10.4.5. Conclusions

The total dry biomass of large soil invertebrates varied from 0.08 to 3.45 g/m^2 decreasing with increasing snow depth. Each ecosystem had a specific composition of the soil invertebrate community. Studied alpine communities differed from that of arctic tundras by a smaller abundance of Enchytraeidae and Tipulidae and by a larger role of Chilopoda and Curculionidae.

The composition of the soil invertebrate community of the ALH was similar to that of plain meadows and Ural alpine tundras. The community of alpine grasslands (FVG, GHM) is closer to alpine communities of the Tian-Shan and the Alps. Apparently, the type of parent soil material (silicate or carbonates) has a strong influence on the composition of soil invertebrate communities, especially for such Ca-demanding groups as Diplopoda or Mollusca.

10.5. Grasshoppers

10.5.1. Introduction and methods

Grasshoppers are important hexapod herbivores in many grasslands including alpine ecosystems. But their role in the regulation of plant species composition is not clear. To understand their role it is necessary to study the abundance of different grasshopper species and food specialization between them. Little information is known about food specialization in Orthoptera (Stolyarov 1975; Sergeev et al. 1995).

The grasshoppers were studied in four alpine communities: alpine lichen heath (ALH), *Festuca varia* grassland (FVG), *Geranium-Hedysarum* meadow (GHM), snow bed community (SBC). Samples of 120 plant species were collected for epidermal cell microscoping. Grasshoppers were collected for investigation of their gut contents and excrements as well as for plant preference studies in cages. Food preference was determined for 110 plant species in 2-3 replications. Estimation of plant species preferences was made on a 6 - point scale: 0 – absolutely non eaten, 1 – very poor eaten (<2% plant material was consumed), 2 – weakly eaten (2-5%), 3 - satisfactorily eaten (5-20%), 4 - well eaten (20-50%), preferable (>50%).

The biomass and population density of grasshoppers in the ALH were monitored on permanent plots with a total area of 62 m^2 during 19 years (1981-1999). The observations were made at the end of August or beginning of September. To compare grasshopper communities in different ecosystems, the population density was determined in 100-120 m^2 plots in each community in August 1999.

10.5.2. Species composition

We found seven species of grasshoppers (Acridoidea) and two species of bush-crickets (Tettigonoidea) in studied plant communities during a season 1999:

Fam. Tettigoniidae
  subfam. Phaneropterinae
    Polysarcus zacharovi Stshelk.
  subfam. Tettigoniinae
    Decticus verrucivorus L.
Fam. Pamphagidae
  subfam. Pamphaginae
    Nocaracris cyanipes F.-W.
Fam. Acrididae
  subfam. Catantopinae
    Podisma teberdina Rmme.
  subfam. Acridinae
    Stenobotrus nigromaculatus H.-Sch.
    Omocestus viridulus L.
    Gomphocerus sibiricus caucasicus Motsh.
    Chorthippus apricarius major Pyln.
    Chorthippus porphyroptera Voronzovsky

We divided all species according to their population density into dominants (more than 1000 individuals/ha), common species (200 - 1000 individuals/ha), and rare species (less than 200 individuals/ha). Six species were found in the ALH (Fig. 10.15). Three species (*Nocaracris cyanipes*, *Stenobotrus nigromaculatus* and *Gomphocerus sibiricus*) were considered as dominants, two *(Podisma teberdina* and *Omocestus viridulus*) were common, one (*Chorthippus porphyroptera*) was rare.

Chorthippus apricarius was absent in the ALH. The population density and biomass of grasshoppers fluctuated greatly between years (Fig. 10.16). The abundance of grasshoppers increased in dry years and decreased in wet years. *Podisma teberdina* was a dominant species in most years (Fig. 10.16).

Five species were found in the FVG (Fig. 10.15). *Nocaracris cyanipes*, *Omocestus viridulus* and *Gomphocerus sibiricus* were dominants there. *Stenobotrus nigromaculatus* was a common species and *Chorthippus apricarius* was rare. Two other species were not found there.

The total population density of grasshoppers was highest in the GHM. It has about 20 000 animals per m^2. (several times more than in other communities). Two species (*Gomphocerus sibiricus* and *Omocestus viridulus*) were dominant there (Fig. 10.15). Other species were much less

frequent. So this high productive alpine plant community was very attractive for some grasshoppers. It may be connected not only with plant production, but with the abundance of bare soil patches (gaps) which are convenient for egg development.

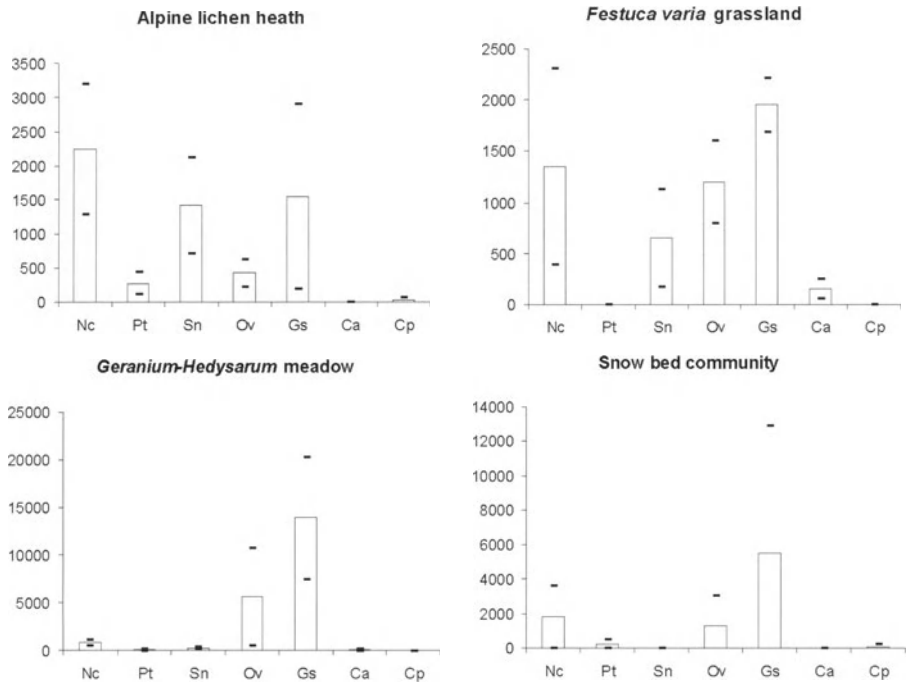

Figure 10.15. Density of grasshoppers in alpine plant communities (individuals per ha, average ± st. er.). Abbreviations: Nc - *Nocaracris cyanipes*, Pt - *Podisma teberdina*, Sn - *Stenobotrus nigromaculatus*, Ov - *Omocestus viridulus*, Gs - *Gomphocerus sibiricus caucacicus*, Ca – *Chorthippus apricarius major*, Cp - *Chorthippus porphyroptera*

Three species (*Nocaracris cyanipes, Omocestus viridulus* and *Gomphocerus sibiricus*) were noted as dominants in the SBC (Fig. 10.15). Two other species were rare.

Only few individuals of bush-crickets were found. *Polysarcus zacharovi* was noted only in the GHM, and *Decticus verrucivorus* only in the FVG.

So, we conclude that there are four main species of grasshoppers (dominants) only (*Nocaracris cyanipes, Stenobotrus nigromaculatus, Omocestus viridulus* and *Gomphocerus sibiricus*).

Podisma teberdina was a common species. It is necessary to note, that at least in the ALH the population density of *Podisma teberdina* was much lower, but the population density of *Gomphocerus sibiricus* was much higher

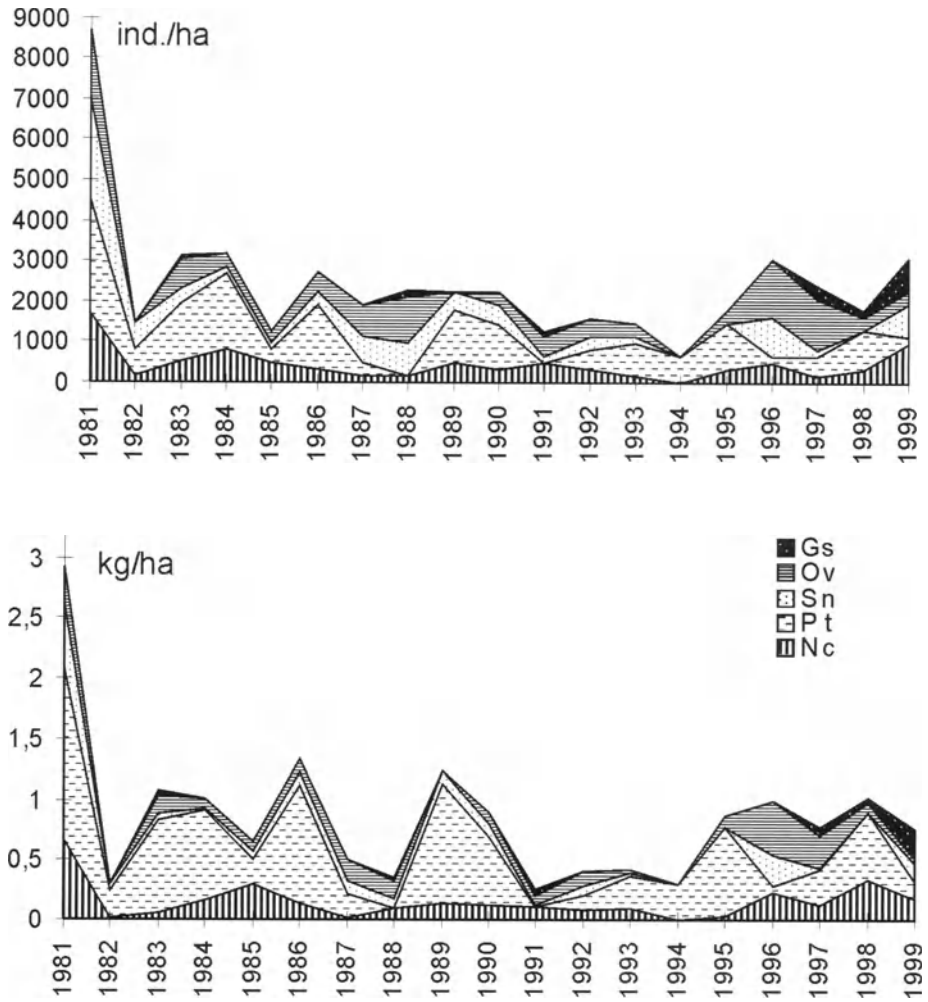

Figure 10.16. The perennial dynamics of abundant grasshopper species on permanent plots of ALH, ind./ha and kg/ha (fresh mass). Abbreviations: Nc - *Nocaracris cyanipes*, Pt - *Podisma teberdina*, Sn - *Stenobotrus nigromaculatus*, Ov - *Omocestus viridulus*, Gs - *Gomphocerus sibiricus caucacicus*

in 1999 than in other years of observation (Fig. 10.16). Three *species (Nocaracris cyanipes, Omocestus viridulus* and *Gomphocerus sibiricus*) are abundant enough in all habitats in spite of a great difference between plant communities. So, the species showed high ecological plasticities. Other species have shown the certain degree of habitat preference. The spatial distribution in the habitats of *Stenobotrus nigromaculatus* has demonstrated

a preference to less snowy communities (ALH and FVG). *Podisma teberdina* and *Chorthippus porphyroptera* prefer habitats with a lower plant cover, *Chorthippus apricarius* was found in tall and closed plant communities.

10.5.3. Plant species preference by grasshoppers (Acridoidea)

Analysis of species consumption by grasshoppers showed that all studied alpine species can be eaten by some of the grasshoppers but at different rates (Tables 10.1, 10.20). In Table 10.1. we represent an estimation of plant species preference by grasshopper species in comparison with other alpine herbivores. Mean indexes of plant group preference are represented in Table 10.20. We divided the species of 3 families into two groups: Poaceae into hard-leaved (*Agrostis vinealis, Festuca* spp., *Helictotrichon versicolor, Nardus stricta*) and soft-leaved grasses (*Anthoxanthum odoratum, Briza marcowiczii, Bromus variegatus, Calamagrostis arundinaceae, Catabrosella variegata, Deschampsia flexuosa, Hyalopoa pontica, Phleum alpinum, Trisetum flavescens*), Caryophyllaceae into broad-leaved (*Cerastium purpurascens, Silene saxatilis*) and narrow-leaved species (*Arenaria lychnidea, Minuartia* spp.), Scrophulariaceae into hemiparasitic (*Euphrasia ossica, Pedicularis* spp.) and others (*Eritrichium caucasicum, Myosotis alpestris, Veronica gentianoides*).

Table 10.20. Estimation of plant group preference by grasshoppers (mean values for families with more than 3 species). Abbreviations: n – number of studied plant species, Nc – *Nocaracris cyanipes*, Pt – *Podisma teberdina*, Sn – *Stenobotrus nigromaculatus*, Ov – *Omocestus viridulus*, Gs – *Gomphocerus sibiricus*. For species data see Table 10.1, for scale points – Chapter 10.5.1.

Plant groups	n	Nc	Pt	Sn	Ov	Gs
Cyperaceae (*Carex* spp.)	5	2.2	1.8	4.0	4.0	4.2
Poaceae: hard-leaved	6	2.0	1.5	4.7	4.3	3.7
Poaceae: soft-leaved	9	3.7	2.3	4.1	4.4	4.6
Apiaceae	5	3.6	3.6	0	0.2	1.6
Asteraceae	20	3.9	3.6	0.7	1.2	2.4
Caryophyllaceae: broad-leaved	2	4.0	4.5	1.0	3.5	3.0
Fabaceae	4	3.5	3.0	2.3	1.3	2.8
Gentianaceae	4	4.3	1.5	1.0	0.3	0.5
Lamiaceae	3	3.3	1.3	0	0.3	1.0
Ranunculaceae	5	3.4	1.4	0	0.6	0.6
Rosaceae	5	4.0	3.3	0.6	0.2	1.0
Scrophulariaceae: non parasitic	3	3.3	1.6	0.2	0.3	0.8
Broad-leaved forbs	71	3.6	2.7	0.5	0.7	1.6
Scrophulariaceae: hemiparasitic	4	3.0	1.5	0.3	0	1.3
Caryophyllaceae: narrow-leaved	4	2.8	2.3	0.5	1.0	1.3
Ericaceae	3	1.3	2.7	0.3	0.7	0

Differentiation between grasshopper species was obvious. It appears, that all studied species, including *Nocaracris cyanipes* and *Podisma teberdina*, eat grasses and others monocotyledons. However, *Stenobotrus nigromaculatus, Omocestus viridulus* and *Gomphocerus sibiricus* prefer

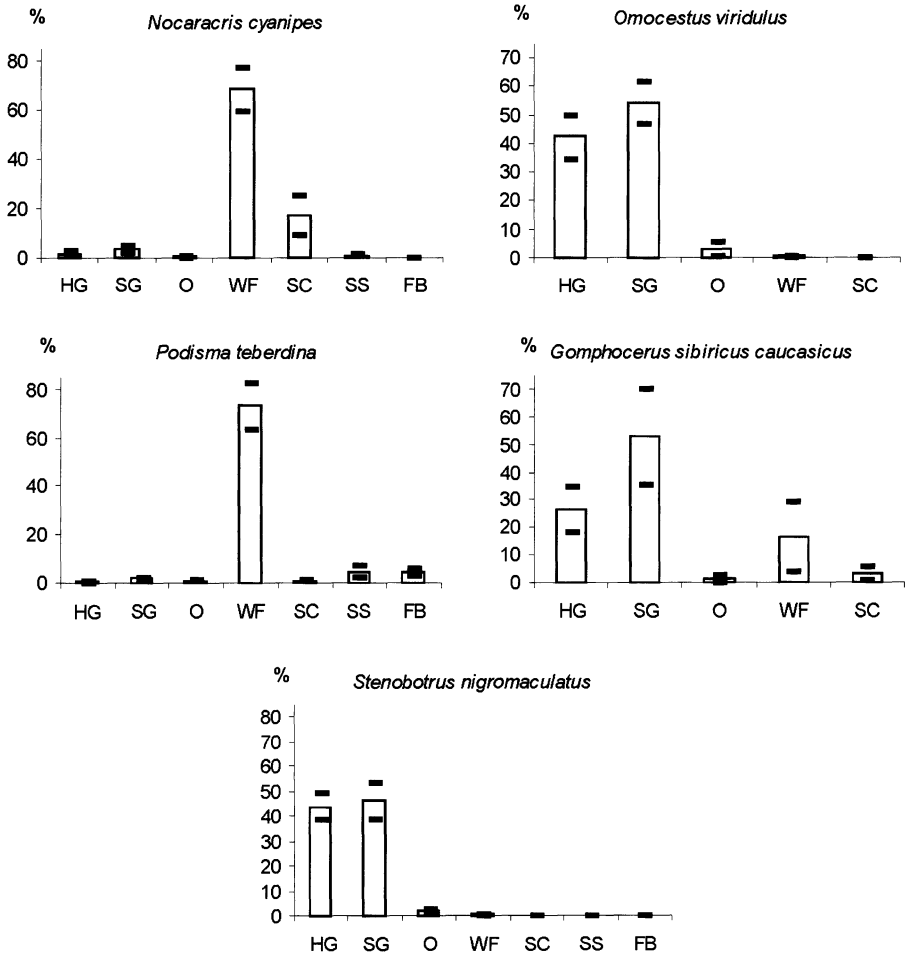

Figure 10.17. The spectra of plants really eaten by abundant grasshopper species in nature (average ± st. er.) based on an analysis of excrements and gut contents. Plant groups: HG - hard-leaved grasses, SG - soft-leaved grasses, O - other monocotyledons (*Carex* spp.), WF - broad-leaved forbs, SC - narrow-leaved Caryophyllaceae (*Arenaria, Minuartia* spp.), SS - hemiparasitic Scrophulariaceae (*Euphrasia, Pedicularis* spp.), FB – *Vaccinium vitis-idaea.*

graminoids. The latter species were considered as graminoid-eating species in previous investigations as well (Chernyakhovskii 1968, 1970). *Nocaracris cyanipes* prefered soft-leaved grasses and broad-leaved forbs, and *Podisma teberdina* willingly ate dwarf shrubs (*Vaccinium* spp.) and forbs under cage conditions.

The cage method has some disadvantages due to the unnatural conditions in cages and the limited number of plants to choose from (Stebaev & Pshenitcina 1984). The real set of consumed plants may be determinated from the analysis of excrements and gut contents (Sergeev et al. 1995). This analysis was made for grasshoppers from the ALH and GHM. Seven groups of plants were identified: hard-leaved grasses, soft-leaved grasses, other monocots, broad-leaved forbs, narrow-leaved Caryophyllaceae, hemiparasitic Scrophulariaceae, evergreen dwarf shrub (*Vaccinium vitis-idaea*) (Fig. 10.17).

The grasses and sedges are well represented in excrements and gut contents in all studied species. But their role was different for various grasshopper species. More than 90% of all plant rests were grasses for two specialised species – *Stenobotrus nigromaculatus* and *Omocestus viridulus*. On the other hand, broad-leaved forbs were the absolutely dominant food plants for the large non-flying grasshoppers *Nocaracris cyanipes* and *Podisma teberdina* (Fig. 10.17). The species ate leaves of hemiparasitic Scrophulariaceae and evergreen *Vaccinium vitis-idaea* as well. *Gomphocerus sibiricus* was a less specialized feeder with some grass preference.

So, as a whole the results of two methods for determination of plant preferences show rather similar results. They allowed us to obtain a real picture of species consumption by grasshoppers in alpine communities.