

Altitudinal variability and diversity in the grassland communities of the Eastern Giant Mts.

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Abstract

Altitudinal gradient represents one of the most important features differentiating plant communities in a mountain environment. Such gradient was studied within the landscape transect using phytocoenological relevés of grasslands. These communities cover secondary meadows in lower altitudes to natural (sub)alpine grasslands. The CCA ordination reveals altitude as statistically significant factor, which has described approximately 3% of total data (species composition) variance. The second most important environmental feature is represented by soil moisture. Terrain configuration and management play important role also. Changes in species diversity are conditioned by altitudinal gradient. This relationship can differ in the whole data set of the complete gradient and in partial sets of selected communities.

Keywords: altitudinal gradient, Giant Mts., grassland communities, ordination, species diversity, temperature, TWINSpan

Introduction

Altitude represents one of the most important environmental conditions because it is the independent factor for the temperature function. It is known, that the year-average temperature decrease by 0.56 °C (MATĚJKA 2010b) or 0.58 °C (KVĚTOŇ 2001) in each 100 m. Relationship temperature on altitude during growing season (April – September) is more steepest – relevant temperature decrease was 0.64 °C per 100 m (MATĚJKA 2010b). Sum of precipitation is related to altitude similarly, but spatial (regional and small-scale) variability is more important.

Altitudinal gradients in grassland plant communities have been studied over whole globe (e.g. FUNES et al. 2003, SIEBEN et al. 2010, VALACHOVIČ et al. 2002, ZHANG et DONG 2009).

The altitudinal gradient in the Czech forests is well known as sequence of forest altitudinal zones, where vegetation can be characterized by species composition of the tree layer.

Mountain environment is suitable to study relationships between altitude and community structure, with often use of gradient analysis principles (e.g. AUERBACH et SHMIDA 1993, FERNANDEZPALACIOS et DENICOLAS 1995, ŠRŮTEK and KOLBEK 1994). The Giant Mountains are well suitable to study altitudinal gradients because broad interval of plant

altitudinal zones (colline to alpine zone) is present there. This gradient embraces three main biomes: broad-leaved deciduous forest, mountain taiga with Norway spruce and tundra (CHYTRÝ 2012). The forest altitudinal zones (in sense of the Czech forest-typological school; VIEWEGH et al. 2003) embrace 3rd to 9th zone. Altitudinal zonation in forest of the Czech Republic is well described (e.g. PRŮŠA 2001). The altitudinal gradients were described in some forest communities in the Bohemian Forest. The gradient increment (described as the change of DCA score along corresponding ordination axis) was comparable in the plant, mushroom, epigeic beetle and oribatid communities (MATĚJKA 2011).

The grassland vegetation was never directly related to altitude as the primary environmental variable, but variability of these communities has been studied in huge set of studies (CHYTRÝ 2007). Many studies have dealt with management practice as main driver of the differentiation and succession in grassland vegetation (POUROVÁ 2009). There is lot of specific grassland-management studies in the Giant Mountais (e.g. HEJCMAN et al. 2010, POUROVÁ et al. 2010, BLAHNÍK 2013). The grass and similar communitie in the Giant Mountains are relatively well known (KRAHULEC et al. 1996), nevertheless, the plant sociological studies have only embraced the altitude into set of environmental conditions important for the phytocoenological unit distribution.

Study area

The investigated plots were localized along a landscape transect in the Czech part of the Giant Mts. (Krkonoše Mts.) or near this transect (Fig. 1). The transect with a total length approximately 18 km and width of 2 km (total area of 34.3 km²) connects the highest localities below the top of the Sněžka Mt. with the agricultural landscape in the vicinity of Vrchlabí, one of the major centers of the Giant Mountains (MATĚJKA 2010a). Complete set of the vegetation altitudinal belts (CHYTRÝ 2012) from the supracolline belt at the lowest altitudes to the alpine belt around the summit in the opposite end of the transect is developed in the study area. There are several historical deforested enclaves in surroundings of the mountain chalets (Hořejší Vrchlabí, Strážné, Luisino údolí, Hřibčcí Boudy, Husí Boudy, Lahrovy Boudy, Přední Rennerovky, Friesovy Boudy, Zadní Rennerovky, Klínové Boudy, Richterovy Boudy). These enclaves are actually covered by grasslands and similar plant communities in prevailing part. Only some plots are managed at present. Many plots have been abandoned, without regular moving. Environmental conditions in the transect were described by MATĚJKA (2010a).

The climate is possible to describe using two meteorological stations managed by the Czech Hydrometeorological Institute: Vrchlabí (H1VRCH01, altitude 482 m a.s.l.) and Luční bouda (H1LUCB01; 1413 m a.s.l.). Weather parameters were read from official weather graph published at web pages www.chmi.cz during two years between 7th December 2014 and 5th December 2016. The graphs were automatically digitalized with following results (LB - Luční bouda, VR - Vrchlabí):

- day average of air temperature $T_{LB} = -5.09 + 0.918 T_{VR}$

- day minimum of air temperature $T_{LB} = -4.03 + 0.937 T_{VR}$

- day maximum of air temperature $T_{LB} = -5.08 + 0.831 T_{VR}$

Average temperature was 8.5 °C at Vrchlabí and 2.8 °C at Luční bouda. It corresponds to 0.62 °C decrease for each 100 m in elevation. Temperature gradient in months May to September was 0.70 °C for each 100 m. Average measured air temperatures are higher than averages calculated according to model for period 1961-1990 using digital elevation model (MATĚJKA 2009): 7.1 and 1.9 °C, respectively.

Inversion with lower air humidity at higher elevated station Luční bouda comparing Vrchlabí occurred in 6.2% of days. The average temperature gradient in days without an inversion was steeper - $T_{LB} = -5.57 + 0.943 T_{VR}$.

Precipitation sum was 800 mm per year at Vrchlabí and 886 mm per year at Luční bouda. Air Humidity also differs: 76 % at Vrchlabí and 90 % at Luční bouda.

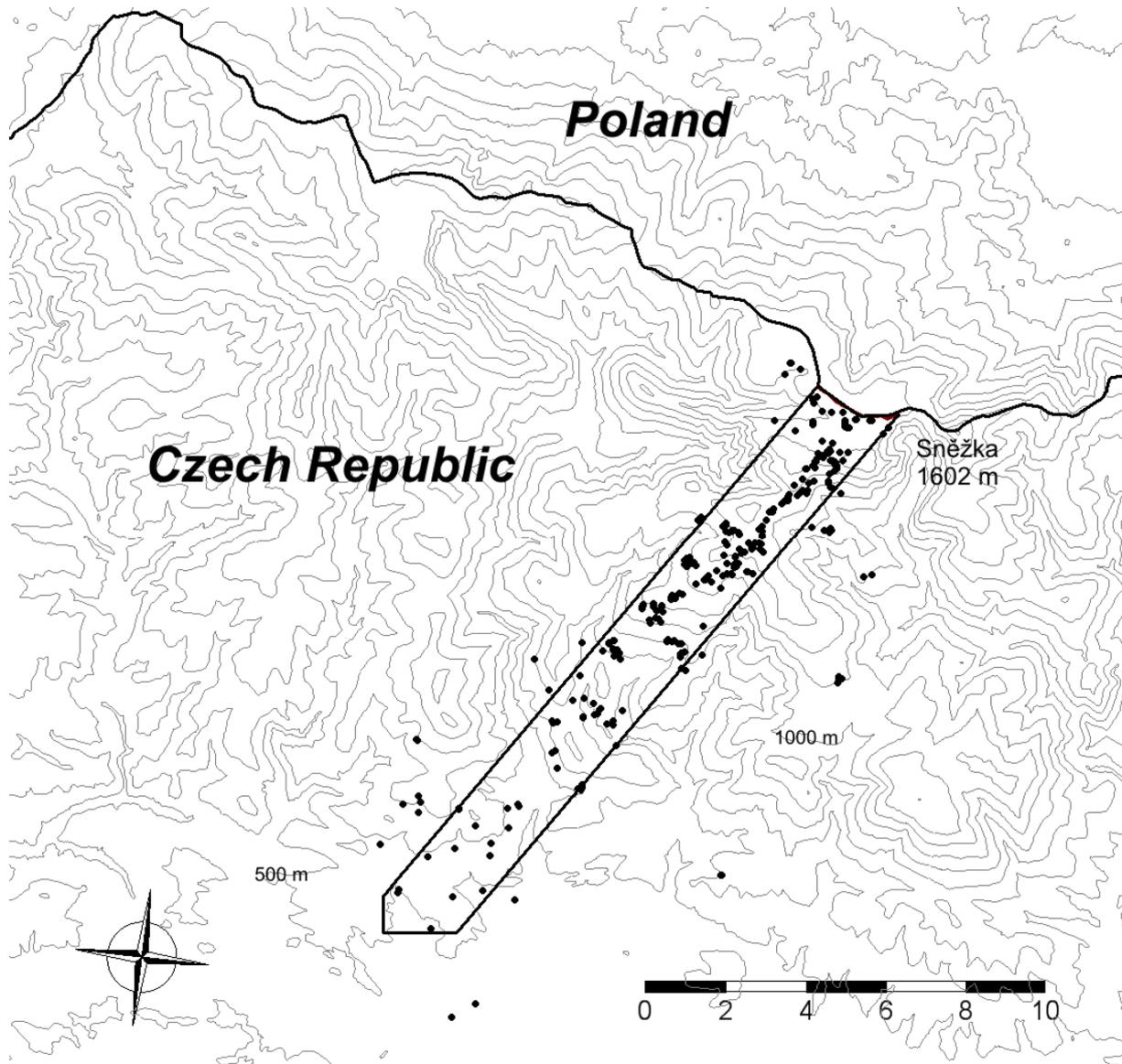


Fig. 1. Localization of the selected relevés (points) and the landscape transect in the Giant Mts. Contour lines with the 100m-step are drawn.

Material and methods

Plant communities of grasslands and similar stands were sampled using standard procedure with the Braun-Blanquet's scale for abundance and dominance. More than 500 relevés were recorded. These relevés were collected in the DBreleve database (MATĚJKA 2016). Each plot was localized as a point in the GIS layer on the base of the GPS precision measurement. The point altitude was compared with value from the digital elevation model (pixel 30 m), possible errors to be revealed. A selection of relevés was carried out: only 242

relevés recorded during 2006 - 2010 with total cover of the tree layer $E_3 < 5 \%$ and of the shrub layer $E_2 < 10 \%$ were accepted.

The species cover grades of used scale were transformed to average percentage cover as value of species representation. Data of species representation were standardized on sum of representations of all species in the etage to be equal to total cover of the etage. All community features described in the following text are related to composition of the herb (E_1) layer.

Herb layers of the communities were classified using TWINSpan procedure with cut-levels 0, 1, 10, 31.62 and 56.23 % (HILL 1979). Three classification levels were assigned to determine basic community groups because they have been well interpretable in ecological sense. All relevés of each basic community group were classified by the agglomerative procedure – group average linkage clustering with the Euclidean distance (Table 1). This method was used to reveal possible heterogeneity of the basic group. The highest cluster level indicates the total group heterogeneity.

Diversity parameters (species richness S , Shannon-Wiener's index H' and equitability e) were calculated in the DBreleve software: total diversity - Shannon-Wiener's index

$$H' = -\sum_i p_i \cdot \log_2 p_i$$

where p_i is relative representation of i -th species, and species equitability

$$e = H' / \log_2 S$$

(MAGURRAN 2004).

CANOCO version 4.5 was employed (TER BRAAK et ŠMILAUER 2002) to calculate canonical correspondence analysis (CCA). Importance of the altitudinal gradient effect in the species composition of the community herb layer was tested by the Monte Carlo permutation test.

The vascular-plant nomenclature follows KUBÁT et al. (2002).

Position of each locality in the terrain was evaluated on the base of digital elevation model (DEM). This raster model (pixel 30 m) was constructed using contour map (contour distance 5 m in altitude). Several indices were calculated from DEM: potential direct radiation in $\nu \text{ MJ cm}^{-2} \text{ year}^{-1}$ (equation 1; according MCCUNE et KEON 2002), model air temperature corresponding to period 1961-1990 and total terrain curvature (MATĚJKA 2009).

Results

There are eight (A to H) well-distinguished classification groups of the plant communities in grasslands of the selected region (Fig. 2a, b). The first TWINSpan division separates high-mountain to alpine grasslands (group *0) and submountain grasslands (Group *1). The second division in the first group differs alpine (group*00) and high-mountain (group *01) communities. This division level in the second main group distinguishes according to the soil water conditions.

Inner group dissimilarity, which has been calculated as maximum linkage distance by the group average linkage clustering, is comparable in all groups (Table 1). The most homogenous group was group G representing single association *Angelico sylvestris-Cirsietum oleracei*.

The altitudinal gradient is very important in the change of the herb-layer species composition (importance was tested by Mote Carlo test: $p = 0.1 \%$), although first ordination

axis (the canonical axis) has described 2.9 % of the total species data variance and second axis (the non-canonical axis) has been corresponding to 6.0 % of total data variance. The first (canonical) axis correlates with altitude closely ($CCA_1 = 3.613 - 0.0032 \text{ altitude}$; $r^2 = 0.876$; Fig. 5). It means that altitude is only one of the significant environmental gradients in our set of the selected grassland communities. The second most important environmental feature is represented by soil moisture (water availability). This factor is of increasing significance in lower altitudes, where is the driver responsible to differentiation between the TWINSPAN classification groups *10 and *11. It is not so much important in subalpine and alpine zone because these localities are under high precipitation and without a dry stress.

* (n=242)
*0 (n=146) <i>Avenella flexuosa</i> 1 <i>Nardus stricta</i> 2 <i>Homogyne alpina</i> 1 <i>Vaccinium myrtillus</i> 1
*00 (n=78) <i>Carex bigelowii</i> 1 <i>Calluna vulgaris</i> 1
*000 (n=40)
Group A: Alpine heathlands and dwarf shrub communities
<i>Calluna vulgaris</i> 1
*0000 (n=32) <i>Carex bigelowii</i> 2
*00000 (n=27) <i>Avenella flexuosa</i> 3 <i>Bistorta major</i> 1 <i>Carex bigelowii</i> 3
*00001 (n=5) <i>Homogyne alpina</i> 2 <i>Calamagrostis villosa</i> 1 <i>Vaccinium myrtillus</i> 2 <i>Vaccinium vitis-idaea</i> 2
*0001 (n=8) <i>Gentiana asclepiadea</i> 1 <i>Calamagrostis villosa</i> 2 <i>Trientalis europaea</i> 1
*00010 (n=3) <i>Calluna vulgaris</i> 2
*00011 (n=5)
*001 (n=38)
Group B: Alpine meadows
<i>Deschampsia cespitosa</i> 1 <i>Anthoxanthum alpinum</i> 1
*0010 (n=7) <i>Trichophorum cespitosum</i> 2
*00100 (n=3) <i>Vaccinium vitis-idaea</i> 1
*00101 (n=4)
*0011 (n=31)
*00110 (n=23) <i>Avenella flexuosa</i> 4 <i>Veratrum album subsp. lobelianum</i> 1
*00111 (n=8) <i>Molinia caerulea</i> 2
*01 (n=68) <i>Silene vulgaris</i> 1 <i>Campanula bohemica</i> 1 <i>Potentilla erecta</i> 1 <i>Festuca rubra</i> 1
*010 (n=28)
Group C: Mountain and subalpine acidophilous meadows with <i>Nardus</i>, alliaceae <i>Nardion strictae</i>
<i>Nardus stricta</i> 2 <i>Luzula sudetica</i> 1 <i>Campanula bohemica</i> 2
*0100 (n=12) <i>Anthoxanthum odoratum</i> agg. 3
*01000 (n=4) <i>Ranunculus acris</i> 1 <i>Botrychium lunaria</i> 1 <i>Campanula bohemica</i> 3
*01001 (n=8)
*0101 (n=18) <i>Festuca rubra</i> 2 <i>Poa chaixii</i> 1
*01010 (n=2) <i>Sorbus aucuparia</i> 1 <i>Vaccinium myrtillus</i> 3
*01011 (n=14) <i>Bistorta major</i> 1
*011 (n=40)
Group D: Mountain and subalpine acidophilous meadows on moist soils
<i>Juncus filiformis</i> 1 <i>Deschampsia cespitosa</i> 1 <i>Rumex arifolius</i> 1
*0110 (n=14) <i>Homogyne alpina</i> 1 <i>Trientalis europaea</i> 1 <i>Vaccinium myrtillus</i> 1
*01100 (n=8)
*01101 (n=6) <i>Crepis paludosa</i> 1 <i>Juncus filiformis</i> 1
*0111 (n=26) <i>Festuca rubra</i> 1 <i>Ranunculus platanifolius</i> 1 <i>Silene vulgaris</i> 2
*01110 (n=15) <i>Juncus filiformis</i> 3
*01111 (n=11) <i>Rumex arifolius</i> 2 <i>Hypericum maculatum</i> 1 <i>Senecio hercynicus</i> 2

Fig. 2a. The TWINSPAN classification of the plant communities, first part with high mountain to alpine communities. Indicator species with respective cut-levels are written. n - number of relevés.

*1 (n=96) <i>Alchemilla vulgaris</i> agg. 1 <i>Dactylis glomerata</i> 1
*10 (n=86) <i>Achillea millefolium</i> 1 <i>Agrostis capillaris</i> 2
*100 (n=25)
Group E: Communities of the alliance <i>Polygono-Trisetion</i>
<i>Silene dioica</i> 1 <i>Deschampsia cespitosa</i> 1 <i>Silene vulgaris</i> 1 <i>Poa chaixii</i> 1
*1000 (n=7) <i>Holcus mollis</i> 1
*10000 (n=3) <i>Veronica officinalis</i> 1
*10001 (n=4)
*1001 (n=18)
*10010 (n=12)
*10011 (n=6) <i>Veronica chamaedrys</i> 1 <i>Ranunculus acris</i> 1
*101 (n=41)
Group F: Communities of the alliance <i>Arrhenatherion</i>
<i>Plantago lanceolata</i> 1 <i>Leucanthemum vulgare</i> agg. 1 <i>Trisetum flavescens</i> 1
*1010 (n=29) <i>Festuca rubra</i> 1 <i>Anthoxanthum odoratum</i> 1 <i>Leontodon hispidus</i> 1 <i>Rumex acetosa</i> 1 <i>Agrostis capillaris</i> 3
*10100 (n=6) <i>Polygala vulgaris</i> 1
*10101 (n=23) <i>Trisetum flavescens</i> 1 <i>Trifolium pratense</i> 1 <i>Trifolium repens</i> 1 <i>Campanula patula</i> 1 <i>Rumex acetosa</i> 1 <i>Stellaria graminea</i> 1
*1011 (n=12) <i>Geranium pratense</i> 1
*10110 (n=7) <i>Plantago lanceolata</i> 1
*10111 (n=5) <i>Arrhenatherum elatius</i> 1
*11 (n=30) <i>Crepis paludosa</i> 1 <i>Filipendula ulmaria</i> 1 <i>Cirsium oleraceum</i> 1
*110 (n=16)
Group G: Communities of the alliance <i>Calthion</i> (assoc. <i>Angelico sylvestris-Cirsietum oleracei</i>)
<i>Cirsium oleraceum</i> 2 <i>Dactylorhiza majalis</i> 1
*1100 (n=13)
*11000 (n=9)
*11001 (n=4) <i>Stellaria graminea</i> 1 <i>Filipendula ulmaria</i> 1
*1101 (n=3) <i>Lysimachia vulgaris</i> 1
*11010 (n=2)
*11011 (n=1) <i>Aegopodium podagraria</i> 1
*111 (n=14)
Group H: Other communities of the alliance <i>Calthion</i>
<i>Chaerophyllum aromaticum</i> 1
*1110 (n=8) <i>Crepis paludosa</i> 1 <i>Equisetum sylvaticum</i> 1 <i>Viola palustris</i> 1 <i>Epilobium palustre</i> 1
*11100 (n=7)
*11101 (n=1) <i>Anemone nemorosa</i> 1
*1111 (n=6)
*11110 (n=3)
*11111 (n=3) <i>Leucjum vernum</i> 1

Fig. 2b. The TWINSpan classification of the plant communities, second part with submontane communities. Indicator species with respective cut-levels are written.

Localization of the communities belonging to different classification groups was specific. They significantly differ not only in altitude (Table 3) and air temperature (Table 4), but also in the terrain configuration (Table 5). The communities of group A are founded at strongly convex places. Communities of groups B and C lies in flat to moderately convex terrain. Middle positions are typical in the groups H, D and E. Concave localities prevails in the community group F. The relevés classified in the group G were recorded in places with very variable localization, because locally wet soils can be found in the terrain with different shape in a middle scale.

Table 1. Variability of the plant communities in the classification groups.

Group	Number of relevés	Maximum linkage distance
A	40	62.7
B	38	71.8
C	28	62.9
D	40	63.2
E	25	58.3
F	41	66.6
G	16	50.1
H	14	76.3

Table 2. Linear regression of diversity indices on altitude (x variable).

Group	Regression	r	p
Species richness (S)			
All	$S = 36.5664 - 0.0163 * x$	-0.6070	< 0.001 *
A	$S = 50.228 - 0.0279 * x$	-0.7571	< 0.001 *
B	$S = 29.135 - 0.0128 * x$	-0.2095	0.2069
C	$S = 13.6607 + 0.0036 * x$	0.1606	0.4142
D	$S = 1.004 + 0.0134 * x$	0.3330	0.0358 *
E	$S = 17.0937 + 0.0043 * x$	0.1510	0.4713
F	$S = 12.0784 + 0.0189 * x$	0.3832	0.0134 *
G	$S = -22.6753 + 0.0751 * x$	0.3855	0.1403
H	$S = 22.9488 - 0.002 * x$	-0.0489	0.8682
Species diversity (H)			
All	$H = 4.179 - 0.0012 * x$	-0.5353	< 0.001 *
A	$H = 7.4986 - 0.0037 * x$	-0.6483	< 0.001 *
B	$H = 5.392 - 0.0023 * x$	-0.1898	0.2538
C	$H = 1.8435 + 0.0009 * x$	0.3183	0.0988
D	$H = 0.2097 + 0.002 * x$	0.3416	0.0310 *
E	$H = 2.5876 + 0.0006 * x$	0.2450	0.2378
F	$H = 2.9862 + 0.0005 * x$	0.1593	0.3198
G	$H = 2.0075 + 0.0023 * x$	0.2654	0.3205
H	$H = 2.3279 + 0.0007 * x$	0.2102	0.4706
Equitability (e)			
All	$e = 0.7718 - 7.7645E-5 * x$	-0.2206	< 0.001 *
A	$e = 1.2399 - 0.0004 * x$	-0.2894	0.0701
B	$e = 1.2235 - 0.0004 * x$	-0.1454	0.3837
C	$e = 0.4812 + 0.0002 * x$	0.3358	0.0806
D	$e = 0.252 + 0.0003 * x$	0.2834	0.0764
E	$e = 0.6212 + 0.00010 * x$	0.2164	0.2988
F	$e = 0.764 - 0.00006 * x$	-0.1341	0.4031
G	$e = 0.7926 - 0.00006 * x$	-0.0600	0.8254
H	$e = 0.5396 + 0.0002 * x$	0.3151	0.2725

Table 3. Variability of the plot altitude (in m) within the classification groups. $M_{0.05}$ - 5%-quantil, $M_{0.95}$ - 95%-quantil, STD - standard deviation, Min - minimal value, Max - maximal value, N - number of relevés.

Group	Mean	$M_{0.05}$	$M_{0.95}$	STD	Min	Max	N
A	1448	1421	1475	85	1223	1510	40
B	1436	1422	1450	42	1340	1508	38
C	1177	1095	1260	213	785	1510	28
D	1230	1197	1263	103	896	1486	40
E	1124	1059	1189	157	791	1347	25
F	694	648	739	144	446	995	41
G	704	671	736	61	599	849	16
H	851	717	986	233	472	1152	14

Table 4. Variability of the modeled average air temperature (in °C) in plots within the classification groups.

Group	Mean	$M_{0.05}$	$M_{0.95}$	STD	Min	Max	N
A	1.82	1.63	2.02	0.61	1.18	3.24	40
B	1.89	1.79	1.99	0.30	1.20	2.39	38
C	3.30	2.81	3.79	1.26	1.25	5.59	28
D	3.04	2.87	3.22	0.55	1.80	4.95	40
E	3.59	3.22	3.96	0.89	2.18	5.36	25
F	5.99	5.75	6.23	0.76	4.41	7.35	41
G	5.92	5.78	6.07	0.27	5.21	6.28	16
H	5.12	4.39	5.84	1.26	3.42	7.11	14

Table 5. Variability of the plot terrain curvature (values×1000) within the classification groups.

Group	Mean	$M_{0.05}$	$M_{0.95}$	STD	Min	Max	N
A	0.49	0.37	0.60	0.36	-0.11	1.03	40
B	0.13	-0.07	0.33	0.60	-1.75	1.55	38
C	0.18	-0.02	0.38	0.51	-1.08	1.64	28
D	-0.04	-0.17	0.08	0.39	-0.65	0.98	40
E	-0.03	-0.21	0.15	0.44	-1.26	0.81	25
F	-0.27	-0.47	-0.08	0.62	-1.96	0.71	41
G	-0.43	-1.08	0.21	1.21	-3.36	0.91	16
H	-0.08	-0.31	0.15	0.40	-0.93	0.82	14

All diversity indices decrease along increasing altitude significantly (Table 2). Although species richness (Fig. 6) and diversity (Fig. 7) decrease with altitude over whole gradient, the opposite trend was recorded in some community types (D and F), which were evaluated separately. It might be caused by an infiltration of the species typically growing at higher altitudes into the community in the place near the upper limit of this community type. So, changes in the species diversity are influenced rather by exchange of the community types, than a gradual decrease.

The correlations altitude × species richness ($r = -0.607$) and air temperature × species richness ($r = -0.608$) are very close. It can be caused by the same or similar slope orientation in prevailing part of the studied localities.

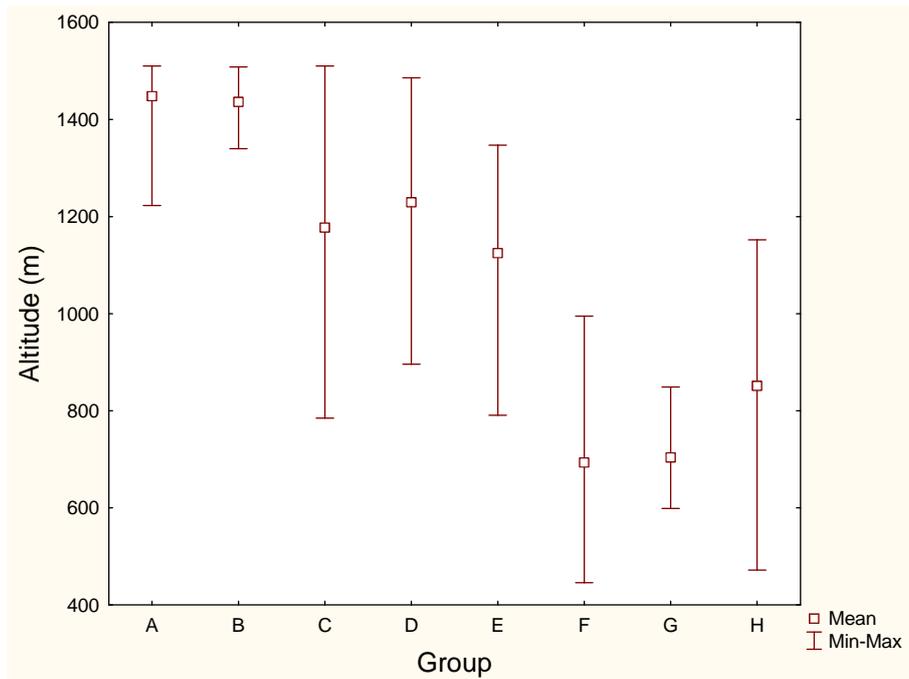


Fig. 3. The range of altitudinal distribution of plant communities in the classification groups within the altitudinal gradient.

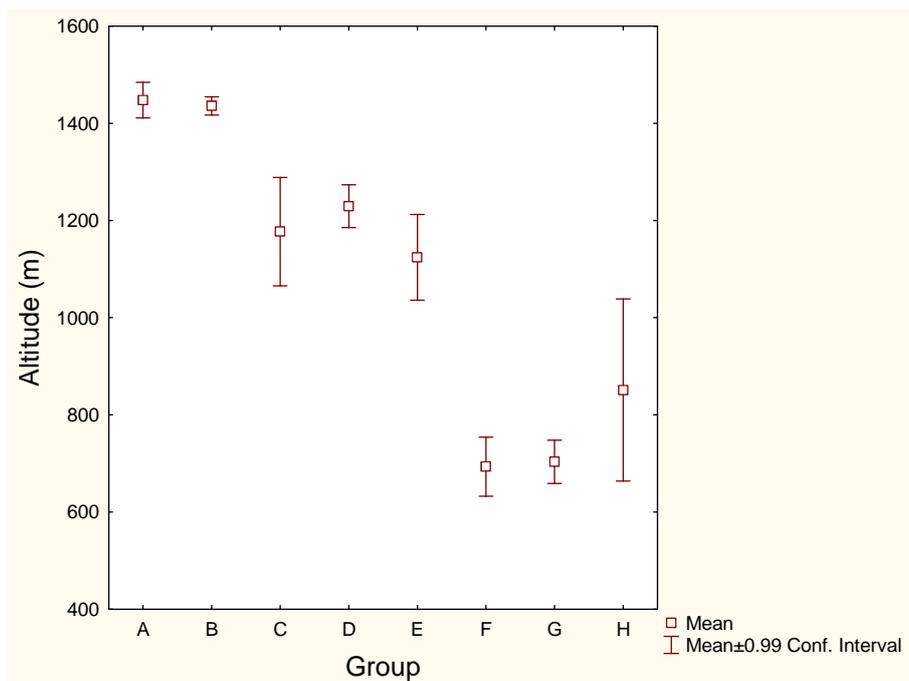


Fig. 4. Mean altitudes according to the classification groups of plant communities within the altitudinal gradient.

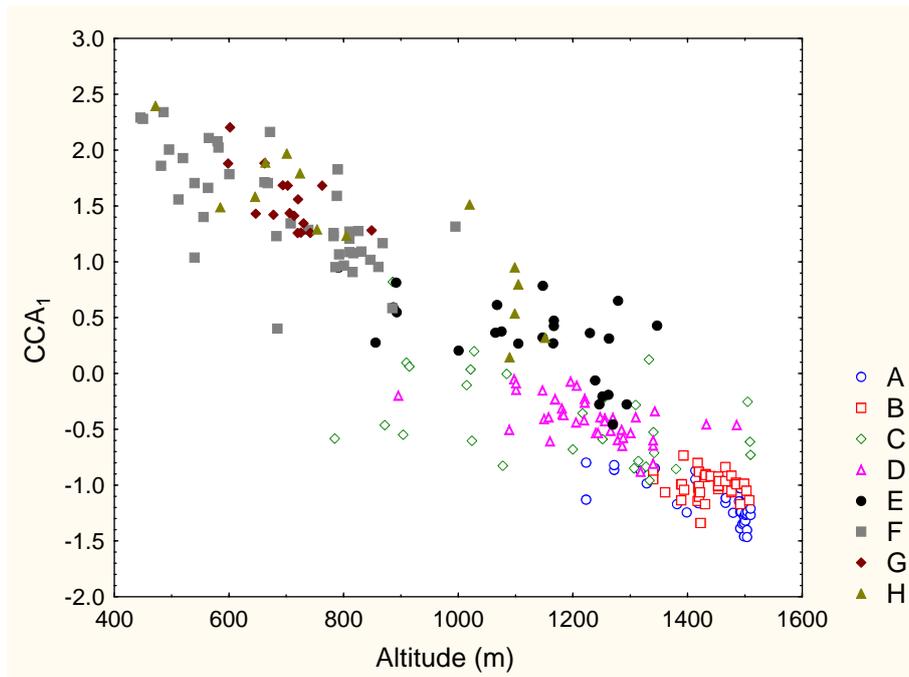


Fig. 5. Relation of the first canonical axis CCA to the altitude ($r = -0.936$). Plots were classified into the basic TWINSpan groups.

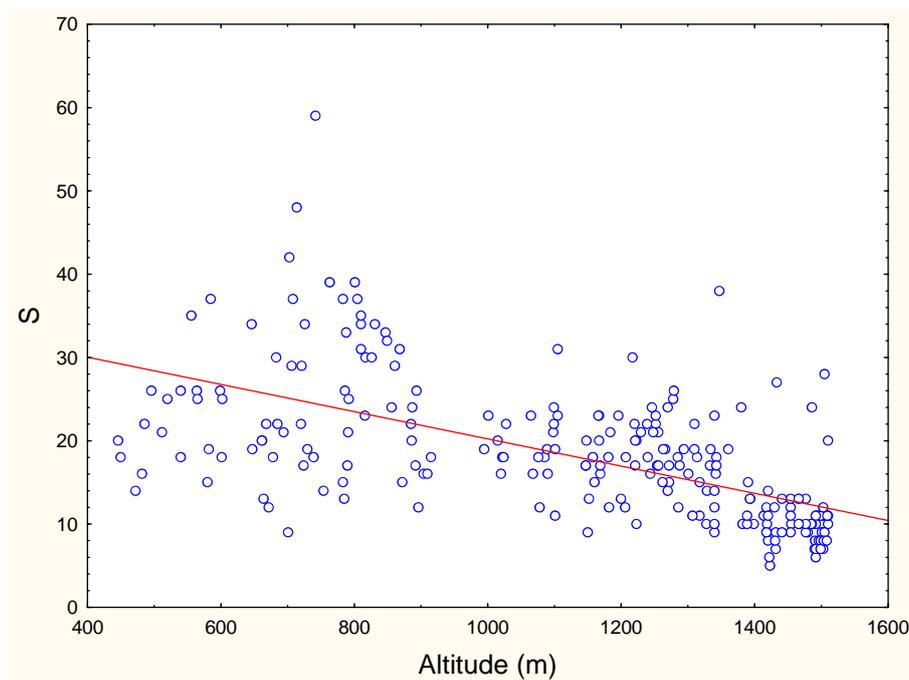


Fig. 6. Species richness (S) of the grass communities along the altitudinal gradient.

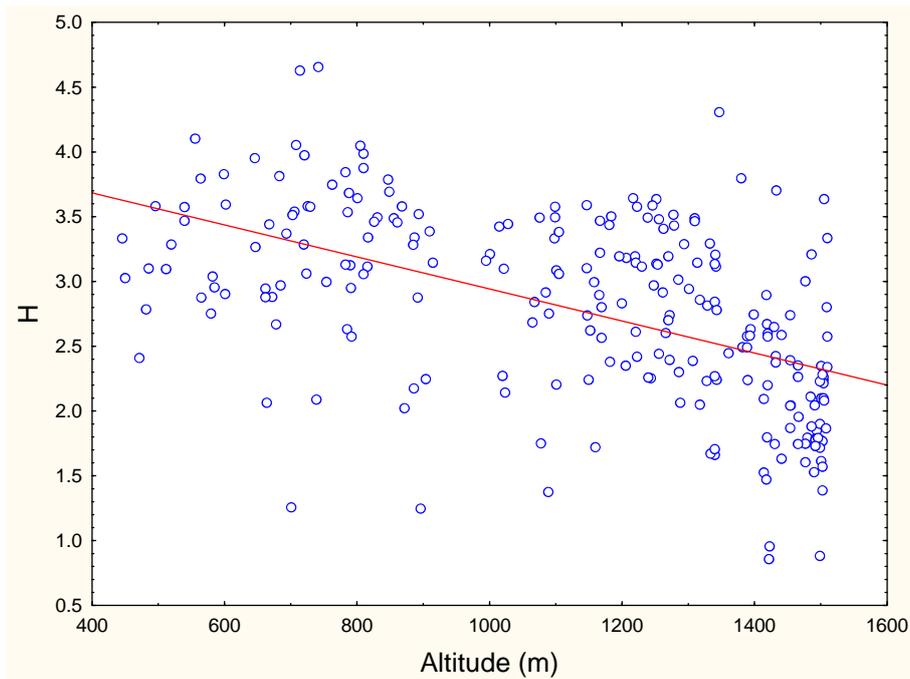


Fig. 7. Species diversity (Shannon-Wiener's index H') of the grass communities along the altitudinal gradient.

Discussion and Conclusions

The basic classification groups correspond to alliance mainly (compare CHYTRÝ 2007). Mathematically defined heterogeneities of higher syntaxa differ, mainly in relation to the average species diversity of the communities. Such species-rich communities on wet soils in lower altitudes, which are classified in the association (group G; *Angelico sylvestris-Cirsietum oleracei*), shows total heterogeneity as groups of species-poor communities in the alpine zone (groups A, B), which are classified in the higher syntaxa (classes or orders).

The diversity altitudinal gradient is based rather on exchange of types of plant communities than on altitudinal gradient within some community. Comparing altitudinal extent of the distinguished classification groups, it is possible to define grassland altitudinal belts in the Giant Mountains. There is significant disparity in the classification group interval of altitudes (Fig. 3) and the confidence interval of mean altitude (Fig. 4). Whereas first indicate total altitudinal extent of the respective communities, second one informs us about the optimal altitude (altitudinal extent).

Species richness decrease along altitudinal gradient is higher in grassland (1.63 per 100 m) than in forests (0.68 per 100 m; MATĚJKA 2012). Similar picture can be drawn for total species diversity (0.12 per 100 m in grasslands and 0.058 per 100 m per 100 m).

Preliminary altitudinal zonation along the studied transect was drawn in MATĚJKA (2010a). The first zone embraces localities up to approximately 890 m a.s.l. It represents the upper limit of alliances *Arrhenatherion* (group F) and *Calthion* (group H). The second zone lies between 890 and 1200 m a.s.l. It is characterized with prevailing communities of the *Polygono-Trisetion* alliance (group E). The third, subalpine zone occurs within 1200 and 1360 m a.s.l. Communities of the *Polygono-Trisetion* alliance (group E) overlaps with the alpine heathlands and dwarf shrub communities (group A) here. The highest alpine zone starts at approximately 1360 m a.s.l. It is the belt of optimal conditions for communities with *Carex bigelowii*. This limit coincides with elevation of alpine timberline, as referred by TREML (2004).

It is known, that altitudinal limits are influenced by topography, namely by heat load (TREML et BANAS 2008). In the case of the used landscape transect, this influence was partly limited because mainly all sites are localized on the same slope of the mountains.

Although altitudinal zonation of the forest communities in the Czech Republic has been well described earlier (e.g. PRŮŠA 2001, VIEWEGH et al. 2003), there are no mention about such division in grasslands. Only optimal altitudes are listed in some communities (CHYTRÝ 2007).

There is neither discontinuity nor a sharp change in the altitudinal gradient of both species diversity and species richness in plant communities of grasslands in the investigated region.

A similar plant-community continuum was reported from many other studies in the world (e.g. AUERBACH et SHMIDA 1993).

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