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Responses of assemblages of Orthoptera to management and use of ski slopes on upper sub-alpine meadows in the Austrian Alps

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Abstract The Orthoptera assemblages occurring on sub-alpine ski slopes were compared with those found on neighbouring unskied meadows by making frequent transect counts at two pairs of sites in the Gastein valley in the Austrian Central Alps. On one of the ski slopes no Orthoptera were present, although two species were abundant on the control meadow a few meters away. On the second ski slope, the Orthoptera assemblage exhibited reduced species richness, lower densities of individuals and a generally accelerated rate of nymphal development compared to the control meadow populations. These results may be explained in terms of the changed habitat conditions on the ski slopes and the known biologies of the species concerned. The implications of the findings for winter tourism management in high altitude ecosystems are briefly discussed.

Key words Grasshoppers · Habitat disturbance Mountains · Winter sports

Introduction

The large-scale physical processes that lead to habitat deterioration and then erosion on ski slopes are now fairly well documented (e.g. review by Cernusca 1986). However, associated changes in ecosystem structure and dynamics may occur over a wide range of scales, and are often more difficult to recognise. Changes in the natural vegetation cover of the ski slopes themselves are similar to those caused by "trampling", and even more extreme disturbance occurs when the slopes are "landscaped" (bulldozed) and then reseeded, often with unsuitable, commercial seed mixtures, to create easier or better skiing conditions. Clearly, such drastic changes have a considerable impact on the animal components of the ecosystems concerned, but as yet this aspect of the problem has received relatively little attention. In the Alps, Haslett (1991) has shown that among assemblages of flower-visiting syrphid flies, "specialist" species are lost from the ski slopes. Similarly, carabid beetle communities of skied montane/sub-alpine meadows have been shown to lose the specialist predator species so that the assemblages become comparable to those typical of agricultural landscapes (Hammelbacher and Mühlenberg 1986).

Here we examine the effects of severe habitat disturbance caused by landscaping and using ski slopes on the orthopteran communities of subalpine/alpine meadows. Particularly, we determine how species presence, population sizes and phenologies are affected by these gross habitat disturbances.

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Methods

The study area

The sites studied are in the Gastein valley in the Austrian central Alps. Two pairs of field sites were selected, each pair consisting of a heavily used ski slope and a neighbouring "control" meadow. All four sites are within the altitudinal range of 2010 – 2030 m (sub-alpine to alpine zone). Sites S1 (ski slope) and C1 (control) are on the Schloßalm mountain on the west side of the valley. They face south to south-east, and are grazed by cattle in the summer months. Sites S2 and C2 are located on the Fulseck mountain on the opposite side of the valley, and have a south to south-westerly aspect. These sites are grazed sporadically by sheep in summer. Both of the ski slope sites (S1 and S2) were artificially landscaped in 1980 (2 years before field work was undertaken) and replanted in the same year with European, but not local, seed mixtures containing various combinations of grasses *Agrostis tenuis, Dactylis glomerata, Deschampsia caespitosa, D. flexuosa, Festuca ovina, F. rubra, F. pratensis, Lolium perenne, Phleum pratense, Poa pratensis*, and a few forb species including *Lotus corniculatus, Trifolium hybridum* and *T. repens*.

Orthoptera sampling

Orthoptera populations were censused at each site by manual searches along 10 × 1 m randomly placed transects. Species, instar

and sex (the last from 3rd instar upwards) of each grasshopper encountered were recorded. Censuses were taken at 1–2 week intervals from 22 June to 7 November 1982 under warm, sunny conditions, though avoiding times of intense midday heat. The total ground area sampled on each occasion at each site varied between 30 and 100 m^2, depending on the stability of the weather. This sampling programme gave estimates of absolute abundances that were within 10% of equivalent estimates obtained from mark/recapture experiments at the same sites (Illich, unpublished). The sampling was thus considered to provide an accurate description of the Orthoptera communities present. The mark/recapture results also provided evidence that most individuals have a limited range of movement, with little tendency to wander between the field sites.

Results

A total of five species of Orthoptera (four Acrididae and one Tettigoniidae) were collected from the field sites (Table 1). It may be seen that the ski-slope site S1 on the Schloßalm mountain harboured none of these insects at all, even though two species were present in the neighbouring control site C1. Although this result is in itself important, it means that detailed comparisons of grasshopper populations on ski slope and control meadow sites is confined to the two Fulseck sites, S2 and C2. Here the ski slope supported a reduced fauna of three species of grasshoppers in comparison to the total of five species of Orthoptera present on the control meadow.

Phenological variations in the total densities (all instars) of each of the species present in the two Fulseck sites and in the Schloßalm control meadow are shown in Fig. 1. *Chorthippus parallelus* was the dominant grasshopper throughout the season in all areas, but in common with *Aeropus sibiricus* and *Miramella alpina*, numbers found on the ski slope were considerably depressed in comparison to the control meadow populations. Further, the seasonal durations of the populations were distinctly shorter on the ski slope, being curtailed by some weeks at the end of the summer. The proportions of the sexes present in the different populations ranged between 48% and 58% female and did not differ significantly between sites or between adult and nymphal stages (X^2 tests, $P > 0.1$ in all cases).

Detailed information on the phenological differences between the ski-slope and control populations of *C. parallelus* is provided in Fig. 2, where the census data are presented as percentage composition of the different instars over the season. Shorter instar durations, particularly before instar 3, are evident in the ski-slope population, where the adults became abundant some 1–2 weeks before those of the equivalent control population.

Table 1 Orthoptera species assemblages found on upper subalpine ski slope and control meadow sites on the Schloßalm (*S1*, *C1*) and Fulseck (*S2*, *C2*) mountains in 1982. + indicates presence, – indicates absence of a species

SPECIES	S1	C1	S2	C2
Metrioptera brachyptera	-	-	-	+
Miramella alpina	-	+	+	+
Euthystira brachyptera	-	-	-	+
Aeropus sibiricus	-	-	+	+
Chorthippus parallelus	-	+	+	+

Discussion

Responses of Orthoptera to habitat disturbance

This study demonstrates that grasshopper communities occurring on sub-alpine ski slopes may exhibit reduced species richness, smaller population sizes, and accelerated nymphal development in comparison to communities found on nearby unskied, control meadows. Some of these differences are explicable, at least partially, by reference to the known biologies and habitat preferences of the particular species.

Chorthippus parallelus, the most abundant species at all sites, is a generalist in its microclimatic preferences (e.g. Voisin 1990) and feeding strategy (e.g. Bernays and Chapman 1970; Schäller and Köhler 1981; Illich and Winding 1989). Thus this species is able to adapt somewhat to the habitat changes caused by the ski slopes. *Aeropus sibiricus* is also a generalist, but has some preference for warmer, dryer habitats with low vegetation cover (Stevanovic 1961; Nadig 1986; Illich and Winding 1989). Such conditions are typical of the open ground of the ski slope (Tappeiner 1985), providing a likely explanation for the presence of the species here. *Miramella alpina* feeds preferentially on herbaceous plants (Illich and Winding 1989) and is usually associated with relatively complex vegetation structure and a more humid microclimate than the above two species (Nadig 1989). Its presence was thus not expected on the ski slope. However, the species was only ever found near the edges of the ski site where the vegetation was less sparse and within close reach of the thicker, more natural vegetation cover, which also contained higher proportions of herbaceous plant species. This "edge effect" explains the presence, in low densities, of the species on the ski slope.

The total absence from the ski slopes of the remaining two species, the grasshopper *Euthystira brachyptera*, and the bush cricket *Metrioptera brachyptera*, is most likely a consequence of their known preferences for taller vegetation with considerable vertical structure. Bush crickets are generally found in such habitats, while rather atypically for the true grasshoppers, the females of *E. brachyptera* are known to require these conditions for egg-laying, the favoured oviposition sites being higher in the vegetation, often on grass stalks (e.g. Sänger 1977). The short, open vegetation of the ski slopes does not provide these conditions. *E. brachyptera* is also a specialist herbivore at the present sites (Illich and Winding 1989), so its absence from the ski slope conforms to the pattern already noted for syrphid fly and carabid beetle assemblages on ski slopes.

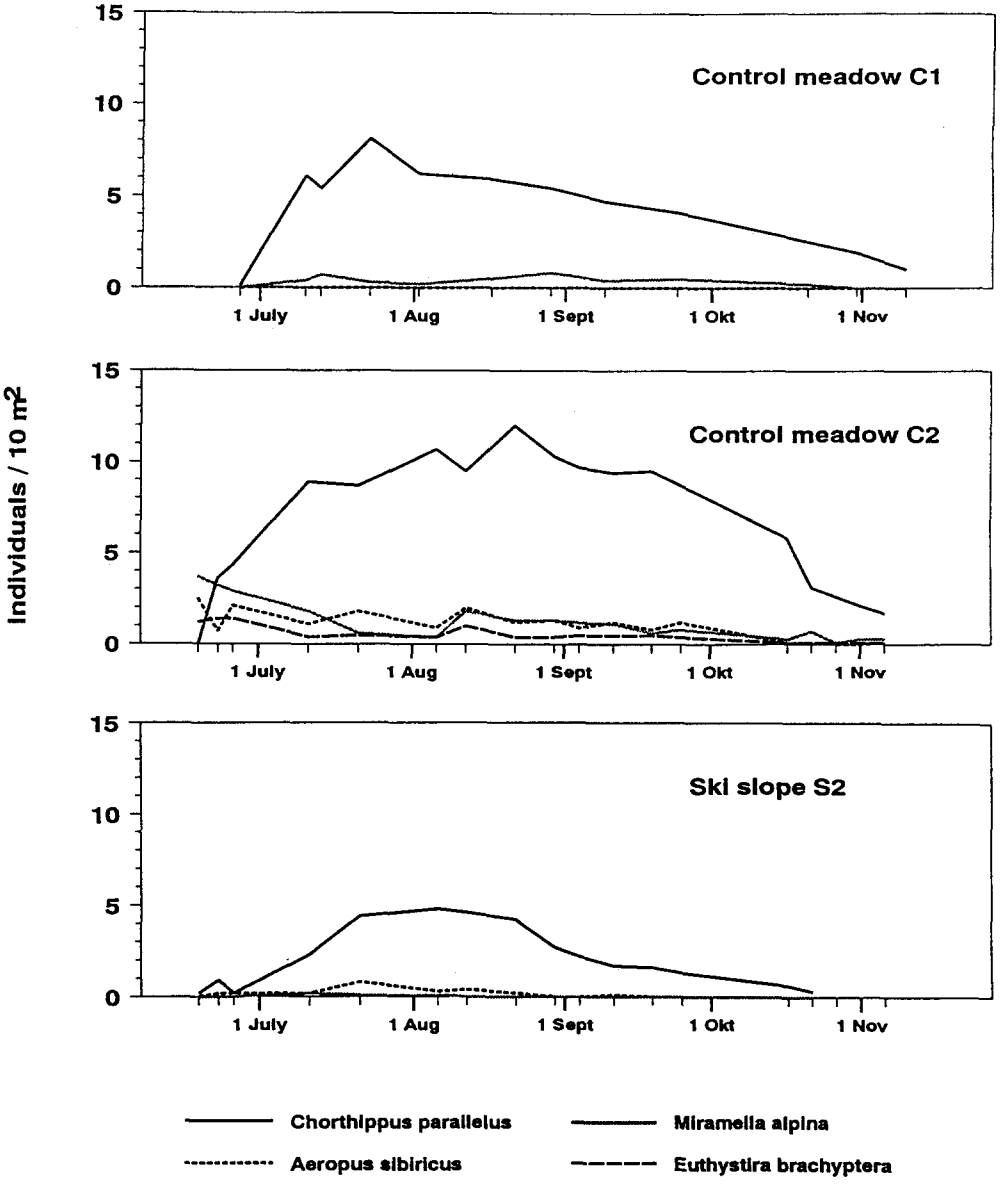

Fig. 1 Seasonal variations in total densities (all instars) of each species of Orthoptera found on the two control upper sub-alpine meadows (*C1*, *C2*) and on the Fulseck ski slope (*S2*) in 1982

The above account of the observed patterns of species presence and abundance is further supported by the relation between patterns of vegetation structure and grasshopper community structure recently described for rangelands in the United States (Kemp et al. 1990). As in the present study, these authors did not design their work specifically to determine which factors influence grasshopper community dynamics, but they were still able to conclude that "habitat type" as defined by the vegetation affects grasshopper species presence and relative abundance.

Turning attention to the observed shorter population durations and the faster rate of nymphal development of grasshoppers on the ski slope, evidence from other studies would suggest that these are a consequence of microclimatic differences between the ski slope and control meadow, very similar to the changes that have been observed along altitudinal gradients. Dingle et al. (1990), working on the North American grasshopper *Melanopus sanguinipes*, found that nymphal development and development of adults to age of first reproduction were both accelerated at higher altitudes. They suggest that soil temperature and basking behaviour are more important for successful nymphal development at high altitudes than other variables such as photoperiod and ambient temperature. Tappeiner (1985) clearly demonstrated that greater penetration of solar radiation to ground level and higher ground temperatures than normal are characteristic of the sub-alpine ski slopes investigated here.

Much has been written about the physiological responses of Orthoptera to weather conditions and microclimate, but exactly which mechanisms are involved in the ski slope Orthoptera remains unknown. Certainly changes in metabolic rate (e.g. Begon 1983) and associated variations in the rate of oxygen uptake (Massion 1983) are likely to be important. How these affect the life history strategies, particularly in relation to variables

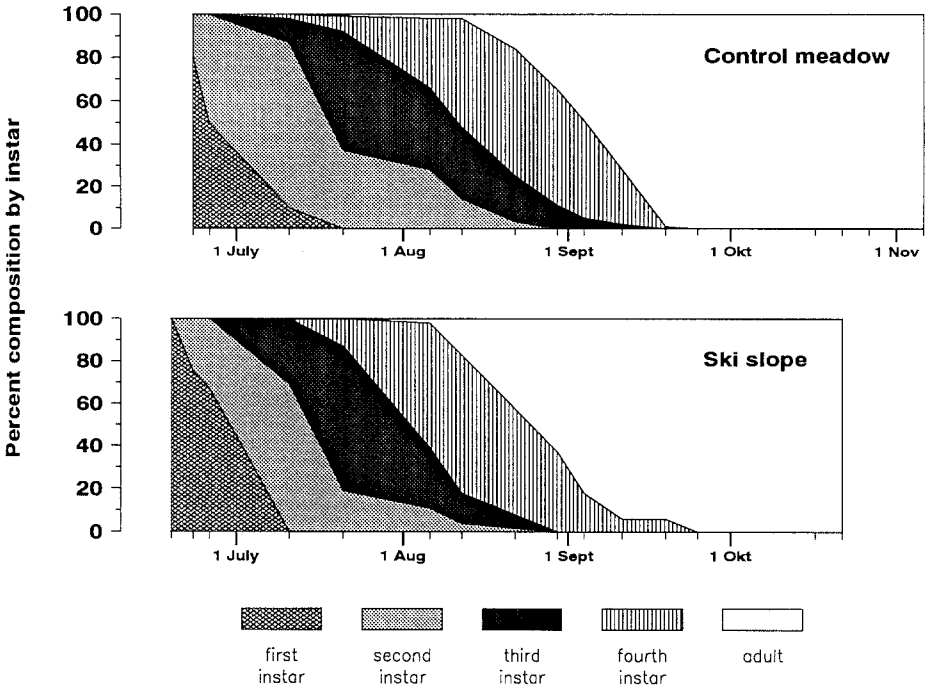

Fig. 2 Developmental phenologies of *Chorthippus parallelus* on the Fulseck ski slope (*S2*) and on the neighbouring control meadow (*C2*) in 1982

such as egg size and the occurrence of an additional instar (IIa) that permits individuals to reach a larger size at maturity, as recently reported for *Chorthippus brunneus* (Grant et al. 1993), must await further research.

Implications for ski slope ecology

From the present results, it could be argued that the ski slopes in the mountains might actually be beneficial to those species of Orthoptera that can utilize the modified habitat type. An accelerated rate of development has indeed been postulated as an advantage to grasshopper survival when a short growing season and extended periods of adverse conditions prevent completion of the life cycle in a single year (Green 1983). However, extensive physical damage to the ground surface on the ski slopes (and hence destruction of over-wintering eggs) caused by skiers and by the snow-moving vehicles that operate in winter more than outweighs any seeming advantages.

Our results add to a growing body of evidence that suggests that skiing causes dramatic and detrimental changes to mountain ecosystems long before we may register them as "damage". Elsewhere, one of us has already drawn attention to the significance of insect/plant interactions as finely-tuned "early warning systems" for detecting habitat change on mountains (Haslett 1991). Given that skiing is a major world tourist industry and that the damage it causes is generally irreversible over human time scales, aids to early prediction and accurate monitoring must be considered an essential aspect of future management strategies on mountains. The Orthoptera, with their sensitivity to microclimate as well as vegetation type, may prove to be an important tool in this respect.

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