiaceae	*Euphorbia seguieriana*	5	5	5	5	5	5		2	5	5		5	5	5	2			6	5	2	2						2	5	5		3.5
Fabaceae	*Astragalus monspessulanus*																															0
	Astragalus onobrychis	8	8	8	5	8	8	8	8	8	9	9	5	8	9	9	8	8	8	8	8	8	8	8	8	8	8	5	8	5	8	12.5
Globulariaceae	*Globularia punctata*																2															0.5
Lamiaceae	*Teucrium montanum*															8						2	8	8	8					8	9	12.5
	Thymus praecox	5		2	5					2	8			2		2				2	2	1	5	1	2					2	5	0.5
Liliaceae	*Allium sphaerocephalon*						6																									5
	Muscari comosum																2															0.5
Onagraceae	*Epilobium dodonaei*								2																							0.5
Orchidaceae	*Orchis morio*						1																									0.25
Rosaceae	*Potentilla pusilla*							2		2	2	5	2			2	2	2		2	5	8	1	2	5			5	5	6	5	0.5
Rubiaceae	*Asperula aristata*															2						2	5	2	2					2	2	0.5
	Galium lucidum	1																													5	1.875
Scrophulariaceae	*Odontites luteus*		2	2	2	2	2	2	2	2	2	3	2	2	2	2			2		2	2			1	5		2		5	2	0.5
Betulaceae	*Betula pendula*																															0
Cupressaceae	*Juniperus communis*																8															12.5
Fagaceae	*Quercus pubescens*																															0
Pinaceae	*Pinus sylvestris*																															0
Salicaceae	*Populus nigra*																															0
	Salix alba																															0
	Salix purpurea																								5							3.5

Tab. 3: Flowering periods of the recorded plants. Families and species listed in alphabetical order.
B = Begin; M = Mid; E = End

Family	Species	E April	B May	M May	E May	B June	M June	E June	B July	M July	E July	B Aug	M Aug	E Aug	B Sept
Asteraceae	*Artemisia campestris*										x	x	x	x	x
	Centaurea vallesiaca							i	x	x	i	i	i	i	i
	Hieracium piloselloides						x	x	x	i	i	i	x	i	i
	Hieracium staticifolium				x	x	i								
	Scorzonera austriaca		x	x											
Berberidaceae	*Berberis vulgaris*			x	x										
Boraginaceae	*Echium vulgare*						x	x							
Brassicaceae	*Erucastrum nasturtiifolium*		x	x											
	Erysimum rhaeticum			x	x	x	x	i							
Caryophyllaceae	*Arenaria leptoclados*		x	x	x	x	x	i	i	i					
	Gypsophila repens			x	x	x	x	x						x	x
	Herniaria glabra						x	x	x	x	x				
	Petrorhagia saxifraga												x	x	x
	Saponaria ocymoides			x	x										
	Silene otites						x	x	i	i				x	x
Cistaceae	*Helianthemum nummularium*			i	x	x	x	x	x	i	i	i	i	i	i
Crassulaceae	*Sedum album*							x	x	x	i	i			
	Sedum montanum							x	i						
Cupressaceae	*Juniperus communis*	x													
Euphorbiaceae	*Euphorbia seguieriana*		x	x	x	x	x	x	x	i					
Fabaceae	*Astragalus monspessulanus*		x	x											
	Astragalus onobrychis				x	x	x	i							
Globulariaceae	*Globularia punctata*		x	x											
Lamiaceae	*Teucrium montanum*						x	x	x	x	i				
	Thymus praecox						x	x	x	x	i	i	i	i	i
Liliaceae	*Allium sphaerocephalon*							x	x	i					
	Muscari comosum		x												
Onagraceae	*Epilobium dodonaei*									x	x	x	x	i	i
Orchidaceae	*Orchis morio*		x												
Rosaceae	*Potentilla pusilla*		x	x	x										
Rubiaceae	*Asperula aristata*							x	x	x	x	x	x	x	x
	Galium lucidum						x	i							
Scrophulariaceae	*Odontites luteus*										x	x	x	x	x

x = flowering
i = single flowers

Tab. 4a: Different surface parameters on site A (percentage per plot).

plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total	mean
moss	10	2.5	2.5	15	20	30	25	20	10	15	10	15	15	10	15	10	2.5	2.5	15	10	5	2.5	15	15	15	15	10	5	2.5	2.5	342.5	11.4
grass	5	5	5	5	15	10	2.5	5	15	10	2.5	5	2.5	5	5	5	2.5	2.5	5	2.5	2.5	2.5	15	15	5	2.5	5	10	5	2.5	702.5	6.0
dicot. herbs	20	25	15	10	15	15	10	10	10	10	5	10	10	10	15	15	10	10	10	10	10	5	5	10	10	10	25	25	20	25		13.0
shrubs <1	10	2.5	0	2.5	2.5	0	0	5	10	5	5	15	0	5	0	0	0	0	0	2.5	0	0	0	0	0	0	5	0	0	5		2.5
shrubs >1	0	0	0	0	10	0	0	0	10	0	0	0	0	5	0	5	5	2.5	10	0	0	10	0	0	0	0	0	0	0	0		1.9
blocks	2.5	0	0	5	0	0	0	0	0	2.5	0	0	2.5	5	5	5	0	10	15	5	10	30	5	10	35	10	10	10	30	0	1355	6.9
stones	0	0	0	2.5	0	2.5	5	5	2.5	5	15	5	15	10	5	5	15	10	10	15	15	10	15	20	15	25	10	2.5	10	10		8.7
coarse gravel	0	5	5	5	0	0	5	0	0	0	20	15	25	15	20	15	25	10	15	15	15	5	5	5	5	15	5	5	15	25		9.8
fine gravel	2.5	15	20	15	0	0	5	5	2.5	5	10	0	10	0	5	0	0	10	2.5	15	15	5	5	2.5	0	0	2.5	0	5	10		5.6
sand	10	15	30	15	15	5	25	20	10	20	25	25	10	20	20	20	25	30	2.5	10	10	15	5	0	2.5	10	5	20	0	5		14.2
litter	25	25	20	20	20	35	20	20	25	25	5	10	10	10	10	15	10	10	10	15	15	10	25	20	10	10	20	20	10	10	600	16.3
dead wood	15	5	2.5	5	2.5	2.5	2.5	10	5	2.5	2.5	0	0	5	0	5	5	2.5	5	0	2.5	5	5	2.5	2.5	2.5	2.5	2.5	2.5	5		3.7

Tab. 4b: Different surface parameters on site B (percentage per plot).

plots	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total	mean
moss	20	40	40	45	20	5	35	20	15	10	20	15	20	30	35	10	15	20	50	55	38	35	45	35	20	35	45	45	35	30	882.5	29.4
grass	10	10	5	2.5	20	15	5	15	15	10	20	10	10	2.5	5	25	20	10	2.5	5	5	5	10	10	25	15	10	2.5	5	5	730	10.3
dicot. herbs	15	10	15	10	10	15	15	15	15	10	20	20	20	15	15	5	15	15	10	15	15	10	10	10	10	15	10	10	10	10		13.0
shrubs <1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0.0
shrubs >1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	10	0	0	0	0	0	0		1.0
blocks	5	0	0	5	2.5	2.5	0	0	5	0	0	2.5	0	2.5	5	0	0	0	0	0	2.5	0	0	5	0	0	0	0	2.5	5	365	1.5
stones	0	2.5	0	0	0	0	0	0	0	5	0	2.5	2.5	5	10	0	2.5	2.5	10	2.5	5	10	5	5	0	0	2.5	0	0	5		2.6
coarse gravel	0	0	0	0	0	0	0	0	0	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10		0.7
fine gravel	0	2.5	0	0	0	0	0	0	0	15	0	0	5	20	10	0	0	0	10	2.5	5	35	15	15	0	0	0	0	2.5	15		5.1
sand	25	5	5	10	2.5	5	0	5	0	0	0	0	0	0	0	2.5	2.5	0	0	0	0	0	0	0	5	0	2.5	0	0	0		2.3
litter	25	30	35	25	45	55	45	45	50	35	40	50	40	15	15	35	45	50	15	15	20	5	15	10	40	35	30	40	35	15	1022.5	31.8
dead wood	0	0	0	2.5	0	2.5	0	0	0	10	0	0	2.5	5	5	2.5	0	2.5	2.5	5	10	0	0	0	0	0	0	2.5	10	5		2.3

Tab. 5: Time schedule of the five sampling series.

sampling	Site A	Site B
1	28.6.04 – 30.6.04	25.6.04 – 30.6.04
2	14.7.04 – 19.7.04	15.7.04 – 20.7.04
3	27.7.04 – 3.8.04	28.7.04 – 3.8.04
4	9.8.04 – 13.8.04	10.8.04 – 12.8.04
5	23.8.04 – 1.9.04	25.8.04 – 2.9.04

Tab. 6: Sum of observations of the Sphecidae species monitored on site A and B. Nomenclature after DOLLFUSS (1991).

	Site A	Site B	Total	%
Prionyx kirbii (VANDER LINDEN, 1827) (=*Sphex albisectus*, Lepeletier & Serville, 1825)	140	258	398	77.6
Sphex rufocinctus (BRULLE, 1832) (=*S. maxillosus*, Fabricius, 1793)	3	0	3	0.6
Ammophila terminata (SMITH, 1856) (=*A. apicalis*, Brulle, 1839)	14	36	50	9.7
Ammophila sabulosa (LINNAEUS, 1758)	2	1	3	0.6
Ammophila sp.	31	28	59	11.5
Total	**190**	**323**	**513**	

Tab. 7: Sum of observations of all Orthoptera species monitored on site A and B. Families and species listed in alphabetical order, nomenclature after CORAY & THORENS (2001). Ecological indications after DETZEL (1998). Details to the red list of Switzerland (southern part) after THORENS & NADIG (1997), with:
1 = threatened by extinction, 2 = strongly endangered, 3 = endangered and
4 = non endangered.

Family	Species	Site A	Site B	Total	%	Ecology	Habitat	Red list for CH
Phaneropteridae	*Phaneroptera falcata* (PODA, 1761)	2	3	5	0.1	thermophil	mesotop	2
Tettigoniidae	*Platycleis (Platycleis) albopunctata albopunctata* (GOEZE, 1778)	172	222	394	9.3	xerophil	stenotop	3
	Tettigonia viridissima (LINNE, 1758)	0	1	1	0.0	thermophil	eurytop	4
Oecanthidae	*Oecanthus pellucens* (SCOPOLI, 1763)	14	23	37	0.9	thermophil	mesotop	4
Acrididae (incl. Catantopidae)	*Calliptamus italicus* (LINNE, 1758)	784	618	1402	33.1	xerophil	highly stenotop	3
	Chorthippus vagans (EVERSMAN, 1848)	105	7	112	2.6	xerophil	mesotop	3
	Chorthippus brunneus (THUNBERG, 1815)	24	8	32	0.8	poly-eurypotent	mesotop	4
	Chorthippus mollis mollis (CHARPENTIER, 1825)	1	0	1	0.0	xerophil	stenotop	4
	Chorthippus sp.	196	188	384	9.1			
	Oedipoda caerulescens (LINNE, 1758)	1444	280	1724	40.7	temperate xerophil	stenotop	3
	Oedipoda germanica (LATREILLE, 1804)	2	0	2	0.0	xerophil	stenotop	3
	Sphingonotus caerulans (LINNE, 1767)	55	11	66	1.6	xerophil	stenotop	1
Mantidae	*Mantis religiosa* (LINNE, 1758)	28	51	79	1.9	thermophil	mesotop	not included

Tab. 8: Sum of observations of all Heteroptera species monitored on site A and B. Families and species listed in alphabetical order, nomenclature after GÜNTHER & SCHUSTER (2000). Specification for diet after WAGNER (1952, 1966, 1967) and PÉRICART (1998), with: z = zoophagous or partly zoophagous, p = phytophagous, pp = monophagous. Details to the red list of Germany according to GÜNTHER *et al*. (1998), with: 0 = extinct or lost (in Germany), 1 = threatened by extinction, 2/3 = endangered or strongly endangered, G = probably endangered (status unknown) and V = species on the advanced warning list.

(dark grey box) = species occurred only on site A

(light grey box) = species occurred only on site B

Tab. 8:

		Site A		Site B				
Family		adult	larvae	adult	larvae	Diet	Red list	Ecology
Alydidae	*Alydus calcaratus* (LINNAEUS, 1758)	20	1	33		p		xero-thermophilic
	Camptopus lateralis (GERMAR, 1817)	15	1	43		p	G	xero-thermophilic
	larvae		1		3			
	Total	**35**	**3**	**76**	**3**			
Coreidae	*Bothrostethus annulipes* (SCHAEFFER, 1835)	1				p	0	
	Coriomeris denticulatus (SCOPOLI, 1763)	3		1		p		xerophilic
	Gonocerus acuteangulatus (GOEZE, 1778)	1				p		
	Syromastes rhombeus (LINNAEUS, 1767)	2		6		pp		thermophilic
	larvae		1		27			
	Total	**7**	**1**	**7**	**27**			
Lygaeidae	*Emblethis verbasci* (FABRICIUS, 1803)	7		14				xero-thermophilic
	Gonianotus marginepunctatus (WOLFF, 1804)	5		5				
	Lygaeosoma sardeum sardeum (SPINOLA, 1837)			1			1	xero-thermophilic
	Lygaeus equestris (LINNAEUS, 1758)			2		pp		meso-xerophilic
	Nysius ericae ericae (SCHILLING, 1829)	42		55		p		xero-thermophilic
	Ortholomus punctipennis (HERRICH-SCHAEFFER, 1838)			1		p		xero-thermophilic
	Rhyparochromus pini (LINNAEUS, 1758)			1		p		meso-thermophilic
	Spilostethus pandurus (SCOPOLI, 1763)	1				p		
	Trapezonotus (Trapezonotus) arenarius arenarius (LINNAEUS, 1758)			3				xerophilic
	Xanthochilus quadratus (FABRICIUS, 1798)			1				xero-thermophilic
	larvae		1		2			
	Total	**55**	**1**	**83**	**2**			
Miridae	*Adelphocoris lineolatus* (GOEZE, 1778)	2				p		
	Lygus gemellatus gemellatus (HERRICH-SCHAEFFER, 1835)	18		46		pp		
	Total	**20**	**0**	**46**	**0**			
Pentatomidae	*Aelia acuminata* (LINNAEUS, 1758)	1		4		pp		
	Aelia rostrata (BOHEMAN, 1852)			1		pp	0	
	Carpocoris fuscispinus (BOHEMAN, 1849)	11		48		pp		xero-thermophilic
	Carpocoris pudicus (PODA, 1761)	1		4		p	2/3	xero-thermophilic
	Dolycoris baccarum (LINNAEUS, 1758)	2		10		p		
	Eurydema ornata (LINNAEUS, 1758)	32		8		p		
	Piezodorus lituratus (FABRICIUS, 1794)	1		5		pp		
	Pitedia pinicola (MULSANT & REY, 1852)	1				pp		
	Sciocoris (Sciocoris) cursitans cursitans (FABRICIUS, 1794)	1				p		
	Staria lunata lunata (HAHN, 1835)			2		p	2/3	xero-thermophilic
	larvae		3		41			
	Total	**50**	**3**	**82**	**41**			
Reduviidae	*Coranus aegyptius* (FABRICIUS, 1775)	1		12		z		
	Coranus (Coranus) subapterus (DE GEER, 1773)			1		z		
	Coranus sp.			3		z		
	Phymata (Phymata) crassipes (FABRICIUS, 1775)	1				z	2/3	xero-thermophilic
	Rhynocoris (Rhynocoris) iracundus (PODA, 1761)	3		19		z	V	xero-thermophilic
	larvae		1		5			
	Total	**5**	**1**	**35**	**5**			
Rhopalidae	*Chorosoma schillingii* (SCHUMMEL, 1829)	3		8		pp		
	Myrmus miriformis miriformis (FALLEN, 1807)	5		2		pp		
	Rhopalus (Rhopalus) parumpunctatus (SCHILLING, 1829)			2		p		
	Stictopleurus abutilon abutilon (ROSSI, 1790)			1		p		
	Total	**8**	**0**	**13**	**0**			
Scutelleridae	*Eurygaster maura* (LINNAEUS, 1758)	7		23		m		slightly thermophilic
	Eurygaster testudinaria testudinaria (GEOFFROY, 1785)			1		m		
	Odontotarsus purpureolineatus (ROSSI, 1790)	2		12		pp	2/3	xero-thermophilic
	larvae				3			
	Total	**9**	**0**	**36**	**3**			
Stenocephalidae	*Dicranocephalus albipes* (FABRICIUS, 1781)			2		pp	1	xero-thermophilic
	larvae		1		1			
	Total	**0**	**1**	**2**	**1**			

Tab. 9: Sum of observed activities of *Prionyx kirbii* and *Ammophila sp.* monitored on site A and B. Dominance index D_i calculated after MÜHLENBERG (1993).

	Site A		Site B	
	P. kirbii	*Ammophila sp.*	*P. kirbii*	*Ammophila sp.*
Total number	140	45	258	64
Dominance index D_i	75.7	24.3	80.1	19.9
Flying	59	27	122	36
Flower visits	56	16	68	18
Digging a nest	19	1	51	4
Prey transporting	2	1	11	2

Tab. 10a: Sum of Heteroptera observed on different host plants on site A. Families and species listed in alphabetical order.

[grey box] = species observed with a large number of individuals on a specific host plant.

	Art. campes	*Ast. onobry*	*Cen. valles*	*Epi. dodona*	*Eru. nasturt*	*Eup. seguie*	grass	*Odo. luteus*	*Sil. otites*	**Total**
Alydidae										
Alydus calcaratus	1	2								**3**
Camptopus lateralis	2	3					3			**8**
larvae	1	1								**2**
Coreidae										
Coriomeris denticulatus		2								**2**
Syromastes rhombeus									2	**2**
larvae		1								**1**
Lygaeidae										
Nysius ericae	1		41							**42**
Miridae										
Adelphocoris lineolatus							1	1		**2**
Lygus gemellatus	14						2			**16**
Pentatomidae										
Aelia acuminata							1			**1**
Eurydema ornata	1	1			28					**30**
Carpocoris fuscispinus			9					1		**10**
Carpocoris pudicus			1							**1**
Dolycoris baccarum			2							**2**
Pitedia pinicola	1									**1**
larvae	1				1					**2**
Reduviidae										
Phymata crassipes							1			**1**
Rhynocoris iracundus							4			**4**
Rhopalidae										
Chorosoma schillingii							2			**2**
Myrmus miriformis				2				2		**4**
Scutelleridae										
Eurygaster maura			3				4			**7**
Odontotarsus purpureolineatus			2							**2**
Stenocephalidae										
Dicranocephalus albipes						1				**1**
Total	**22**	**10**	**58**	**2**	**29**	**1**	**18**	**4**	**2**	**146**

Tab. 10b: Sum of Heteroptera observed on different host plants on site B. Families and species listed in alphabetical order.

[grey box] = species observed with a large number of individuals on a specific host plant.

	All. sphaer.	*Art. campes*	*Ast. onobry*	*Cen. valles*	*Epi. dodona*	*Ery. rhaeti*	*Eup. seguie*	grass	*Hie. pilose*	*Odo. luteus*	*S. otites*	*Teu. montan*	**Total**
Alydidae													
Alydus calcaratus		1	4					1					**6**
Camptopus lateralis		2	18					1		1	1		**23**
larvae		7	18	1				3					**29**
Coreidae													
Coriomeris denticulatus								1					**1**
Syromastes rhombeus											3		**3**
Lygaeidae													
Lygaeus equestris					1				1				**2**
Lygaeosoma sardeum											1		**1**
Nysius ericae		1	1	51		2							**55**
Rhyparochromus pini								1					**1**
Trapezonotus arenarius				3									**3**
larvae				2									**2**
Miridae													
Lygus gemellatus		25		3				3			10		**41**
Pentatomidae													
Aelia acuminata		1						3					**4**
Aelia rostrata								1					**1**
Eurydema ornata		1	2			2				1	2		**8**
Carpocoris fuscispinus	1	2	10	30				4			1		**48**
Carpocoris pudicus			1	1							2		**4**
Dolycoris baccarum				3				3		2			**8**
Piezodorus lituratus		1	3					1					**5**
Staria lunata				2									**2**
larvae	3	1	9	14			1	8		1	2		**39**
Reduviidae													
Coranus aegyptius		1	1										**2**
Rhynocoris iracundus		1	1	2				1			14		**19**
larvae												2	**2**
Rhopalidae													
Chorosoma schillingii								6					**6**
Myrmus miriformis			1					1					**2**
Rhopalus parumpunctatus											1		**1**
Stictopleurus abutilon			1										**1**
Scutelleridae													
Eurygaster maura		2		17				3					**22**
Odontotarsus purpureolineatus		1		9			2						**12**
larvae				3									**3**
Stenocephalidae													
Dicranocephalus albipes		1											**1**
larvae		1											**1**
Total	**4**	**49**	**70**	**141**	**1**	**4**	**3**	**41**	**1**	**5**	**37**	**2**	**358**

8. Figures

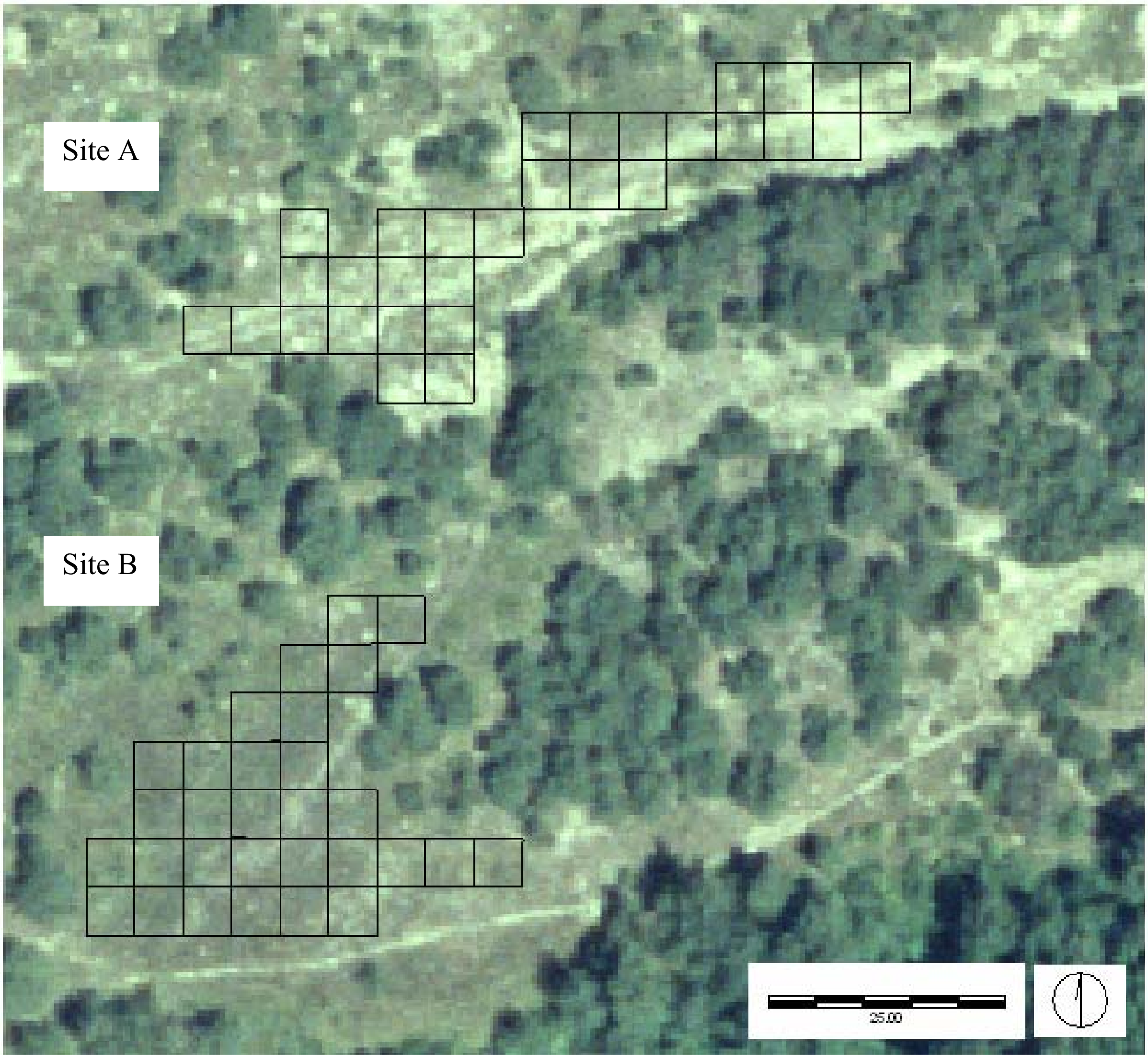

Fig. 1: Aerial photograph with the two study sites in the Rottensand. Grid: 5x5m.

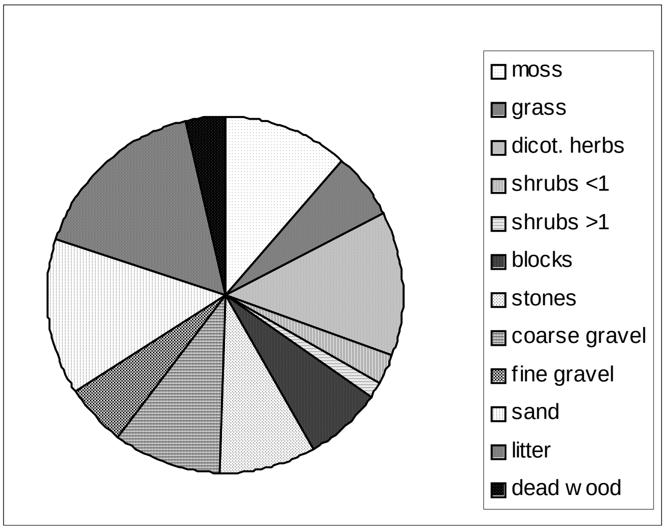

Fig. 2a: Percentage of the different habitat parameters pooled over all plots for site A. For details see Tab. 4a.

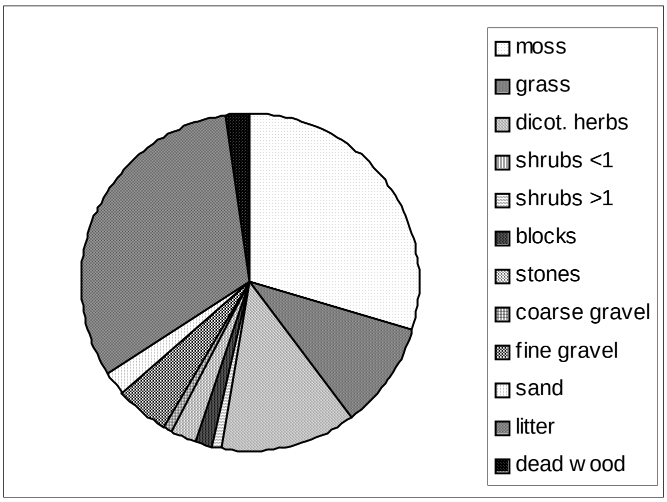

Fig. 2b: Percentage of the different habitat parameters pooled over all plots for site B. For details see Tab. 4b.

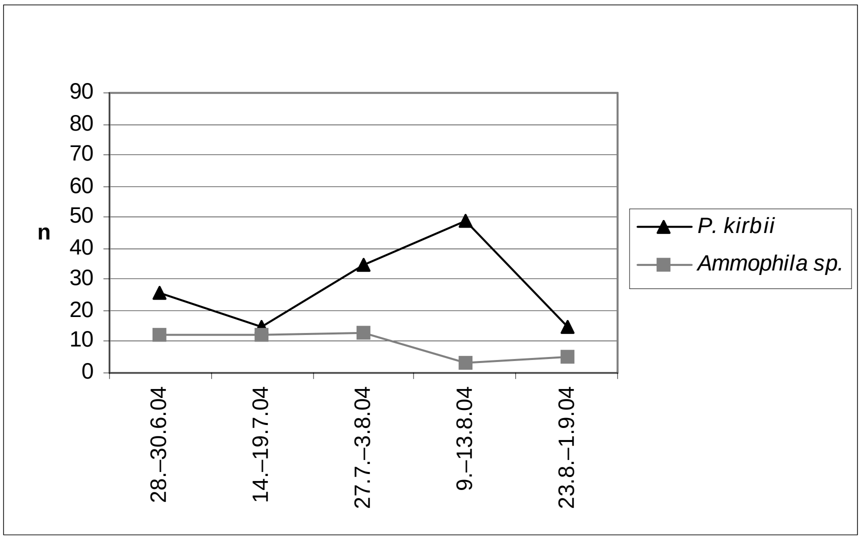

Fig. 3a: Phenology of *Prionyx kirbii* and *Ammophila sp.*: total number of observations per sampling series on site A.

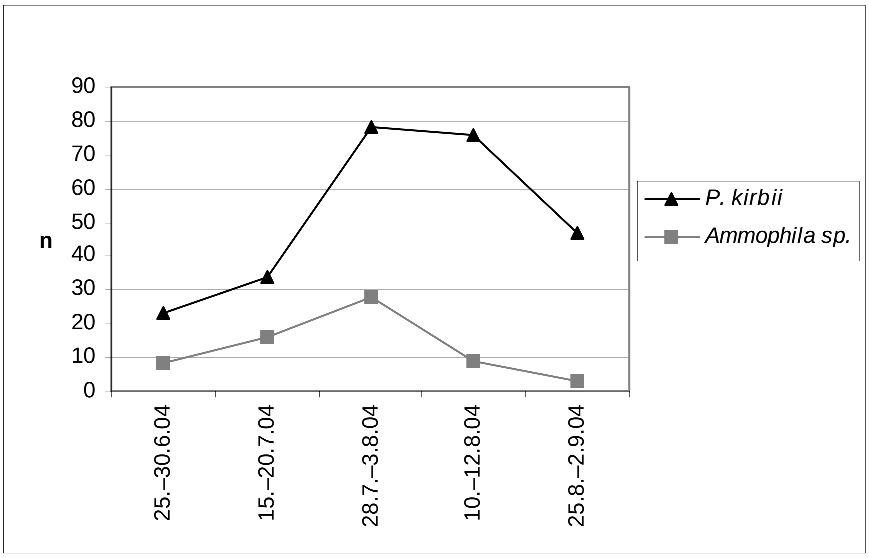

Fig. 3b: Phenology of *Prionyx kirbii* and *Ammophila sp.*: total number of observations per sampling series on site B.

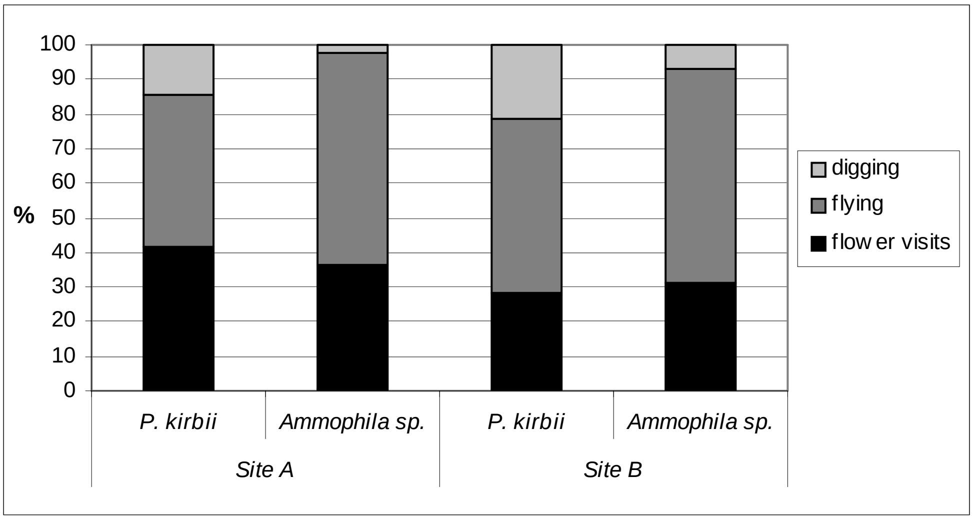

Fig. 4: Percentage of three different activities recorded for *Prionyx kirbii* and *Ammophila sp*. on sites A and B. Data pooled over all sampling series.

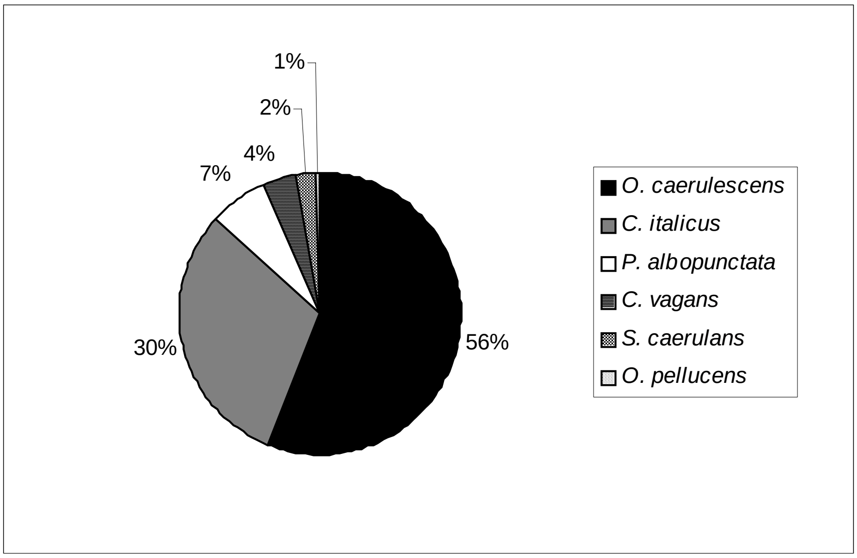

Fig. 5a: Relative abundance of the Saltatoria (adults and larvae) on site A. Mean values for the 30 plots pooled over all sampling series.

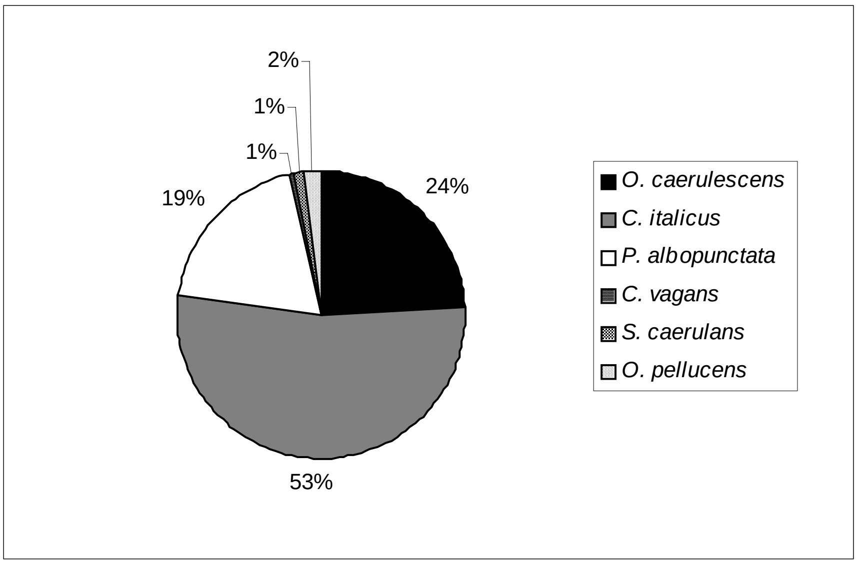

Fig. 5b: Relative abundance of the Saltatoria (adults and larvae) on site B. Mean values for the 30 plots pooled over all sampling series.

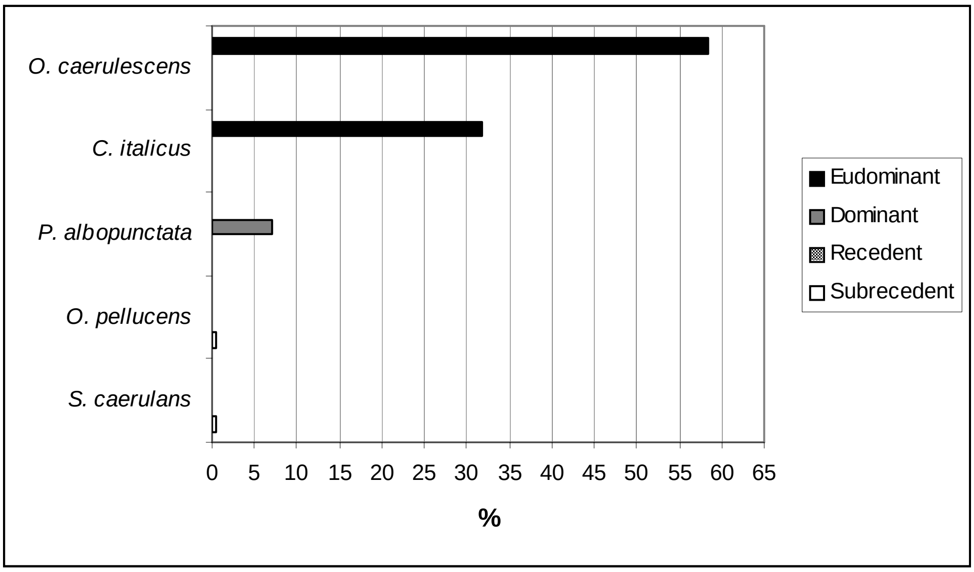

Fig. 6a: Dominance structure for Saltatoria (adults and larvae) on site A. Dominance index D_i after MÜHLENBERG (1993).

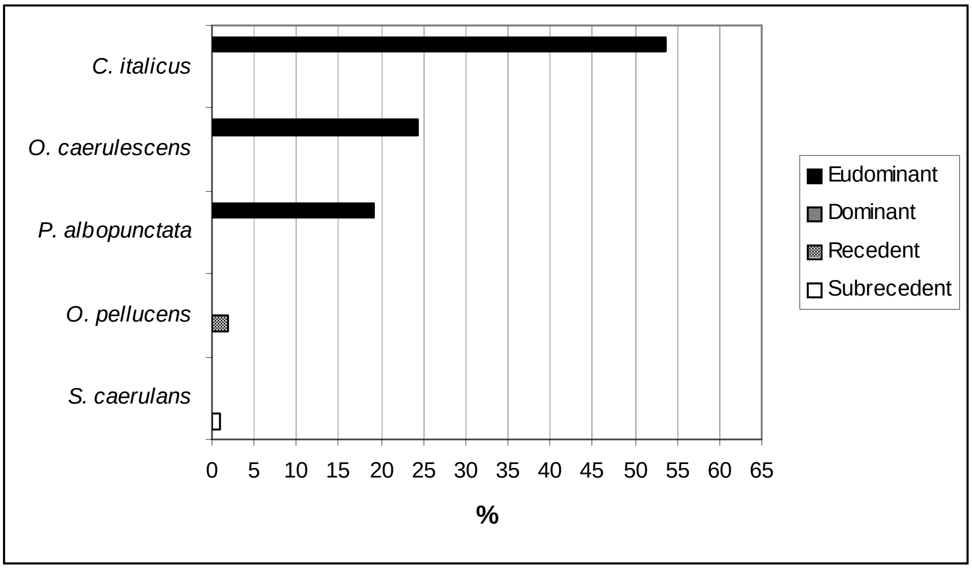

Fig. 6b: Dominance structure for Saltatoria (adults and larvae) on site B. Dominance index D_i after MÜHLENBERG (1993).

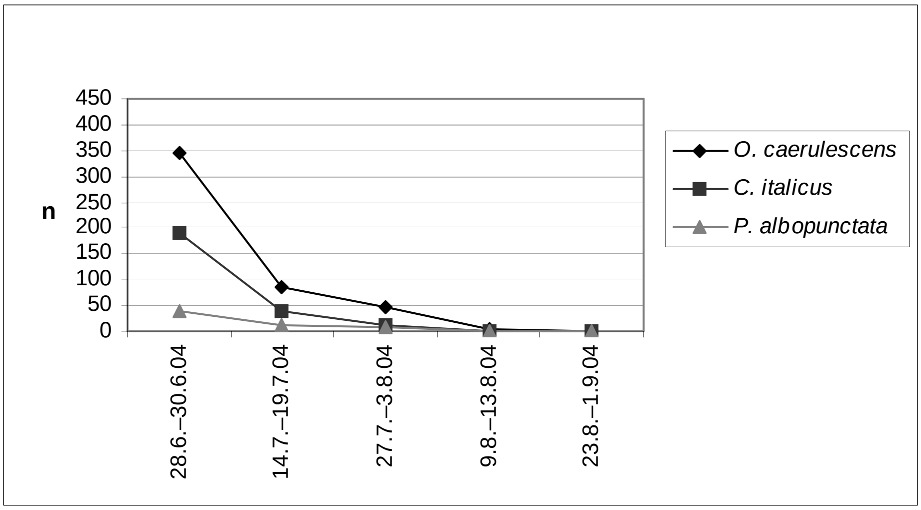

Fig. 7a: Phenology of the three most abundant Saltatoria species (larvae) on site A. Values of all plots pooled.

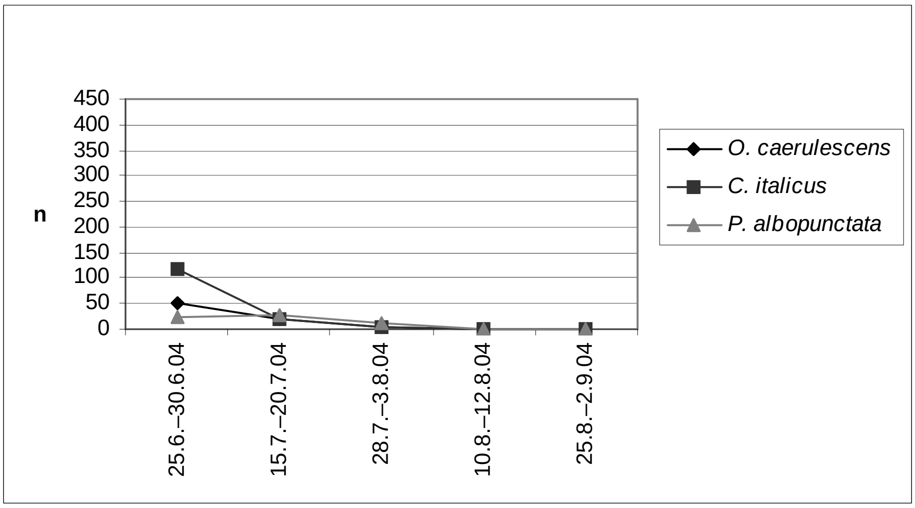

Fig. 7b: Phenology of the three most abundant Saltatoria species (larvae) on site B. Values of all plots pooled.

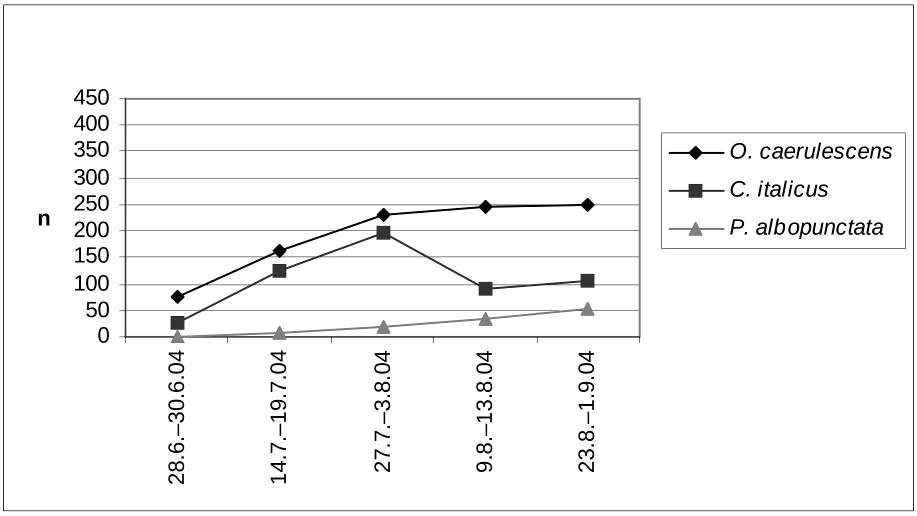

Fig. 8a: Phenology of the three most abundant Saltatoria species (adults) on site A. Values of all plots pooled.

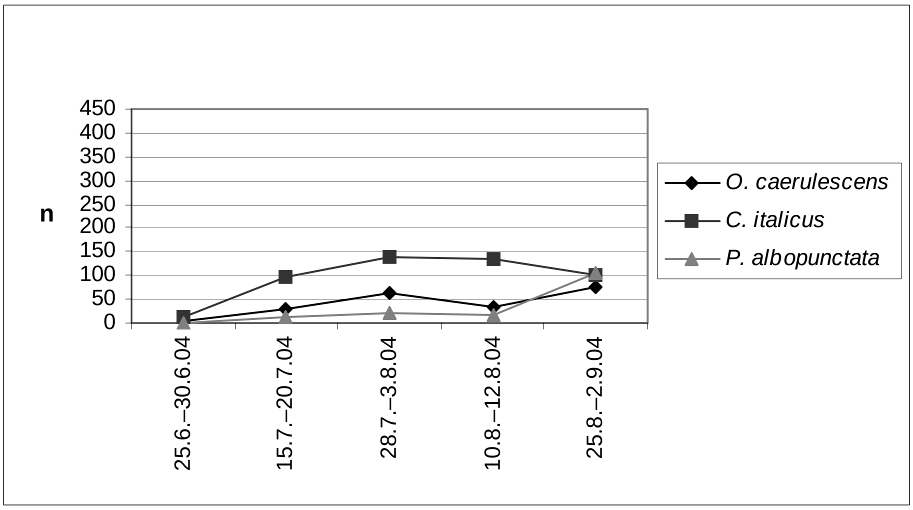

Fig. 8b: Phenology of the three most abundant Saltatoria species (adults) on site B. Values of all plots pooled.

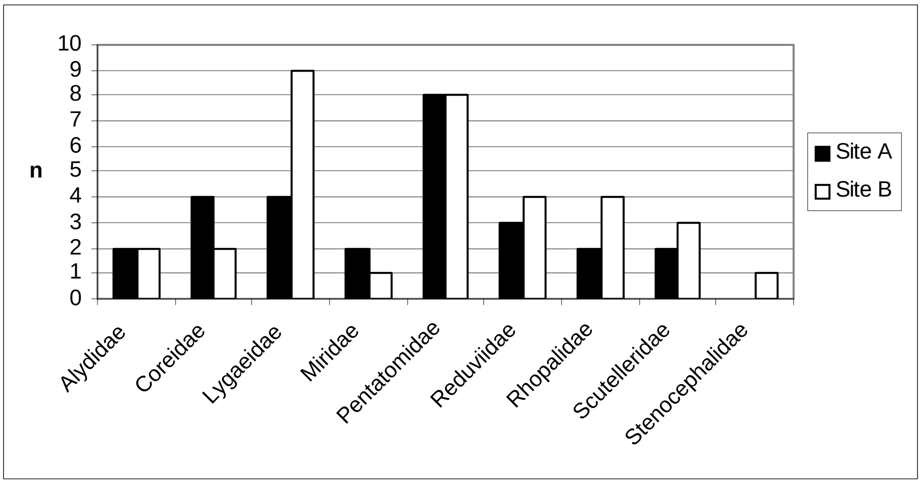

Fig. 9: Number of Heteroptera species per family observed on sites A and B. Data pooled over all plots and sampling series.

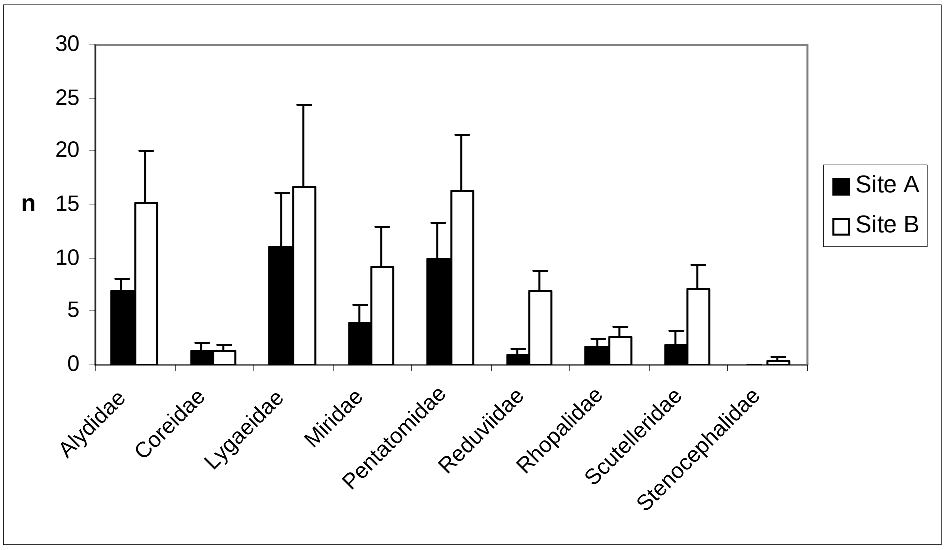

Fig. 10: Number of Heteroptera individuals per family on sites A and B. Individual number per species pooled over all series and plots per site (Mean and SE).

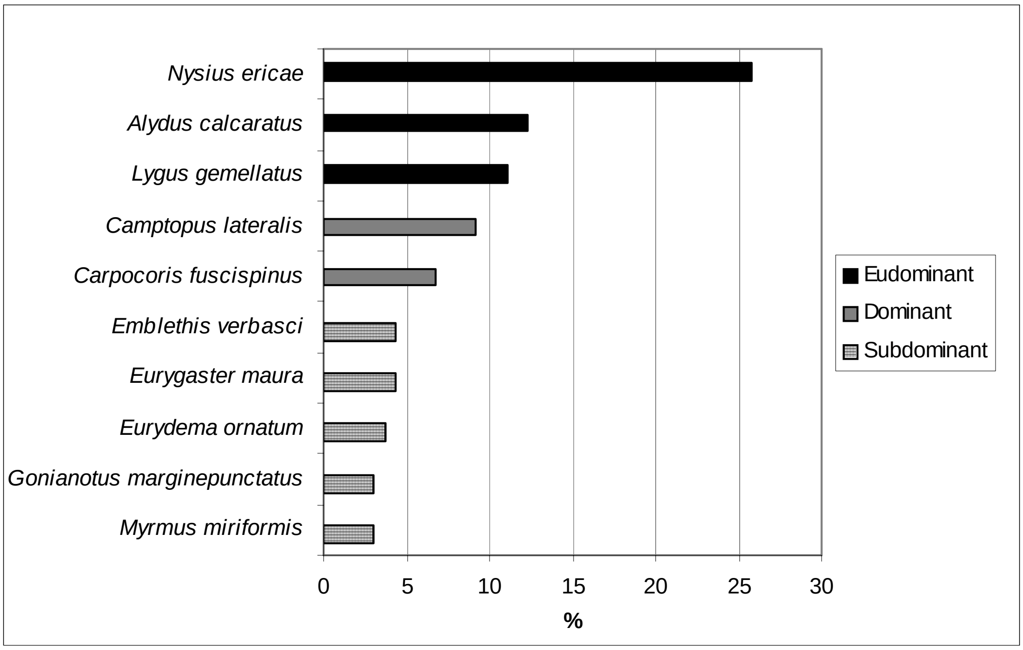

Fig. 11a: Dominance structure of Heteroptera (adults) on site A. Recedent and subrecedent species omitted from diagram. Dominance index D_i after MÜHLENBERG (1993).

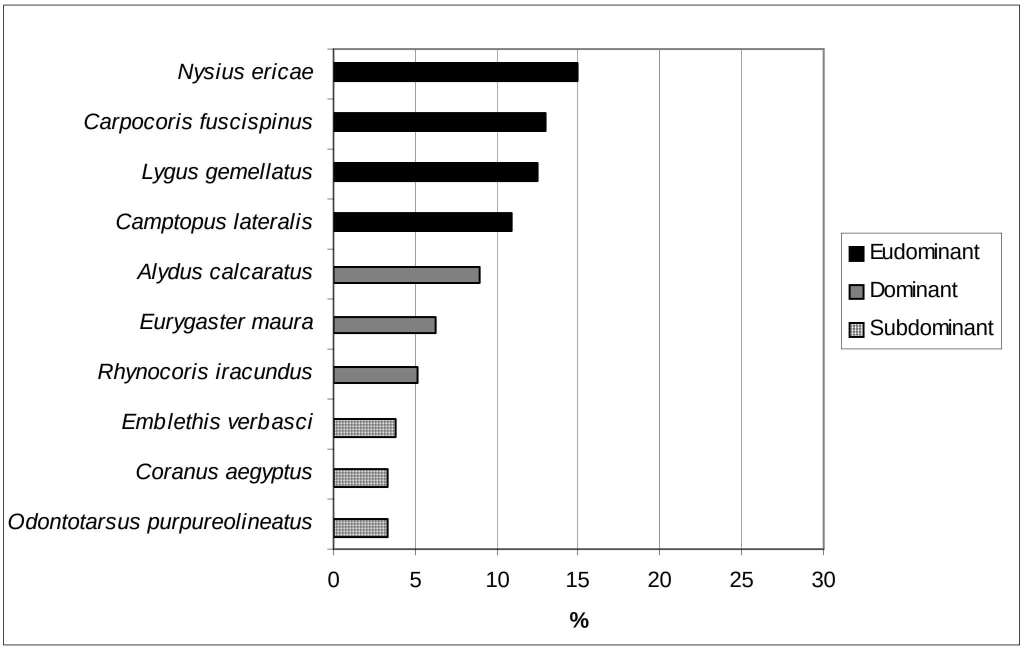

Fig. 11b: Dominance structure of Heteroptera (adults) on site B. Recedent and subrecedent species omitted from diagram. Dominance index D_i after MÜHLENBERG (1993).

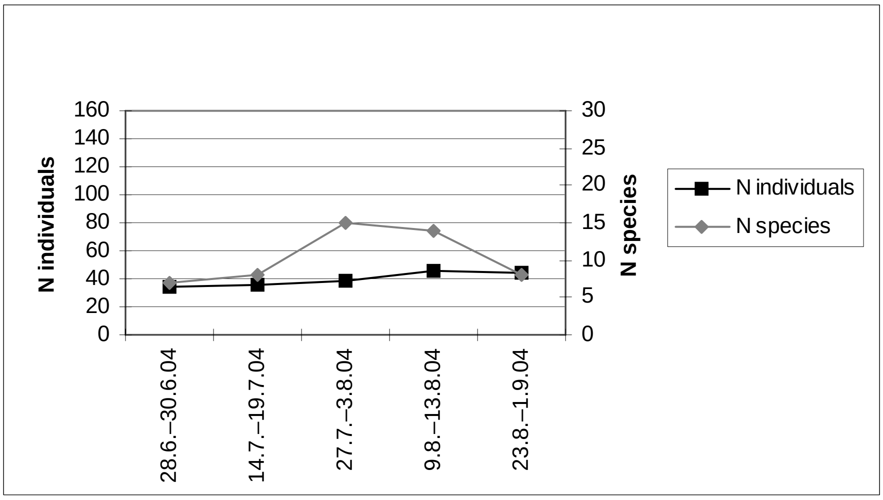

Fig. 12a: Phenology of Heteroptera species and individuals on site A. Data of all plots pooled.

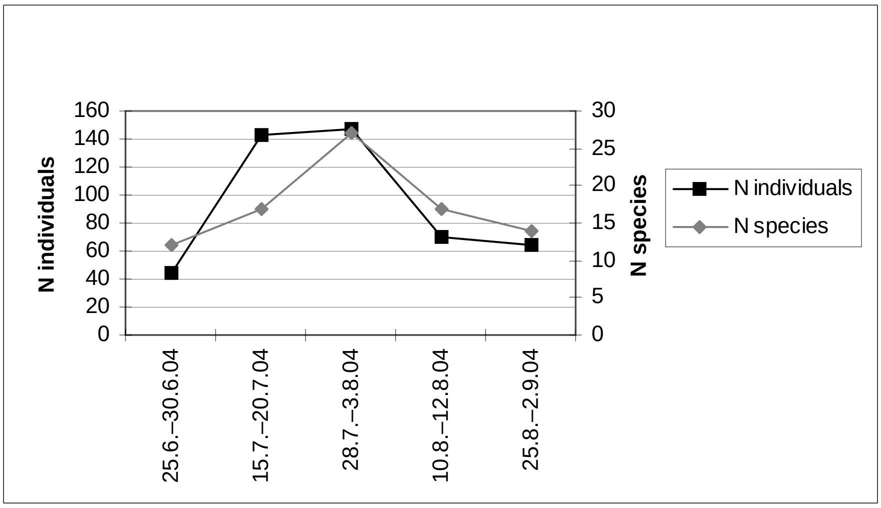

Fig. 12b: Phenology of Heteroptera species and individuals on site B. Data of all plots pooled.

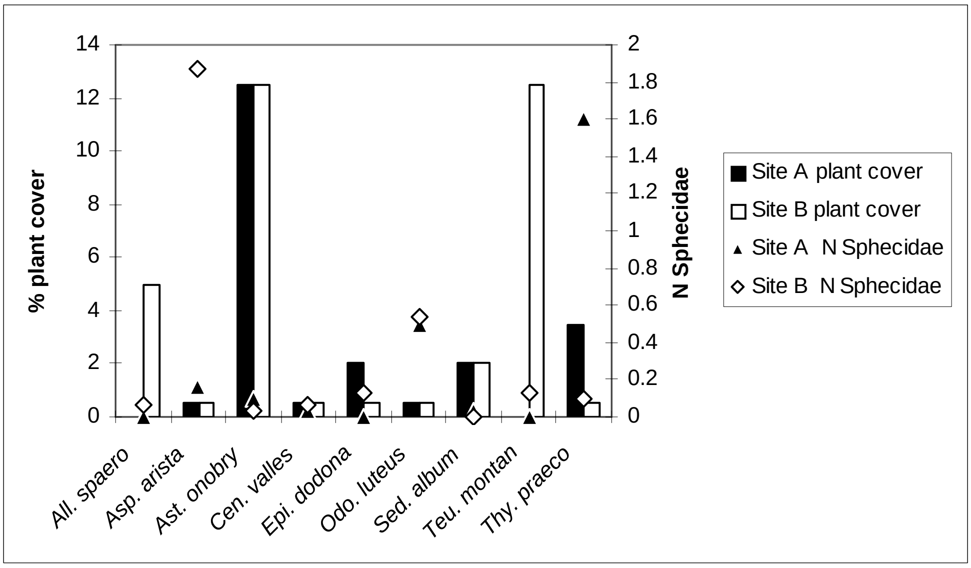

Fig. 13: Flower visits by Sphecidae on sites A and B. Comparison of plant abundance (median of percentage cover on all plots) and the activity of the digger wasps (sum of individual observations through all sampling series).

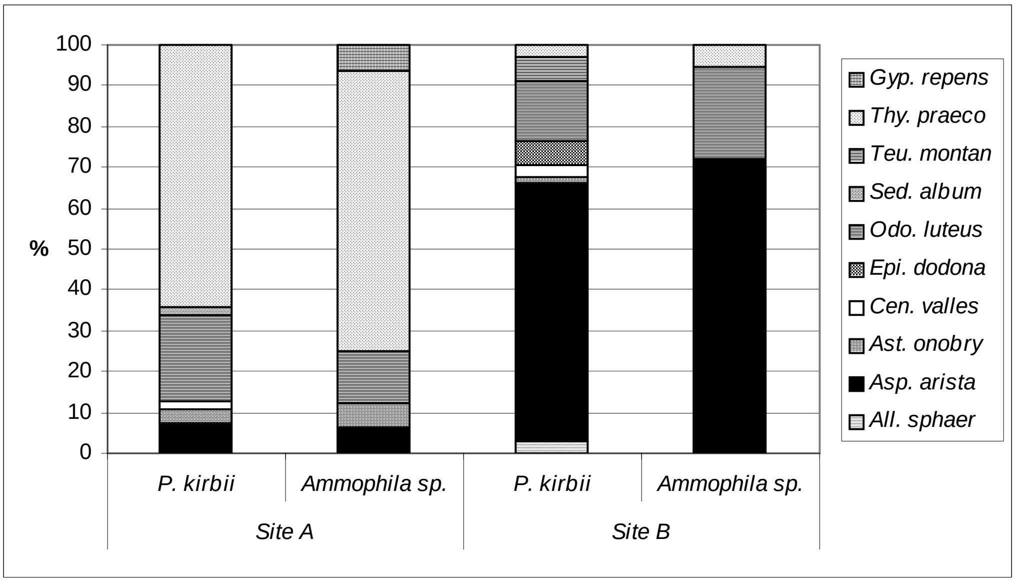

Fig. 14: Percentage of different flower species visited by *Prionyx kirbii* and *Ammophila sp.* on sites A and B.

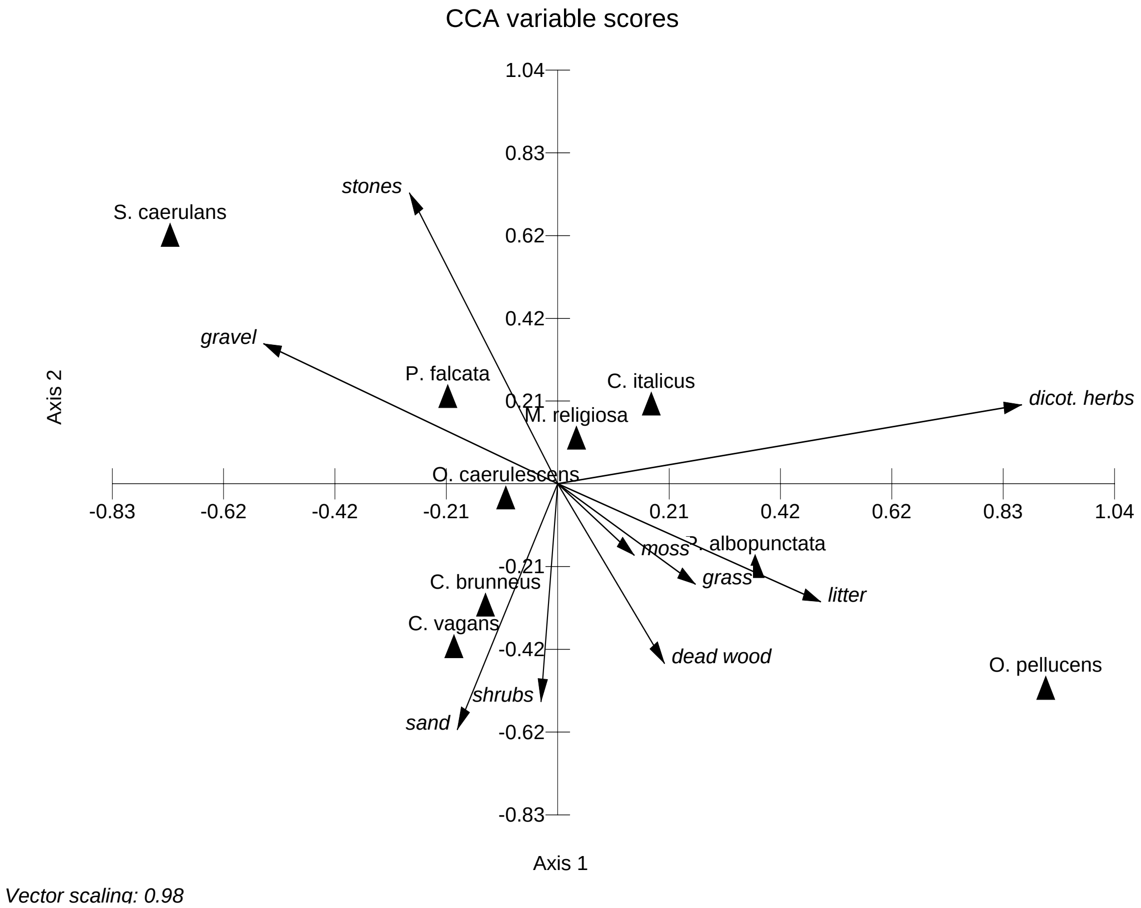

Fig. 15a: Ordination diagram based on Canonical Correspondence Analysis (CCA) for site A. Environmental variables are represented as arrows and species as triangles. Adults and larvae pooled. For further information see text.

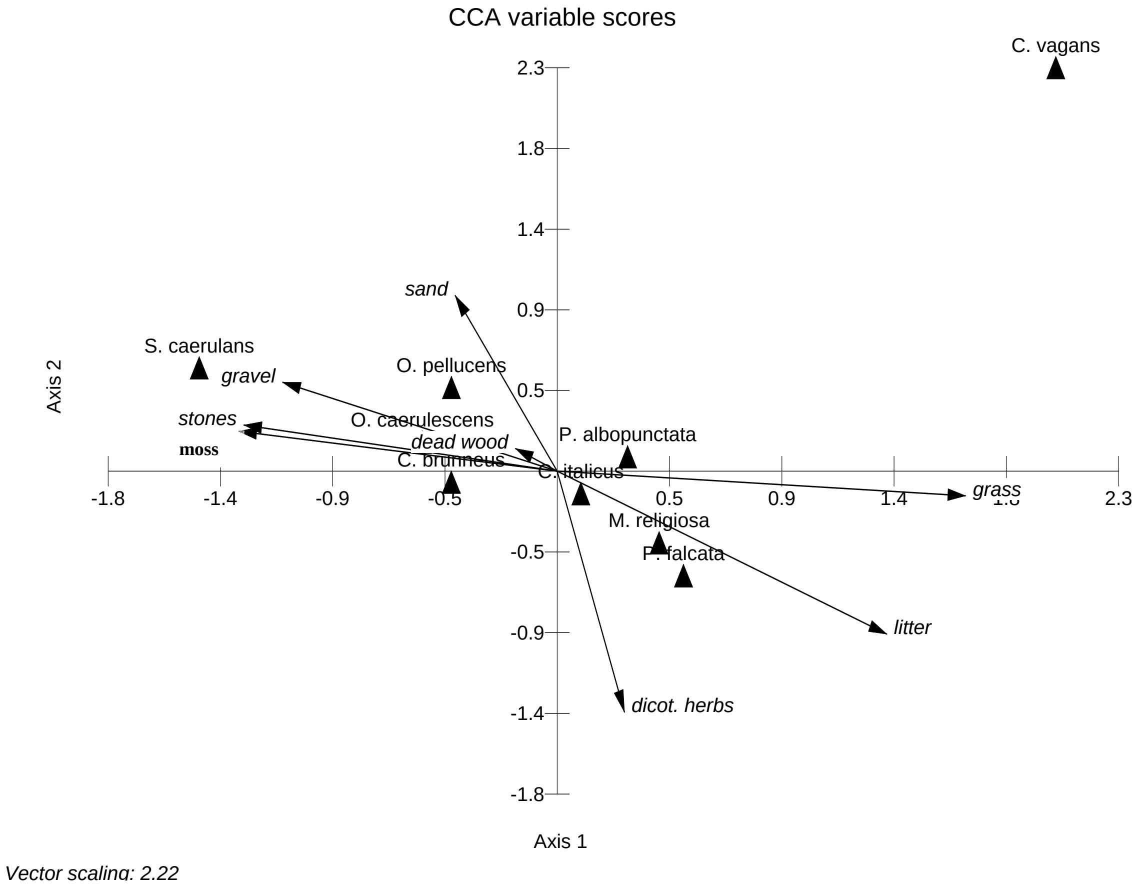

Fig. 15b: Ordination diagram based on Canonical Correspondence Analysis (CCA) for site B. Environmental variables are represented as arrows and species as triangles. Adults and larvae pooled. For further information see text.

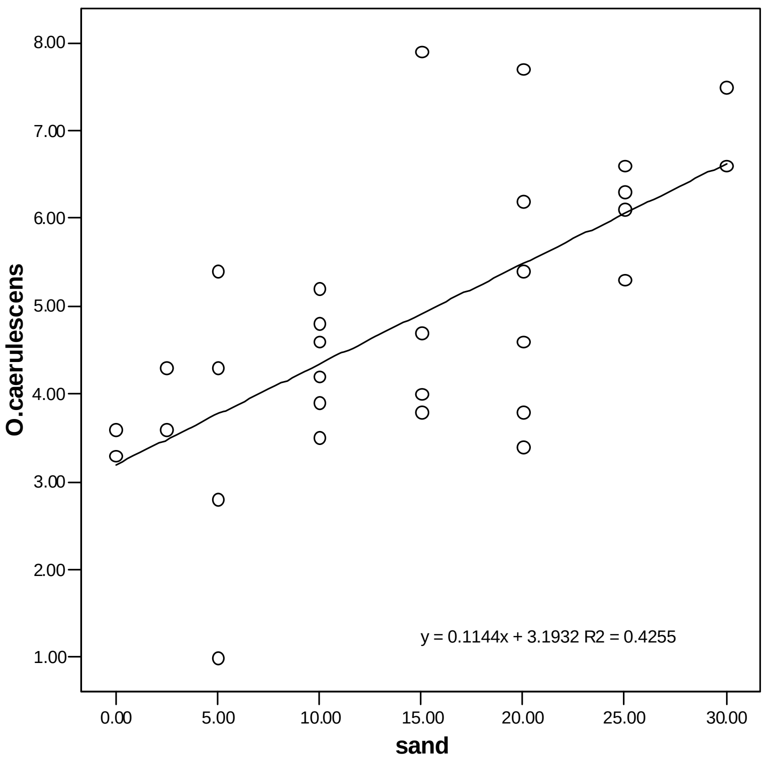

Fig. 16a: Mean abundance of *Oedipoda caerulescens* plotted against the surface parameter "sand" (in %) on site A. Each dot represents a plot (Pearson correlation r = 0.652; N = 30; p < 0.0001 (r significant at the 1% level)).

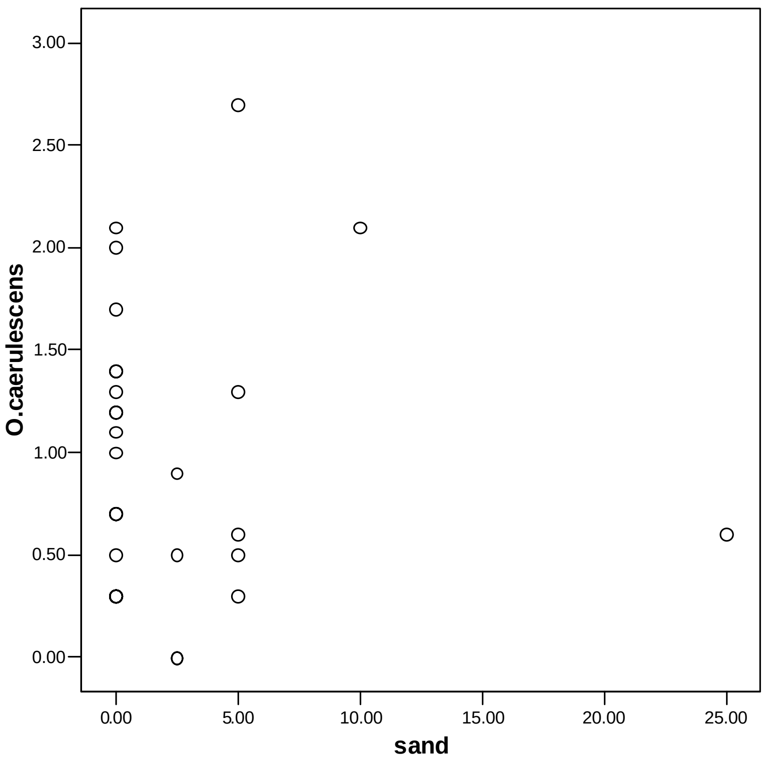

Fig. 16b: Mean abundance of *Oedipoda caerulescens* and the surface parameter "sand" (in %) on site B. Each dot represents a plot (Spearman rank correlation $r_s = -0.069$; $N = 30$; $p < 0.716$).

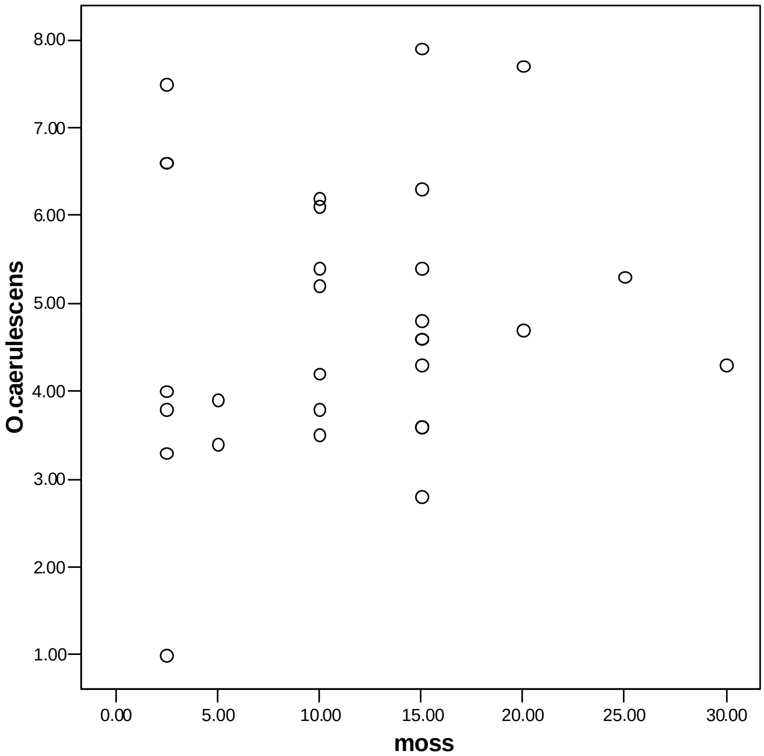

Fig. 17a: Mean abundance of *Oedipoda caerulescens* and the surface parameter "moss" (in %) on site A. Each dot represents a plot (Pearson correlation $r = 0.131$; $N = 30$; $p < 0.491$).

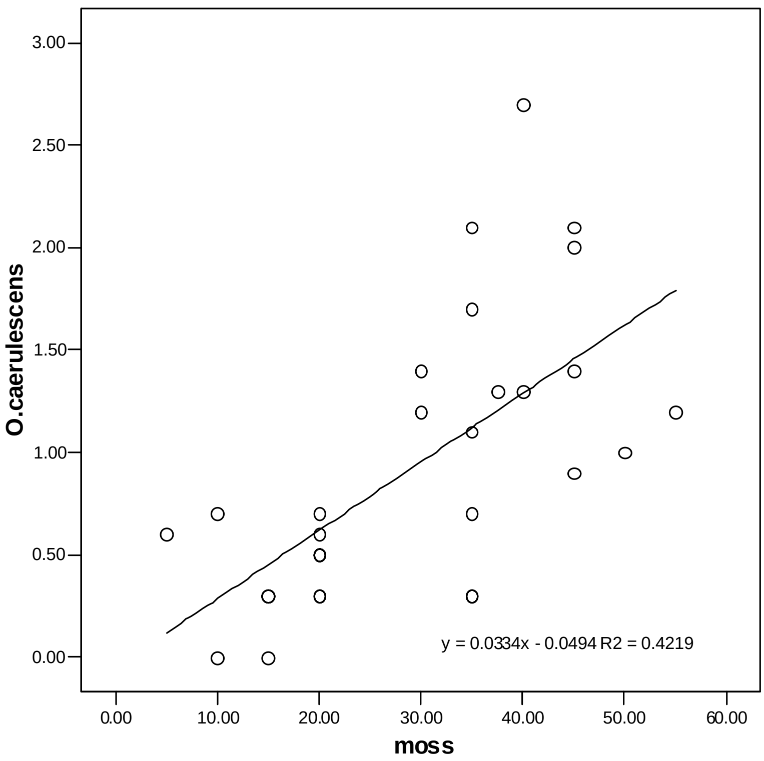

Fig. 17b: Mean abundance of *Oedipoda caerulescens* and the surface parameter “moss” (in %) on site B. Each dot represents a plot (Spearman rank correlation $r_s = 0.690$; $N = 30$; $p < 0.0001$ (r is significant at the 1% level)).

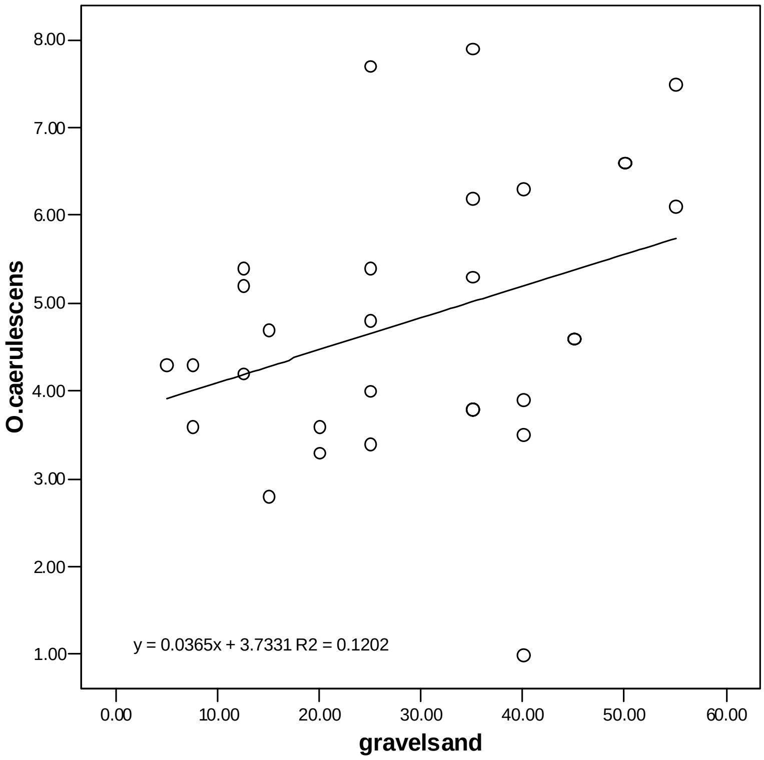

Fig. 18a: Mean abundance of *Oedipoda caerulescens* and the combined surface parameter "gravel and sand" (in %) on site A. Each dot represents a plot (Pearson correlation $r = 0.347$; $N = 30$; $p < 0.060$).

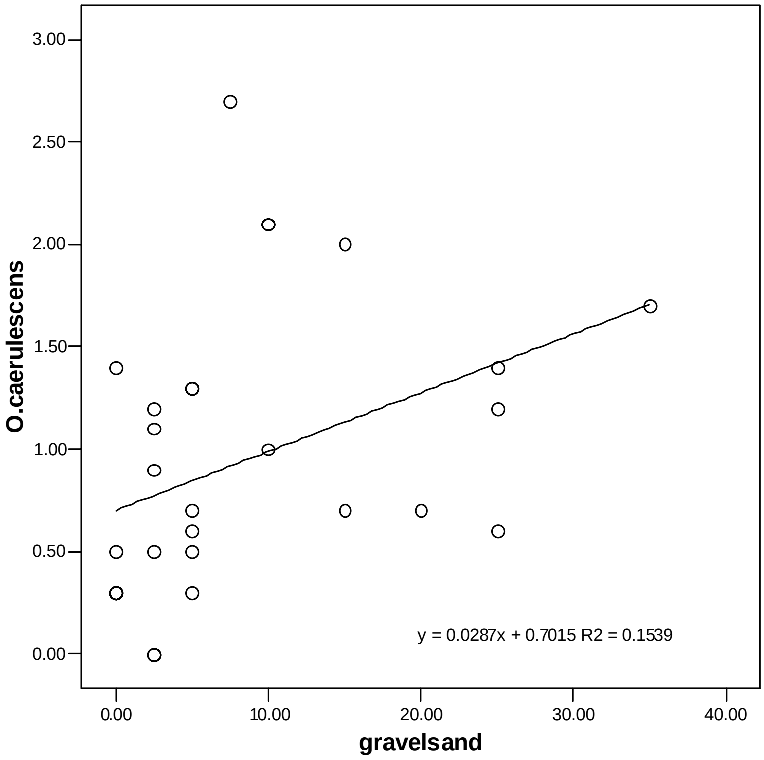

Fig. 18b: Mean abundance of *Oedipoda caerulescens* and the combined surface parameter "gravel and sand" (in %) on site B. Each dot represents a plot (Spearman rank correlation $r_s = 0.582$; N = 30; $p < 0.001$ (r is significant at the 1% level)).

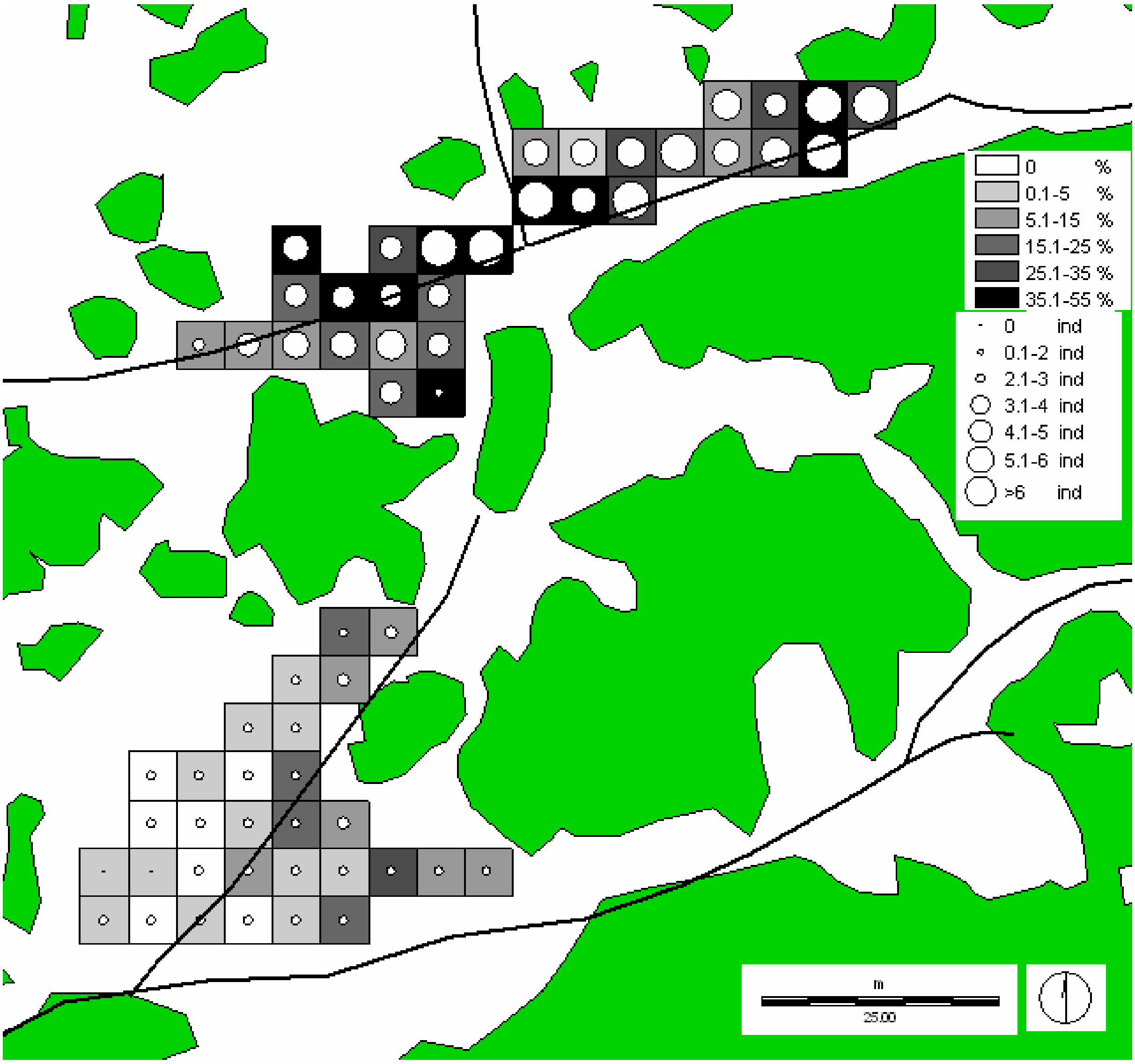

Fig. 19: Dependence of the grasshopper *Oedipoda caerulescens* on soil surface structure: % cover of sand and gravel and mean number of *O. caerulescens* (adults and larvae pooled, through five samplings).

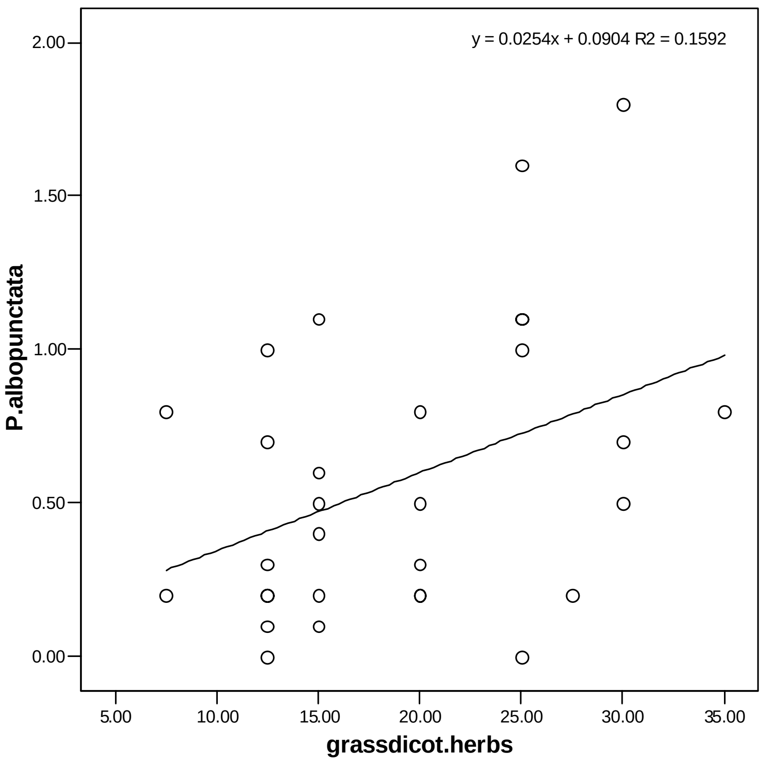

Fig. 20a: Mean abundance of *Platycleis albopunctata* and the combined surface parameter "grass and dicotyledonous herbs" (in %) on site A. Each dot represents a plot. (Pearson correlation r = 0.399; N = 30; $p < 0.029$) (r is significant at the 5% level)).

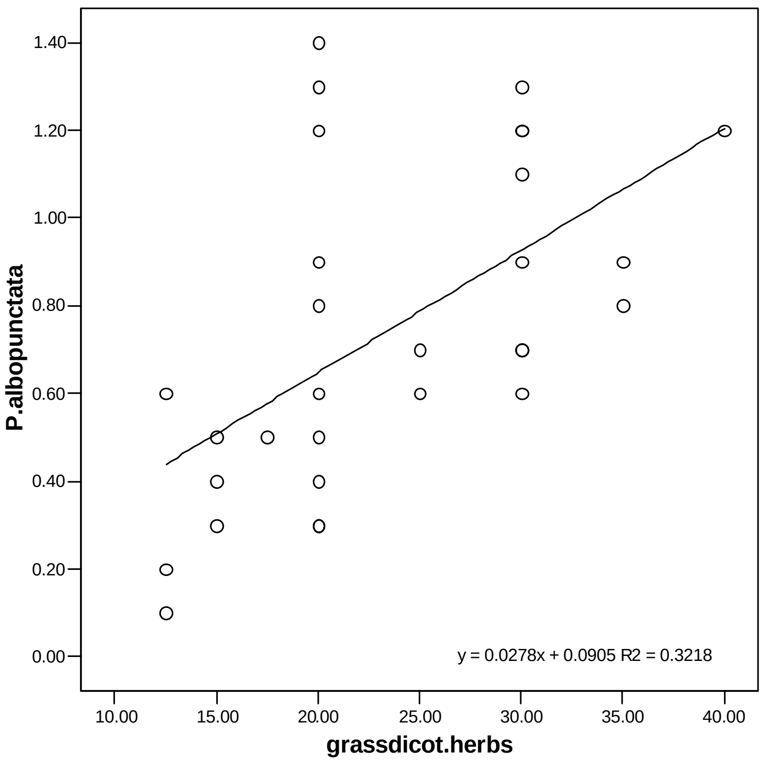

Fig. 20b: Mean abundance of *Platycleis albopunctata* and the combined surface parameter "grass and dicotyledonous herbs" (in %) on site B. Each dot represents a plot (Pearson correlation r = 0.567; N = 30; $p < 0.001$ (r is significant at the 1% level)).

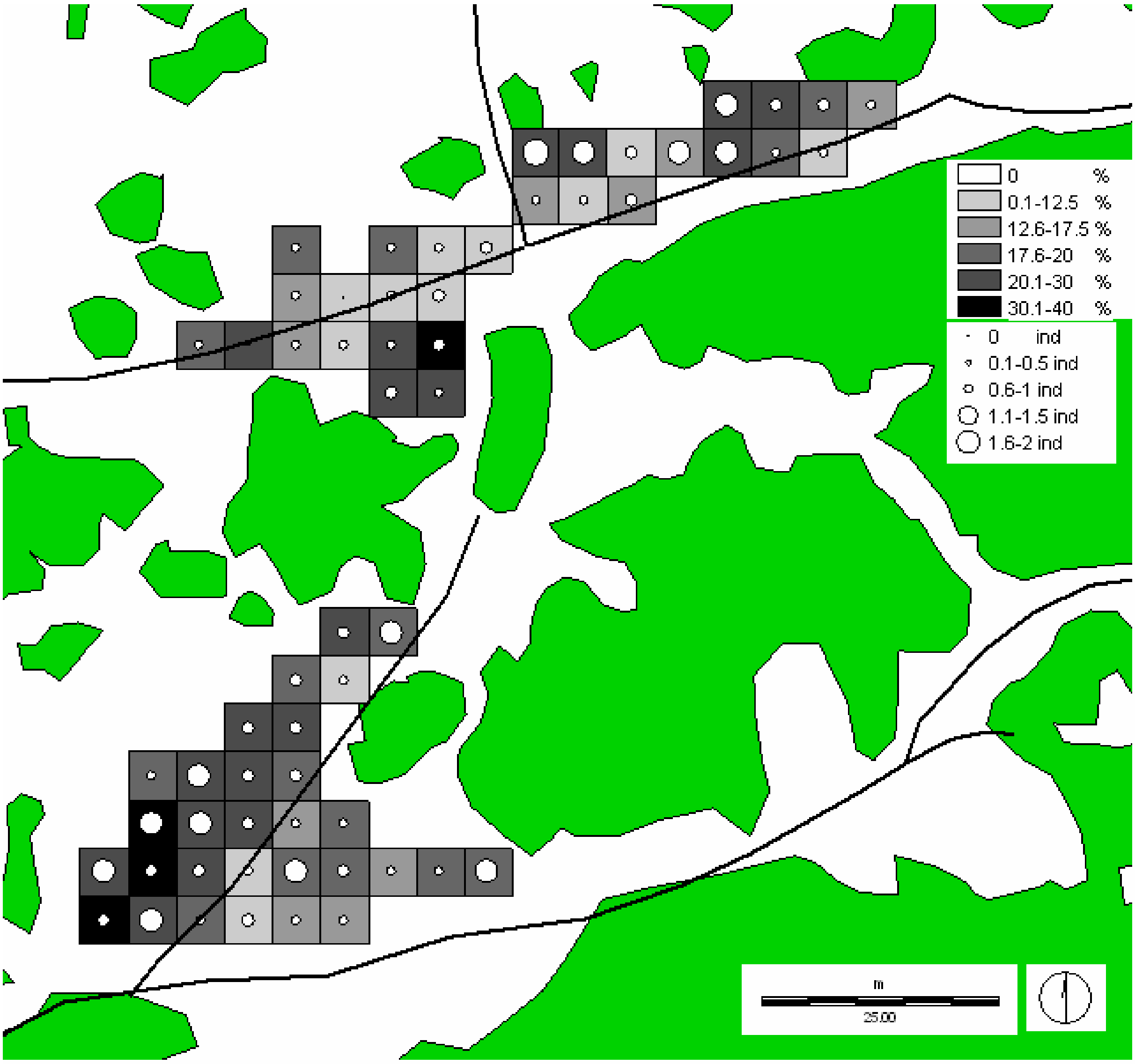

Fig. 21: Dependence of the grasshopper *Platycleis albopunctata* on vegetation composition:

% cover of grass and dicotyledonous herbs and mean number of *P. albopunctata* (adults and larvae pooled, through five samplings).

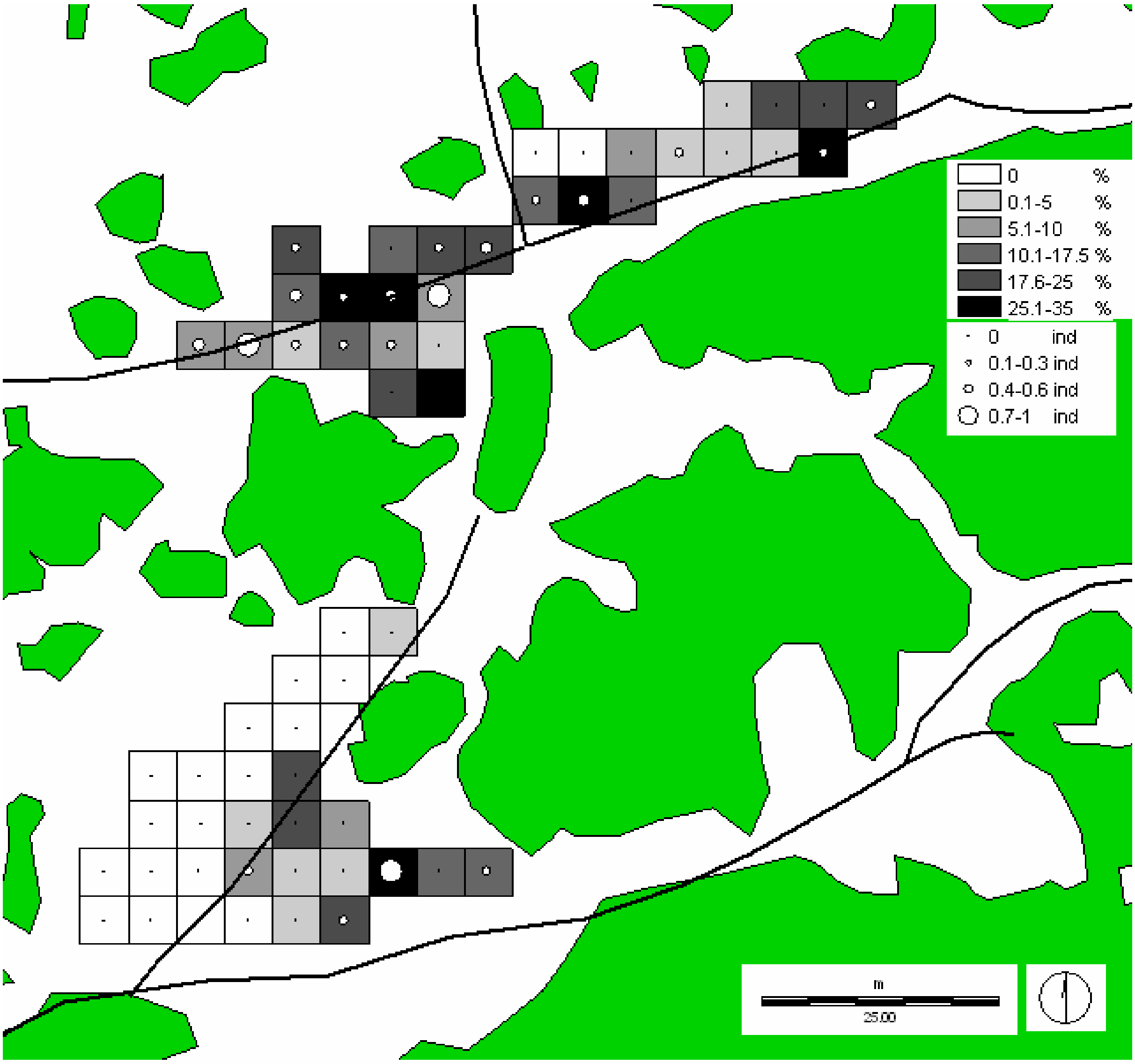

Fig. 22: Dependence of the grasshopper *Sphingonotus caerulans* on soil surface structure: % cover of gravel and mean number of *S. caerulans* (adults and larvae pooled, through five samplings).

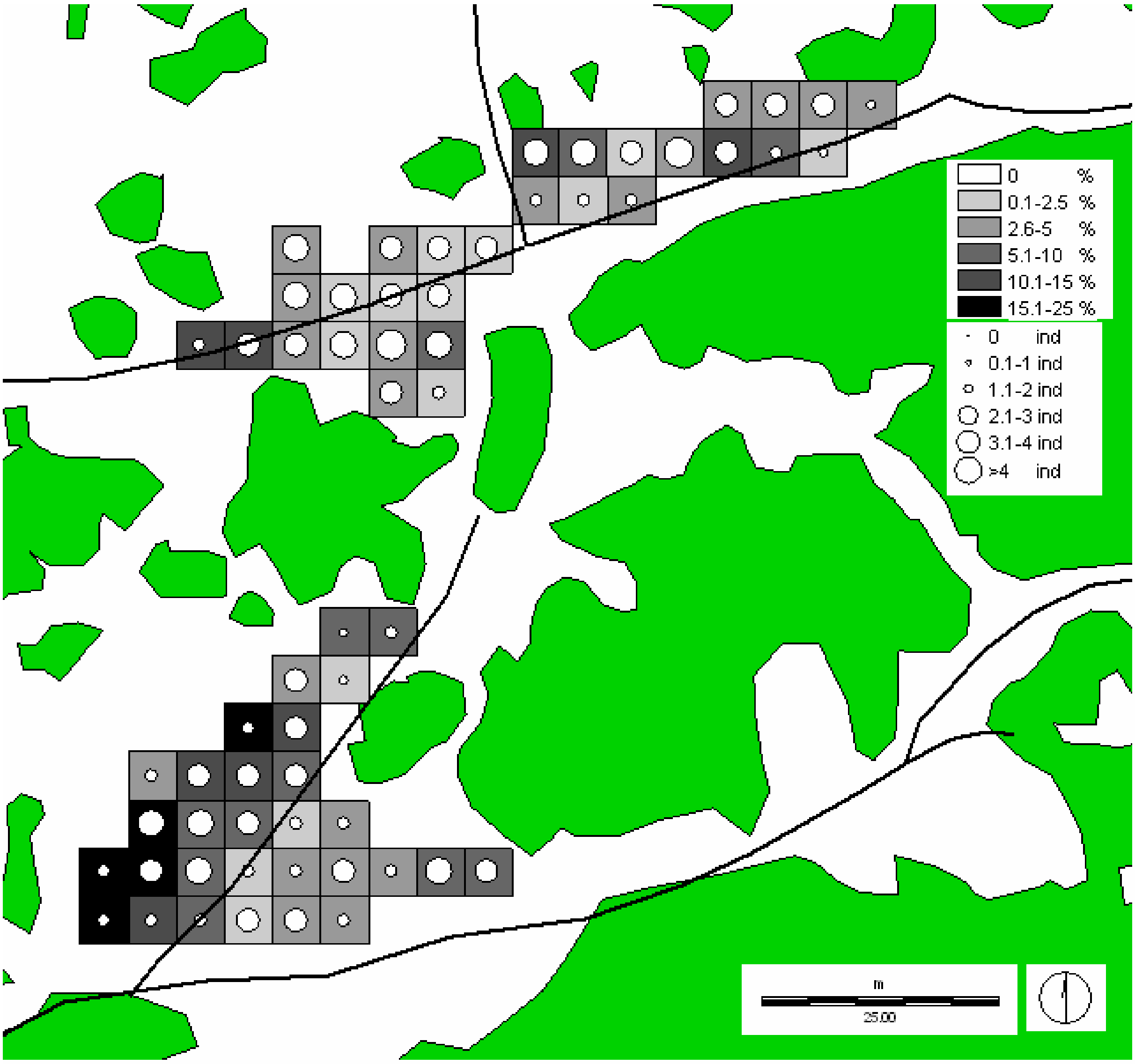

Fig. 23: Dependence of the grasshopper *Calliptamus italicus* on grass abundance: % cover of grass and mean number of *C. italicus* (adults and larvae pooled, through five samplings).

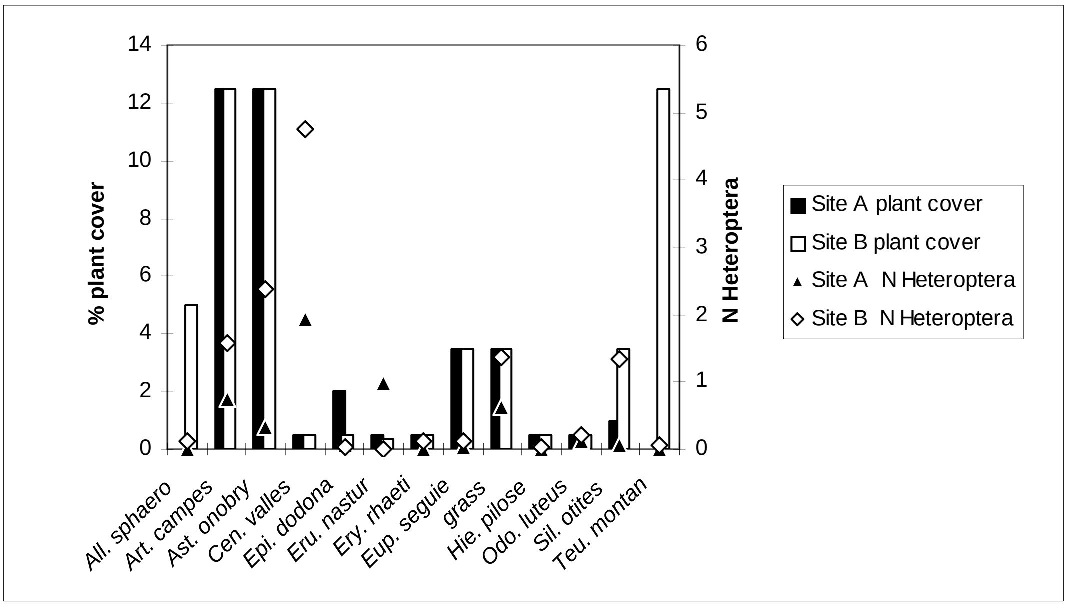

Fig. 24: Relation between Heteroptera and host plants on site A and B. Comparison of plant abundance (median of percentage cover over all plots) and true bug abundance (sum of individual observations through all sampling series).

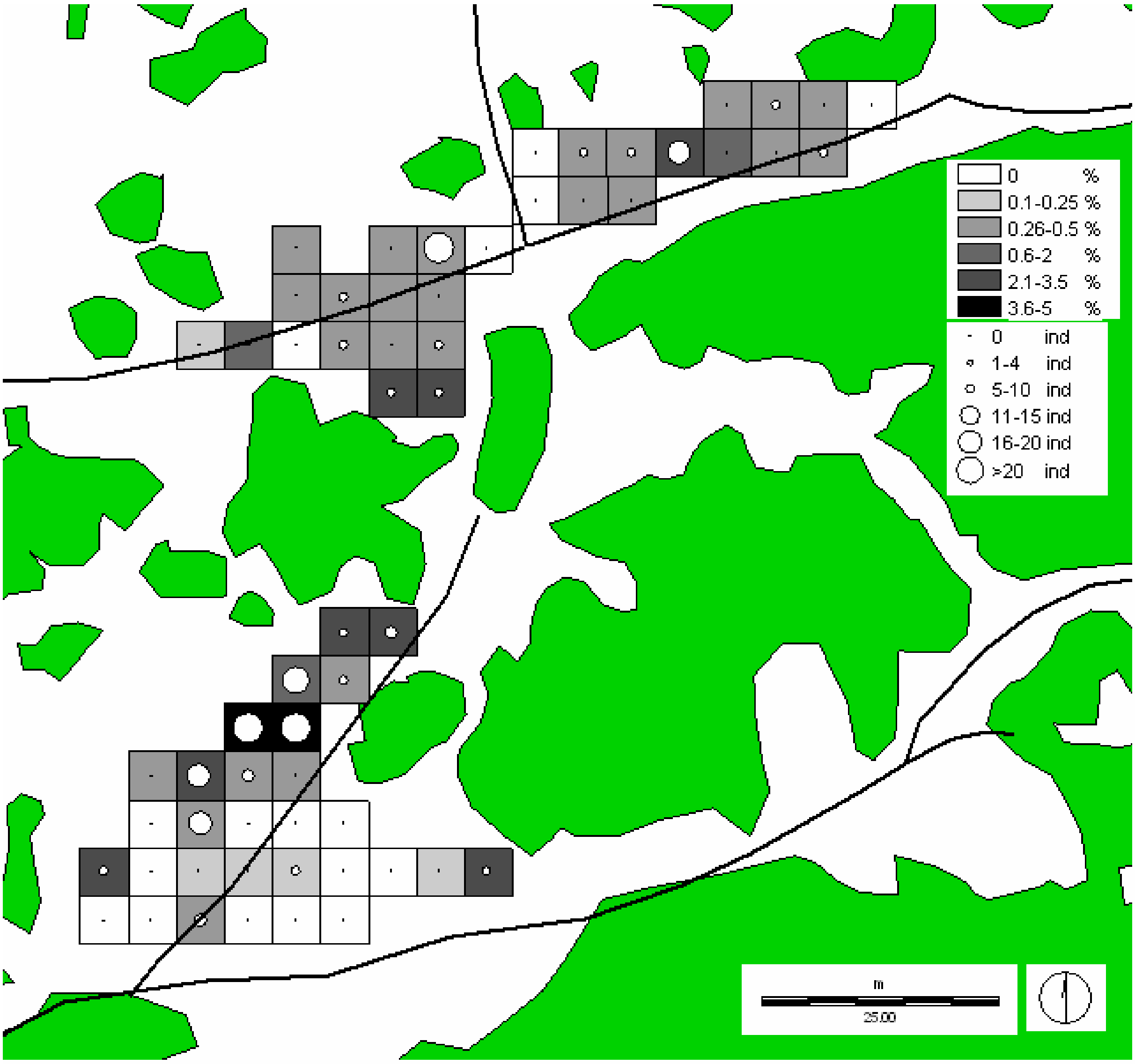

Fig. 25: Significance of *Centaurea vallesiaca* for Heteroptera:

Comparison of abundance of host plant (median % cover per plot) and observations of true bugs (all observed species, mean number of individuals per sampling).

9. Appendix

Appendix 1: Overview site A (2.5.2004; Copyright by R.C. Stettler).

Appendix 2: Overview site A (19.7.2004; Copyright by D. Bärtschi).

Appendix 3: Overview site B (2.5.2004; Copyright by R.C. Stettler).

Appendix 4: Overview site B (6.9.2004; Copyright by D. Bärtschi).