

Full Length Research Paper

The biodiversity and stability of alpine meadow plant communities in relation to altitude gradient in three headwater resource regions

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Accepted 12 September, 2012

***Kobresia pygmaea* meadow community diversities in relation to altitude gradients (4200, 4300, 4400, 4450) on free grazing grassland was studied in the range of Chenduo county, Yushu prefecture, Qinghai province. Species richness and diversity index of vegetations in the four altitudes were comparatively analyzed. The results showed that the shape of species richness responsive curves to altitude gradient is “Bell-shape”. There were the same 11 common species in the four communities. The relative abundance of *K. pygmaea* decreased along increasing altitude. Moreover, the fuzzy membership functions were used to calculate the degree of stability, showing medium altitude > high altitude > low altitude, which suggested that grass land vegetation in low altitude of the sampling site had lower diversity, and the grade of species vulnerability risks may be decided with the help of the degree of stability.**

Key words: Alpine meadow, Yangtze, Yellow and Yalu Tsangpo river source region, altitude gradient, species diversity, membership functions.

INTRODUCTION

The source region of three headwaters, the Yangtze, Yellow and Yalu Tsangpo Rivers (SRYYYTR), known as the ‘water tower of China’ is located on highland of over 4200 m above sea level (Sun and Zheng, 1996) and in central part of the Qinghai-Tibetan Plateau (Liu et al., 2006). The vegetation is mainly composed of alpine meadow, alpine swamp and alpine grass. The population is about 568,000 and most of the residents are Tibetan, with a nomadic lifestyle. The ecosystem stability and conservation of biota, particularly the response of vegetation change to environmental factor change in SRYYYTR have attracted the attention of international scholars (Xu et al., 2011). Grassland ecosystem is an important part of terrestrial ecosystem. Currently, in

studies on ecosystem function of biodiversity, grass land ecosystem receives much more concern (Yang et al., 2004).

Known as the third pole in the world with resounding and vast terrain, complicated topography and unique physical geographic condition, Tibetan plateau is regarded as one of the most sensitive regions to global changes (Zhou et al., 2011). Climate change has already triggered shifts in species distribution in many parts of the world. Increasing impacts are expected for the future, and some studies have aimed for a general understanding of the regional basis for species vulnerability (Thuiller et al., 2005). Studies have revealed that the plant species diversity across global ecosystems show distinctive distribution features along the latitudinal gradient (Yang et al., 2004). Similar to latitudinal gradient, altitudinal gradient has become the major aspect for studies on biodiversity gradient pattern due to many environmental factors, including temperature, humidity and solar

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Figure 1. Location of the experimental site on the Tibetan plateau.

radiation (Gaston, 2000).

However, knowledge about the change of species diversity with geographic environment gradient as one of the major contents for spatial pattern of biodiversity in alpine ecosystems is still rudimentary because of extremely geographic situation. The species diversity of vegetations in different altitudes of SRYYYTR was surveyed in this study, and the species distribution pattern in four different altitudes was comparatively analyzed to ascertain the possible reasons why plant communities change with altitudinal gradients. This study was aimed at providing a reference for the restoration and rebuilding of grassland ecosystem in Tibetan Plateau or the continuous and reasonable utilization of grass land resource, and also providing a basic data support for studies on the corresponding mechanism of alpine grassland to global climate change.

MATERIALS AND METHODS

Site description

The experiments were conducted at a site (27°35'–36°35'N, 89°35'–97°55'E) in the Qinghai-Tibetan plateau, located in northwest of China. This site belongs to the Alpine Meadow Ecosystem Research Station (QAMERS), owned by the Department of Agriculture, China (Figure 1). The site experiences a typical plateau continental climate, which is dominated by the southeast monsoon from May to September in summer and high pressure from Siberia in winter. Summers are short and cool, while winters are long and

severely cold. The mean annual air temperature was -6.4~4.3°C, the average air temperature was 11.7~21.0°C in July, -27.9~14.3°C in January and mean annual precipitation was 374.2 mm~721.2 mm (The Livestock Husbandry Programming Office of Qinghai Province, 1984). Over 80% of the precipitation falls during the summer monsoon season.

Three sampling sites were randomly selected in each of the four different altitudes (4200, 4300, 4400 and 4450 m). In each sampling site, three 1 m × 1 m plots were distributed along Maowa Mountain for community investigation. Measurements were carried out on October 8 to 15 in 2011 (3 replicates × 4 elevations × 3 samples). The coverage, height, density and dry weight of various plants species were recorded, and the latitude and longitude or altitude of sampling sites were both recorded by global positioning system (GPS).

Data analyses

Relative abundance

Relative abundance was calculated by the formula:

$$D' = \frac{n_i}{N}$$

Where, D' is the i th species density occupied the total density' value.

Species richness

Species richness was calculated using the following equation:

R = S

Where, S is the total species number.

Species diversity index

Many indicators could be used for measuring species diversity. Meanwhile, ecological dominance index (Simpson index), species diversity index (Shannon-Wiener index), evenness index (Pielou's homogeneity index) were used in this study. The Simpson index is calculated as follows (Whittaker, 1960):

$$\lambda = \sum_{i=1}^S \left(\frac{n_i}{N} \right)^2$$

The Shannon-Wiener index is calculated using the formula (Whittaker, 1960):

$$H' = - \sum_{i=1}^S \left(\frac{n_i}{N} \right) \ln \frac{n_i}{N}$$

While Pielou's homogeneity index is calculated as follows (Whittaker, 1960):

$$E' = \sum_{i=1}^n \frac{H'}{H_{\max}}$$

Where, n_i is the i th species number, N is the total of species in this area, S is species number in this altitude, and H_{\max} is Ins. In practical application, n_i or N could be replaced by other parameters such as biomass or coverage (Chang et al., 2004), and the species number was used for calculation in this study.

Comprehensive evaluation index

Many indicators could be used for measuring stability of grassland plant communities, membership functions was used in this study.

$$X_{(u)} = (X - X_{\min}) / (X_{\max} - X_{\min}) \quad (1)$$

$$X_{(u)} = (X - X_{\min}) / (X_{\max} - X_{\min}) \quad (2)$$

Where, X_{\max} is the most of certain index, while X_{\min} is the least of certain index, and formula (2) is the index which is negative correlation with plant communities' stability.

RESULTS

Changes of species richness in plant communities of different altitude gradient

According to the statistics of plant species in sampling sites from different altitudes (Table 1), there were 45 plants species in the plots belonging to 17 families of 40 genres. Six major families and the number of their species belonging to vegetations in plots are shown in Table 1. The six major families concluded Compositae, Gramineae, Cyperaceae, Gentianaceae, Leguminosae

and Rosaceae, which accounted for 17.78, 13.33, 8.89, 6.67, 4.44 and 4.44% of the total surveyed plant species respectively, while other 11 families of plant species accounted for 44.45%.

With the increase of altitude, species richness of grassland vegetations gradually decreased after increasing, resulting in the "Bell" shape, and the species number in 4450 a.s.l decreased by 34.62% than that in 4300 a.s.l. Meanwhile, the value of richness in 4450 was the least, which belonged to 16 families of 15 genus, while the value of 4300 was best belonging to 26 families of 38 genus. Eleven kinds of plant species were distributed in four different altitudes, including *Kobresia pygmaea*, *K. humilis*, *Stipa purpurea*, *Poa pratensis*, *Leontopodium leontopodioides*, *Taraxacum maurocarpum*, *Oxytropis kansuensis*, *Polygonum capitatum*, *Potentilla nivea*, *Gentiana squarrosa*, *Thalictrum alpinum*, which indicated that these plants had broader ecological amplitude and wide adaptability. In addition, some plants were investigated in same altitude, e.g. *Morina chinensis*, *Torularia humilis*, *Gentianopsis paludosa*, *Parnassia trineruis*, *Veronica eriogyne* appeared in the sampling site of 4300 m.

Changes of relative abundance of common species in different altitude gradients

In this study, the value of relative abundance varied in the order of Cyperaceae (37.55) > Gramineae (35.51) > Compositae (9.39) > Rosaceae (8.57) > Leguminosae (2.86) > Gentianaceae (1.22) in 4200 m, the other four families only occupied for 4.9. Moreover, *K. pygmaea* was the best and the dominate specie, which occupied 26.53 in the surveyed plants. The main company specie was *K. humilis* (9.80). The order of the other three altitude gradient was Cyperaceae (33.12) > Gramineae (26.43) > others (20.06) > Compositae (12.42) > Leguminosae (3.82) > Rosaceae (3.18) > Gentianaceae (0.96) in 4300 m, and Cyperaceae (45.59) > others (21.08) > Gramineae (12.75) > Leguminosae (4.90) > Compositae (3.92) > Rosaceae (3.18) > Gentianaceae (1.96) in 4400 m, and Cyperaceae (43.41) > others (26.37) > Gramineae (16.48) > Rosaceae (4.40) > Leguminosae (3.85) > Compositae (2.75) = Gentianaceae (2.75).

From the statistics, both Cyperaceae and Gramineae had the important status in the four altitude gradient. The relative abundance of plant species exhibited different with the increase of altitude. Analysis of Figure 2 indicated that while some species, e.g. *P. capitatum*, *T. alpinum*, were increasing, some such as *S. purpurea*, *T. maurocarpum*, *P. nivea* were decreasing. Still, some others presented no identity. As far as contractive species were concerned, *K. pygmaea* decreased with the increase of altitude. Moreover, the higher its relative abundance, the less the dominate spices and the simpler

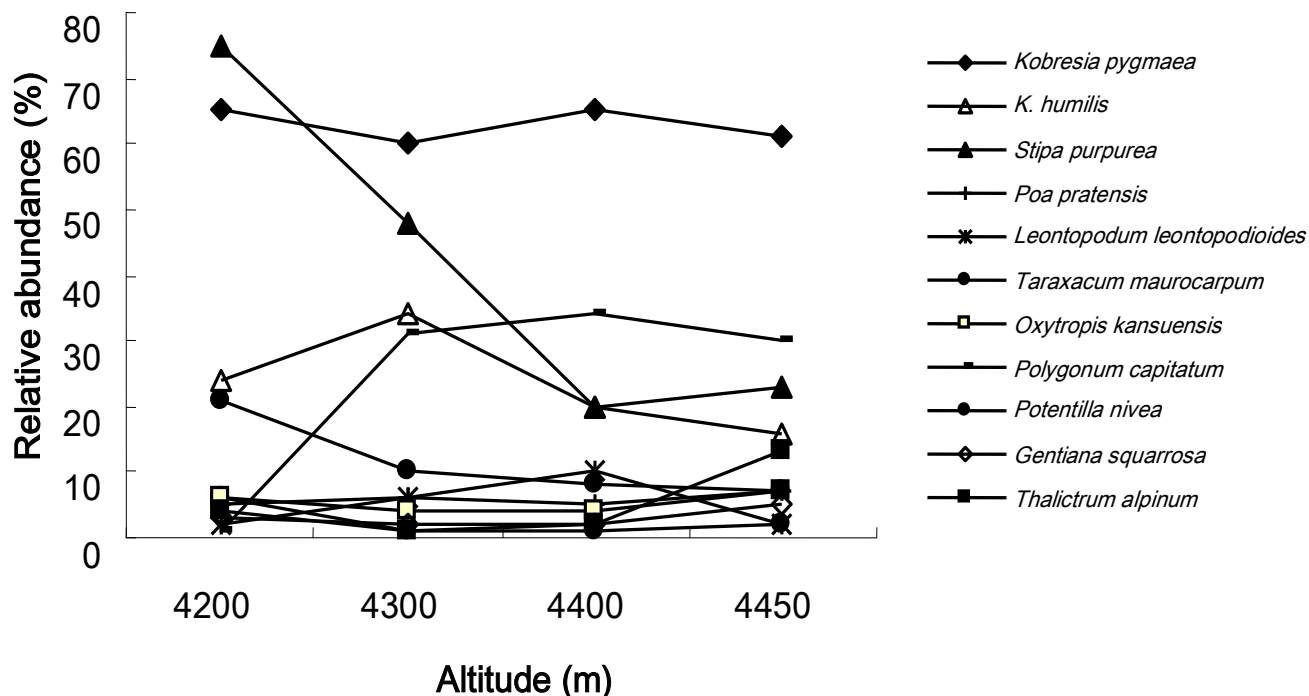


Figure 2. The changes of relative abundance of common species in different altitude gradients.

Table 1. The changes of species richness in plant communities of different altitude gradients.

Family	Altitude (m)			
	4200	4400	4300	4200
Compositae	4 (25.00%)	4 (23.53%)	7 (25.93%)	4 (22.22%)
Gramineae	2 (12.50%)	3 (17.65%)	4 (14.81%)	3 (16.67%)
Cyperaceae	3 (18.75%)	3 (17.65%)	4 (14.81%)	3 (16.67%)
Gentianaceae	1 (6.25%)	2 (11.76%)	3 (11.11%)	1 (5.56%)
Leguminosae	1 (6.25%)	2 (11.76%)	2 (7.41%)	2 (11.11%)
Rosaceae	2 (12.50%)	1 (5.88%)	1 (3.70%)	1 (5.56%)
Others	3 (18.75%)	2 (11.76%)	6 (22.22%)	4 (22.22%)
Summary	16	17	27	18

the community structure; otherwise, the more of dominate spices and sub-spices.

Changes of plant community diversity in different altitude gradients

Species diversity index (H'), which is the value that exhibits the state of some population, is a measure of the amount of information (entropy) in the system and gives more weight per individual to rare than common species. Outwardly then, it seems a good general measure to use with diverse communities. A closer look, however, reveals major problems (Tom et al., 2006). It is simply

pointing out that a particular sample had the highest H' and hence appears to be the most diverse. Yet, the stability of the communities improved with decrease in ecological dominance index (λ) and similar dominate species are composed of the grassland communities (Sun et al., 2000).

Results from this study indicated that the case of ecological dominance index, except 4200 m, was increasing with altitude' elevating. The wavelength of 4300 m was the most and reached to 0.096 ± 0.062; *K. pygmaea* was the best and the dominate specie in this altitude gradient. However, the others had low wavelengths, which revealed that the stability of the community was poor. The evenness index (E') also

Table 2. The changes of species richness in plant communities of different altitude gradients.

Plot	Altitude (m)	Simpson index (λ)	Shannon-Wiener index (H')	Pielou's homogeneity index (E')
1	4200	0.187 \pm 0.081	2.091 \pm 0.183	0.723 \pm 0.035
2	4300	0.096 \pm 0.062	2.965 \pm 0.245	0.818 \pm 0.046
3	4400	0.158 \pm 0.037	2.276 \pm 0.172	0.803 \pm 0.067
4	4450	0.174 \pm 0.078	2.143 \pm 0.096	0.773 \pm 0.059

Table 3. Standardized values of subordination functions of indexes concerning plant community diversity s of different altitude gradient.

Plot	Altitude (m)	Comprehensive Evaluation Indexes			SV
		λ	H'	E'	
1	4200	0.000	0.000	0.000	0.000
2	4300	1.000	1.000	1.000	1.000
3	4400	0.319	0.212	0.842	0.458
4	4450	0.143	0.059	0.526	0.243

λ : Simpson index; H' : Shannon-Wiener index; E' : Pielou's homogeneity index; SV: subordination value.

indicated non-significance of dominate species, common species, and rare species. So the community attained a uniform development. The fuzzy membership functions were used to calculate the degree of memberships, which was according to the calculation of Simpson diversity index and Pielou's homogeneity index. The change trend of Simpson diversity index and homogeneity index of grassland vegetation in different altitudes of mountain with altitude was identical, showing medium altitude > high altitude > low altitude (Tables 2 and 3), which suggested that grass land vegetation in low altitude of the sampling site had lower diversity, and the grade of species vulnerability risks can be decided with the help of the degree of membership.

DISCUSSION

Species richness along with different altitudes

Species distribution pattern is the product of several ecological processes, which are all mainly controlled by species evolution (speciation, species migration and extinction), geographic variation and environmental factors such as geology, landform, climate and soil (Whittaker and Niering, 1965; Whittaker et al., 2001; Wills and Whittaker, 2002). The essential conditions for plant growth, including light temperature and water are determined by climate, so climate has a vital impact on the spatial distribution of species richness (Yang et al., 2004). According to investigation results, with the increase of altitude, the shape of species richness responsive curves to altitude gradient is "Bell-shape". In other words, species richness of vegetations gradually

decreases. The species richness of vegetations in four different altitudes is in the order: medium altitude > low altitude > high altitude. Moreover, the kinds of plants in low altitude increase slightly. Grazing with various degrees in different altitudes leads to mottled bare surface, causing the various changes of organic matter in surface soil. Meanwhile, animals like even and warm land in free grazing grassland, and thus have impacts on community structure and species richness, which is possibly one of the reasons why the kind of plants species richness in low altitude decreases.

Species diversity along with different altitudes

Species diversity is the basis for knowing organizational level and functional status of communities (He et al., 2009; Zheng et al., 2007). Diversity itself is not an independent variable, and its maintenance is affected by many factors. The results in this study have revealed that species number of vegetations in medium altitude is much more than that in high altitude and low altitude, which is in accordance with study on the change of species diversity for eastern Front Range Mountains near national park in Qilian Mountains with altitudes by Sun. However, the result indicating that the species diversity decreases with increasing altitude except 4200 m is different from other studies (Wilson et al., 1990; Itow, 1991). Meanwhile, the results showed that species diversity increases along with elevating monotonously of altitude (Peet, 1978; Baruch, 1984). However, the main form of plant communities is meadow. Therefore, the different vegetations have been disturbed by local grazing in certain degree, which will lead to the smaller

Simpson's index, Shannon-Wiener's index, and Pielou's homogeneity index of plant communities in low and high altitudes compared with that in medium altitudes.

ACKNOWLEDGEMENTS

The research was funded by the central level, scientific research institutes for basic R & D special fund business project, Grassland Research Institute of Chinese Academy of Agriculture Science, and Yushu field station for resources and ecological environment of alpine meadow steppe of Ministry of Agriculture, PR, China, state natural sciences foundation monumental projects (Grant No: 70933004 /G0312), natural sciences foundation of Qinghai Province (Grant No: 2012-Z-941Q). We are grateful to Guotai Sheng and others for assisting in field survey and direction of this paper.

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