

Chapter 2

Response of Arctic Alpine Biota to Climate Change – Evidence from Polar Urals GLORIA Summits

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Abstract Polar Urals as one of target regions of Global Observation Research Initiative in Alpine Environments (GLORIA) comprises a suite of four summits, representing an elevation gradient of alpine vegetation patterns. The sampling areas cover the summits from the tops down to the 10 m contour line and are divided into eight sections. For each section, a complete list of vascular plants and herpetobiotic arthropods was collected and resurveyed. In the period from 2001 until 2015, the species numbers steadily increased and the total surplus of vascular plants was up to 13 species on separate summit. A general decrease in the total cover of vascular plants and changes in percentage cover of the dominant species was recorded on the permanent plots; certain species of herbs decreased and certain shrub species increased. Among the dominant species of invertebrates, ground beetles and millipedes were replaced by click beetles and spiders. After 14 years the altitudinal index calculated for vascular plants gave an average upward movement of 13.6 m, that is more pronounced than in Northern and Southern Urals. The thermophilization of the alpine plant communities of Polar Urals was found equal to 9.3% of one vegetation belt. The temperature sums obtained from data loggers demonstrate the slight tendency of increase, especially for the lower summits.

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2.1 Introduction

The field sites of this study are located in the Polar Urals and constitute a part of the international long-term monitoring network GLORIA (Global Observation Research Initiative in Alpine Environments). This GLORIA initiative focuses on the alpine life zone, the area above the forestline, for tracing and understanding the response of alpine ecosystems to ongoing climate change (Pauli et al. 2015). The vascular plant species occurrence was recorded first in the year 2001 on 72 mountain summits distributed across 18 study regions in Europe, with Polar Urals among them. Since then the surveys were repeated twice, in 2008 and 2015.

The Urals is a unique submeridional mountain range in Eurasia, extending over 2000 km in north-south direction from the Barents Sea and Kara Sea shores at ca. 70°N to the Pre-Aral Sea sands at ca. 48°N. The mountain range crosses several zoniomes from arctic tundra to steppe and is, accordingly, divided into five orographic regions: Polar, Subpolar, Northern, Middle and Southern Urals (Mikhailov and Olschwang 2003). From these regions, Polar Urals is situated mainly inside the North Polar Circle and is a part of the Arctic floristic region as delimited by Yurtsev (1994). Alongside with Khibiny, Putorana Plateau and other meta-arctic mountains (Makarova et al. 2013), Polar Urals is situated at the North Polar Circle and having alpine life zone in closest contact with the arctic tundra zoniome. That is why the results of this study are of interest for both alpine and Arctic research.

In contrast to meteorological and glaciological studies, long-term observations of climate change impacts on alpine ecosystems are scarce and mainly based on incidental historical data from the Alps, Scandes and the Scottish Mountains (Pauli et al. 2015). For the arthropod communities similar records are limited mainly for 20–30 years comparison of the ground beetle assemblages in the Apennines and the Dolomites (Brandmayr et al. 2002; Pizzolotto et al. 2014).

Resurveys of the historic summit sites in the Alps showed that vascular plants have been found at higher altitudes than recorded earlier (Pauli et al. 2012). Furthermore, recent resurveys of 60 summits of the major European mountain ranges provide evidence that more warm-demanding plant species, which usually dwell at lower elevations, increase and more cold-adapted species occurring at high elevations show concurrent decline. This process was described as thermophilization of alpine plant communities (Gottfried et al. 2012). Alongside with it, a general upward shift of plant species was observed across the continent during the past decade. In northern and central Europe, this led to an increase in species numbers, while in the Mediterranean region, species numbers were stagnating or decreasing (Pauli et al. 2012).

Within alpine biota only very few attempts have been made to search for a restricted set of organisms acting as surrogates for overall species richness. According to Pauli et al. (2015) vascular plants as sessile and macroscopic organisms that can be readily identified in the field represent such a group. On the other hand, the studies of Finch and Löffler (2010) in alpine areas of Norway resulted in advice to use, apart from vegetation, at least one abundant group of invertebrates as

indicator for general species richness pattern. The arthropods that depend strongly on abiotic factors and plant species distribution are exactly such a group.

2.2 Materials and Methods

The detailed description of the standard long-term monitoring design and method of GLORIA, is given in the field manual available online (Pauli et al. 2015), where the authors of this paper contributed as well. According to this Multi-Summit Approach a target region in the Polar Urals was established in 2001. It comprises a suite of four summits (see Table 2.1) distributed in equal elevation intervals and representing an elevation gradient of vegetation patterns, characteristic for this mountain region (Gorchakovky 1975). The summits are situated in Yamalo-Nenets region of Russia in the valley of Sob' river ca. 45 km NNW Salekhard (66°54' – 67°00' N, 65°35' – 65°46' E) along the Sob'-Elets passageway and quite easily accessible by the railway from Labytnangi to Ust-Vorkuta.

The sampling area covered each summit from its top (highest summit point) down to the 10 m contour line and was divided into eight summit area sections (SAS). The standard records for each SAS include a complete species list with the estimation of the abundance of each species and percentage top cover of surface types. The 3m×3m quadrat clusters are placed at the 5-m level in all four main compass directions (Fig. 2.1).

Each quadrat cluster includes four 1-m² quadrats, where the top cover of surface types and cover of each vascular plant species are recorded (Pauli et al. 2015). Four T-loggers (GeoPrecision Mlog-5W) positioned on each summit has been measuring the soil temperature 10 cm below the surface at hourly intervals since 2001 until 2015. Polar Urals is one of the few GLORIA target regions, where invertebrate monitoring as an extra approach is used according to research protocol by one of the authors (Mikhailov 2015).

The field teams included leading experts of regional biodiversity, able to identify all vascular plant taxa at the vegetative stage on site. For arthropods the exact determination of collected specimens followed later on by comparing with reference

Table 2.1 The number of species of vascular plants found on the summits of Polar Urals during the three monitoring campaigns

| Summit | Altitude, m a.s.l. | Raw data | | | Filtered data | | |
|------------------------|--------------------|----------|------|------|---------------|------|------|
| | | 2001 | 2008 | 2015 | 2001 | 2008 | 2015 |
| Pourkeu (POU) | 839 | 4 | 3 | 3 | 0 | 0 | 0 |
| Malyi Pourkeu (MPO) | 641 | 51 | 54 | 61 | 46 | 47 | 51 |
| Slantsevaya (SLA) | 417 | 38 | 45 | 51 | 34 | 39 | 40 |
| Shlem (SHL) | 300 | 35 | 38 | 37 | 26 | 28 | 27 |
| Total in target region | | 72 | 79 | 90 | | | |

Raw data columns refer to unprocessed data, filtered data columns to the data pre-processed

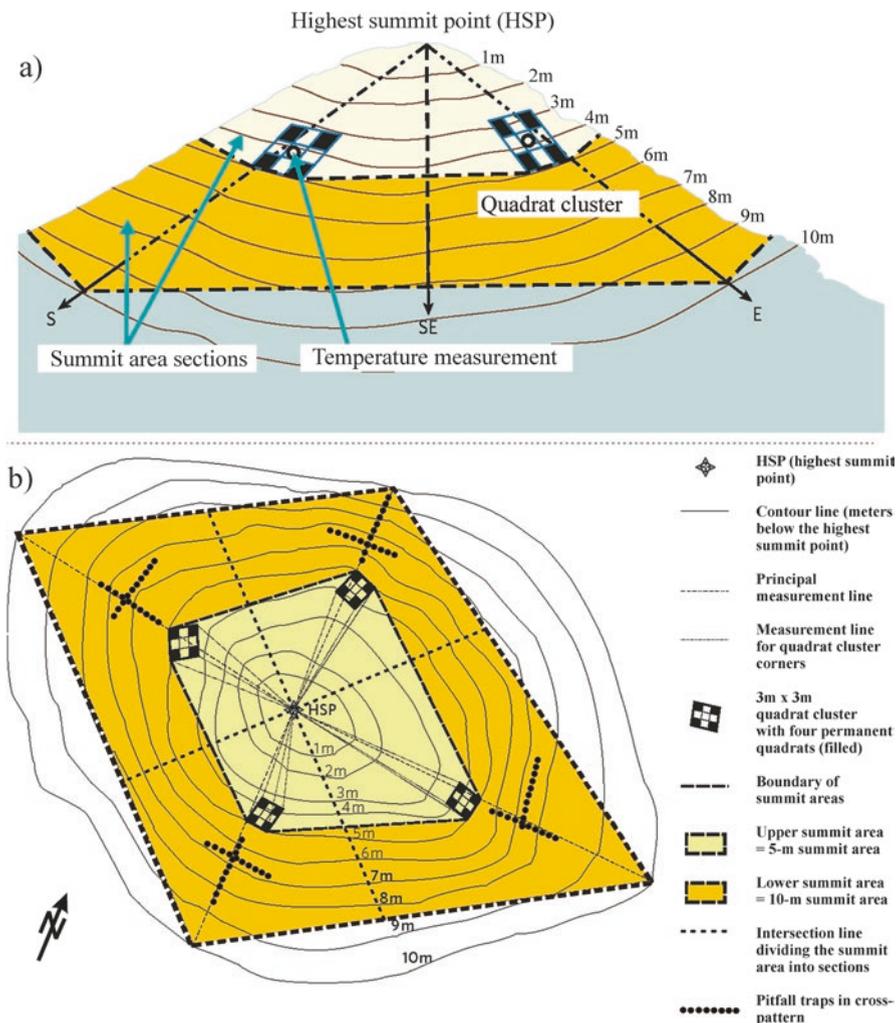


Fig 2.1 The Multi-Summit sampling design illustrated on an example summit. (a) Oblique view with schematic contour lines; (b) Top view. The 3m×3m quadrat clusters, pitfall traps in cross-pattern (extra approach) and the corner points of the summit areas are arranged in the main geographical directions (Modified from Pauli et al. 2015)

collections or by specific expertise. To gain representative data the results from single pitfall traps were pooled for each line of ten traps in each SAS; for plants data from single SAS and 1-m² quadrat were used in the analyses as independent replicates. To avoid observation errors in collecting species lists the same experts participated in all surveys and the data was filtered to remove single records and potentially misidentified species from the list before analysis.

To evaluate whether the changes in summit species richness might be related to a possible upward or downward move of species ranges, an altitudinal index for each species of vascular plants and first for invertebrates was calculated following Pauli et al. (2012).

For detection of a warming effect or thermophilization the first step is assigning an altitudinal rank to all recorded plant species according to their optimum performance (see Supplementary Materials for Gottfried et al. (2012)). Using data on altitudinal ranks and cover of each plant species within 1-m² quadrats a composite score in the following thermic vegetation indicator S was then calculated. Its differences between respective years were used to quantify transformations of the plant communities and termed thermophilization indicator D ($D = S_{year1} - S_{year2}$) (Gottfried et al. 2012).

2.3 Results and Discussion

Using data from T-loggers we computed temperature sums that influence species diversity patterns. As the threshold temperatures for plant growth in alpine regions are not commonly agreed (Körner 2012), we used temperature sums above 3 °C for May–July and from them revealed slight tendency of increase especially for the lower summits (SLA and SHL) (Fig. 2.2).

On two summits with polygonal alpine tundra (SLA and MPO), the number of plant species has been steadily increasing as estimated in summit area sections. Between 2001 and 2008 the increase was from 3 to 7 species, between 2008 and 2015 – from 6 to 7 species (Table 2.1). After 14 years the surplus was up to 13 species on the separate summit and 18 species for the whole target region.

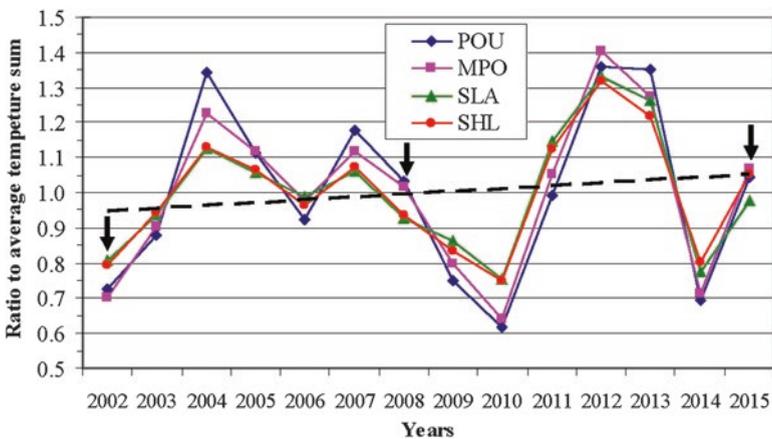


Fig. 2.2 Temperature sums > 3 °C for May-July (indexed to the average value) computed from T-loggers data from the summits of Polar Urals

Across 66 summits surveyed by GLORIA-Europe, the average numbers of species per summit increased by ca. 8% between 2001 and 2008. However, only in boreal and temperate regions most summits have gained additional species (average increase was from 38.0 to 41.9, that is 10.3%), while in Mediterranean regions the majority of summits had less species (Pauli et al. 2012). In the Polar Urals there was a similar 10% increase for this period and 10.6% between 2008 and 2015 (Table 2.1).

Comparable data for herpetobiotic arthropods is available between 2008 and 2015 for two lower summits (SHL and SLA) where the increase in number of species yielded 3–4 for all species and 2–4 after filtration of species lists.

At the continental scale, counts of altitudinal index from 2001 till 2008 suggest that plant species were shifting their distributions to higher altitudes by 2.7 m on average (Pauli et al. 2012). The results for the Polar Urals for the same period gave the shift for 9.2 m and from 2008 till 2015 – for 4.4 m so that in general for 14 years the shift was 13.6 m upslope. In opposite, for invertebrates, the shift was 20.6 m downslope from 2008 to 2015.

With the general decrease of total cover of vascular plants on the permanent quadrat clusters, changes were found in percentage cover of the dominant species in the communities between the years 2001 and 2015. The common tendency was a decrease of some species of herbs (e.g. *Luzula confusa* Lindeb., *Festuca ovina* L.) and increase of certain shrub species (e.g. *Ledum decumbens* (Ait.) Lodd. ex Steud., *Dryas octopetala* L., *Vaccinium vitis-idaea* L.). The percentage cover of alpine sweetgrass *Hierochloa alpina* (Willd.) Roem. & Schult., a common species on all summits, was obviously decreasing on eastern and northern sectors and increasing in southern sectors.

The dominance level for each arthropod species was calculated according to the classification of Engelmann (1978) and the dominance structure was analyzed at species and family levels. The most comparable results during surveys in 2008 and 2015 were obtained for SLA summit (Table 2.2).

In both surveys true bugs *Chlamydatus opacus* Zett. and *Calacanthia trybomi* Sahlb. were dominating, but in 2008 they were co-dominating while in 2015 *C. trybomi* got higher dominance class than *Ch. opacus* and the percentage almost five times as higher. Besides, the most notable tenfold decrease of abundance was found for ground beetle *Carabus truncaticollis* Popp. while click beetle *Oedostethus similarius* Dolin et Medv. increased its abundance also tenfold and Lycosid spider *Pardosa septentrionalis* West. increased four times.

For the Polar Urals between 2001 and 2008, the thermophilization indicator D was 0.057, almost the same value as a European mean (Gottfried et al. 2012). In the next period, between 2008 and 2015, D was lower (0.037) (Table 2.3).

This gives the extent of transformation of alpine summit communities in the Polar Urals in the magnitude of 5.7% of one vegetation belt between 2001 and 2008, 3.7% between 2008 and 2015 and resulting 9.3% for 14 years. Among the summits, the third one, MPO, had almost no changes, the lowest one (SHL) represented almost the same D values as the average for the region, while the second summit, SLA, had the highest value of 18% of one vegetation belt for 14 years (Table 2.3).

Table 2.2 The dominance structure of herpetobiotic arthropods on Slantsevaya (SLA) summit at species and family levels

| Dominance class | 2008 | | 2015 | |
|---|-------------------------------|-------------|--------------------------------|------------|
| | Species | Family | Species | Family |
| Eudominant | <i>Chlamydatus opacus</i> | Miridae | <i>Calacanthia trybomi</i> | Saldidae |
| | <i>Calacanthia trybomi</i> | Saldidae | | |
| Dominant | <i>Lithobius curtipes</i> | Lithobiidae | <i>Chlamydatus opacus</i> | Miridae |
| Subdominant | <i>Carabus truncaticollis</i> | Carabidae | <i>Alopecosa hirtipes</i> | Lycosidae |
| | <i>Alopecosa hirtipes</i> | Lycosidae | <i>Pardosa septentrionalis</i> | Lycosidae |
| | | | <i>Oedostethus similarius</i> | Elateridae |
| S (number of species) | 21 | | 24 | |
| N (total number of collected specimens) | 469 | | 410 | |
| H (Shannon index) | 1.79 ± 0.05 | | 1.71 ± 0.07 | |
| E (evenness index) | 0.59 | | 0.54 | |

Table 2.3 Thermic vegetation indicator (S) and thermophilization indicator (D) for the summits of Polar Urals for each period of survey

| | SHL | SLA | MPO | D average |
|-------------|------|------|------|-----------|
| S 2001 | 3.36 | 3.40 | 3.00 | |
| S 2008 | 3.41 | 3.51 | 3.01 | |
| S 2015 | 3.45 | 3.58 | 3.01 | |
| D 2001–2008 | 0.05 | 0.11 | 0.01 | 0.057 |
| D 2008–2015 | 0.04 | 0.07 | 0.00 | 0.037 |
| D 2001–2015 | 0.09 | 0.18 | 0.01 | 0.093 |

The presented data on climate-induced transformation of alpine biota within 14 years can be considered a rapid ecosystem response to ongoing climate change. In comparison with Northern and Southern Urals upwards migration of more warm-demanding plant species in the Polar Urals is more pronounced. The lack of similar data from other meta-arctic and arctic mountains prevents us from making broader circumpolar conclusions, however ongoing GLORIA activities expect further data from Alaska, Greenland and Svalbard.

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