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Anthropogenic influence on primary succession: A comparative study of 3 glacier forelands of the Central -Alps, Austria

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Abstract

Glacier forelands are ideal ecosystems to study community assembly processes. Previous research has shown that these processes are mainly driven by stochastic events, like the occurrence of safe sites and seed availability. This study focuses on possible anthropogenic influences on these primary successions.

Floristic data of three glacier forelands show that anthropogenic influences in form of (i) grazing sheep and (ii) hiking trails are creating patterns, visible in the floristic community composition and in change of species numbers. (iii) Additionally, it was found that the special protected area 'Inneres Untersulzbachtal', where grazing has been absent for decades didn't show any of these patterns, underlining the importance of process-protection in glacier forelands, as one of the last truly wild ecosystems in central Europe.

Keywords

Glacier foreland, primary succession, anthropogenic influence, grazing, wilderness

Introduction

Spatially ordered chronosequences provide scientists with unique insights into processes of primary succession, like community assembly (WHITTAKER 1993; STÖCKLIN & BÄUMLER 1996; NIEDERFRINIGER 2000; RAFFL & ERSCHBAMER 2004; ERSCHBAMER 2007; ERSCHBAMER et al. 2008). Previous studies have shown that community assembly on glacier forelands is driven by stochastic events (Del Moral et al. 1995) where the availability of safe sites and seed occurrence (DEL MORAL et al. 1988; STÖCKLIN & BÄUMLER 1996) play a major role, leading to a patchy and chaotic fine scale vegetation structure (BURGA et al. 2010). Considering that Central Europe mostly consists of anthropogenically modified landscapes, glacier forelands, that recently have become ice-free, represent one of the last examples of unaffected natural environments, which might qualify as wilderness (DUDLEY 2008; WILD EUROPE 2013). Nowadays, sheep are roaming in the mountains by themselves during the summer months, exert some grazing pressure on those pristine locations even in protected areas. Due to a lack of shepherds there is little control over grazing location and intensity (SPANGENBERG-RESMANN 1978). Free access to glacier foreland sites may have tremendous effects on plant community composition (AUGUSTINE & MCNAUGHTON 1998; AUSTRHEIM & ERIKSSON 2001; EVJU et al. 2006; AUSTRHEIM et al. 2008). HODKINSON et al. (2003) have pointed to a shortfall of previous research on glacier forelands: 'One factor that is almost invariably overlooked when studying glacial chronosequences is the impact of additional external factors such as animal influences on ecosystem development (VAN DER WAL et al. 2001; WOOKEY et al. 2002). The present study aims to analyse mechanisms of community assembly processes, while accounting for the effects of sheep grazing on the proglacial areas. Therefore, following questions have been examined: (i) does grazing and (ii) do hiking trails have effects on the community structure of succession sites? (iii) Does the ungrazed special protected area 'Inneres Untersulzbachtal' (National park Hohe Tauern Salzburg) show different patterns of community assembly processes than the grazed sites 'Viltragental' and 'Frosnitztal' (National park Hohe Tauern Tyrol)?

Material and methods

Study area

In summer 2016 plant surveys were conducted on three glacier forelands of the Venediger Mountain Range (Salzburg and Tyrol, Austria, 47° 6′ N, 12° 20′ E), namely in the 'Viltragental' (Viltragenvalley), 'Frosnitztal' (Frosnitzvalley) and 'Untersulzbachtal' (Untersulzbachvalley).

Methods

Plant relevés (DIERSCHKE 1994 after BRAUN-BLANQUET 1964) were selected by a stratified random sampling approach. On every glacier foreland, six transversal transects with eight 1m² plots each (RAFFL & ERSCHBAMER 2004; RAFFL et al. 2006) where studied. Around every survey plot a 3x3m area was investigated for signs of trampling and damage caused by grazing. Faeces were recorded and determined and the number of dung piles noted.

Statistical analysis

Community structure

To get insights into processes shaping communities on glacier forelands, species data of all relevés and data of every single glacier foreland were ordinated by distance-based-redundancy-analysis (dbrda).
For the full model, the glacier and the transect number were set as random factors, in comparison, for all sub-models only the transect number was set as random factor.

Species numbers

To analyse how different processes affect the number of species in different succession stages of glacier forelands, regression analysis of species numbers for all relevés and for the three subsets (every single glacier foreland) were performed, using Generalized Linear Mixed Effect Models (GLMM).

Results

Results of community structure (dbrda) and species numbers (GLMM) are summarized in Tab. 1. Special attention should be paid to the importance of distance to hiking trails explaining community structure and species numbers of different models.

	Community structure	Species numbers
Full-model	(glac/tra)	(glac/tra)
Distance to hiking trails	0.002**	<0.001***
goodness of fit	0.07	0.35/ 0.64
Untersulzbachvalley	(tra)	(tra)
Altitude	0.006**	-
goodness of fit	0.07	0.04 / 0.44
Frosnitzvalley	(tra)	(tra)
Distance to hiking trails	0.094.	<0.001***
Altitude	0.074.	
Soil-type		0.05*
goodness of fit	0.07	0.63 / 0.80
Viltragenvalley	(tra)	(tra)
Distance to hiking trails	0.002**	
Altitude	0.002**	
Soil-type		0.02*
goodness of fit	0.15	0.04 / 0.42
. p<0.1, * p<0.05, ** p<0.01, *** p<0.001		

Table 1: this table shows significant results for the four different (sub-)models. All results are corrected by Holm-Bonferroni method. Depicted are results of the analysis of community structure, (dbrda based on a Bray-Curtis-dissimilarity index) and the analysis of the species richness (GLMM). Brackets show the random factor(s) of the models (glac: glacier, tra: transect number). Goodness of fit refers to the cumulative proportion of explanation given by the first two axes of the dbrda (Community structure), while for the GLMM (Species numbers) values are accounting for marginal and conditional R^2 values.

Effect of hiking trails

The number of sheep faeces significantly drops with increased distance to hiking trails in the Viltragenvalley ($p<0.001$, 89 samples) and in the Frosnitzvalley ($p=0.004$, 15 samples). No sheep faeces were found in the Untersulzbachvalley where domestic animals have been excluded since many decades.

Discussion

The impact of herbivores on the primary succession of glacier forelands is almost invariably overlooked when studying chronosequences (HODKINSON et al. 2003).

The present study found that anthropogenic influence is discernible in the plant community structure of two glacier forelands, to which sheep had free access, whereas in the special protected area 'Inneres Untersulzbachtal' no anthropogenic influence was found.

The distance to the hiking trail is the most important factor of the full model explaining differences between relevés in both, community structure and species numbers. Distance to hiking trail is also one of the significant predictors explaining community structure of the Viltragenvalley, while in the Frosnitzvalley distance to hiking trail shows a trend explaining community structure and is the most important predictor for differences in species numbers.

Results of the special protected area 'Inneres Untersulzbachtal' show that neither community structure nor species numbers were affected by distance to hiking trails.

Looking closer at the factor 'distance to hiking trails', results from faeces counts give indications that sheep favour areas closer to hiking trails or even use them (GANSKOPP et al. 2000 after VALLENTINE 1974). This behaviour would reduce their energetic costs of movement (BAILEY et al. 1996) and would be in line with the optimum foraging hypothesis after MACARTHUR & PIANKA (1966). This kind of behaviour was also observed while sampling in the field.

Additionally, the Frosnitzvalley is located at the border of the so called 'Tauernfenster', where different geological strata arise at the southern boundary of the glacier foreland, while the hiking trail is located at the northern side of the proglacial area. Vegetation pattern show a decrease in species numbers with distance to hiking trails. This result cannot be explained by the influence of basic rock (which should lead to an increase in species numbers (e.g. GOUGH et al. 2000)) and further supports the hypothesis of a biotic influence (e.g. grazing, trampling or fertilization) on the vegetation.

To sum up, anthropogenic influences of (i) grazing sheep are obviously affecting the primary succession of investigated glacier forelands and (ii) they are most prominent along hiking trails. And (iii) the special protected area 'Inneres Untersulzbachtal' did show different pattern for community structure and species numbers which can be attributed to the absence of anthropogenic influence. These findings underline the sensibility of the primary succession on glacier foreland sites to grazing pressure by domestic animals and emphasise the importance of process protection in one of the last wild areas in central Europe.

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