Biodiversity Features of the Main Steppe Communities in Inner Mongolia and their Relations to Climate and Grazing

LI YONGHONG

Institute of Botany, Chinese Academy of Sciences, Beijing 100044

(Received May 3, 1993; Revised June 12, 1993)

ABSTRACT

One hundred steppe communities were investigated on climate gradients in the central Inner Mongolia. The main communities were dominated by *Stipa gobica*, *S. breviflora*, *S. krylovii*, *S. grandis*, *S. baicalensis*, *Aneurolepidium chinense*, *Filifolium sibiricum* and *Festuca dahurica*, etc.. Their species diversity features were analyzed in relation to climate factors and grazing intensities. The results showed that species richness (S) in steppe communities was positively correlated with precipitation ($S = -5.1 \cdot e^{0.00627P}$; $r = 0.85$, $p = 0.001$), but negatively with temperature (T) ($S = 50.9 \cdot e^{-0.225T}$; $r = 0.92$, $p < 0.001$). The species richness decreased as climate aridity (A) increased ($S = -41.81 + 48.03 e^{1/A}$, $p < 0.001$). The community diversity had similar tendency of change with species richness along climate gradient. The highest diversity always appeared at moderate level of grazing intensity for a certain community, which was due to the prevention of exclusive competition of species by moderate grazing. An integrated schematic model on the relationship of community diversity with climate aridity and stocking rate was proposed.

Key Words Inner Mongolia, steppe, biodiversity, climate, grazing

INTRODUCTION

Temperate grassland is one of the 5 biomes recommended by IUBS-SCOPE-UNESCO for inventoring and monitoring biodiversity in the first instance (Di Castri, et al. 1992). The steppe on the Mongolian plateau is situated in the easternmost part of the Eurasian steppe region, and is highly representative of the geographical and ecological conditions (Lavrenko, 1970). It has been traditionally used as rangelands since the ancient time. But the irrational utilization during the last several decades has resulted in serious degradation (Li, 1991), and loss of its species diversity. Among various human activities, livestock grazing is the most widely distributed disturbance influencing species diversity. Numerous scientists (Grime, 1973; Naveh et al., 1980; Bakker, 1989) studied the relationship of community diversity with grazing and other disturbances in different grasslands and arrived at similar conclusions that moderate levels of disturbance (including grazing) were the prerequisites for a high species diversity. This kind of studies did not start until present in the steppe grasslands of Inner Mongolia. This paper focused on the general features of species diversity in the main steppe communities of Inner Mongolia, especially on their relationship of geographical patterns with climate factors, based on which, the diversity changes of different steppe communities under grazing influence were analyzed, and a schematic model on

the relationships between community diversity, climate aridity and stocking rate was proposed.

STUDY AREA

The study area lies on the southeast part of Mongolian Plateau at $111^{\circ}10' \sim 117^{\circ}50'E$ and $41^{\circ}20' \sim 45^{\circ}40'N$ with an altitude between $900 \sim 1500m$ declining from southeast to northwest. It is under a temperate, semiarid climate with a gradient also from southeast to northwest. Along this direction, annual precipitation decreases from $370mm$ to $170mm$, mean annual temperature increases from $-0.5^{\circ}C$ to $5. ^{\circ}C$, and climate aridity (Penman's) increases from 2 to 6. Chernozem, chestnut and brown calcareous soils are also successively distributed along the direction. Steppe is a zonal vegetation, dominated by a series species of *stipa* and *Aneurolepidium chinese*, *Filifolium sibiricum*, *Festuca hahurica*, etc.

STUDY METHODS

In order to cover all the steppe vegetation zones and inventory all the main steppe communities, two inventory itineraries along a climate gradient from desert-steppe zone to forest-steppe zone were adapted. One hundred steppe sites were investigated during plant growing season (July~August). Species composition was recorded with nest-quadrat of $8 m^2$; and the species surrounding the quadrat in the same homogeneous site were also recorded. The density, height and aerial phytomass were measured with 5 quadrats of $1m^2$ in each site. Grazing intensities were divided into several classes (light, light-moderate, moderate, heavy-moderate, heavy) and estimated during the investigation according to the distance of site to water resources or villages, the livestock excrements and the grassland situations. The gradients of climate factors were also divided into several classes (ranges), and the situation of climate factors for each site were determined according to the climatological data collected from the nearby meteorological stations. The communities were clustered according to their first dominant species, and then the main communities were chosen. Their species richness (S) was analyzed in relation to climate factors by regression techniques. The evenness (E) and diversity (H) indices of these communities were calculated by Shannon's formula ($H = - \sum P_i \cdot \ln P_i$ and $E = H / \ln s$; where P_i is the dry matter proportion of species i). Their relationships to climate factors were revealed by locating them on a hydrothermic plane according to their regional preferences to precipitation and temperature. The preference of a community on a factor gradient was calculated on the basis of its presence in different classes of the factor by formula the following (Daget et al., 1982):

$$P = \sum (F_k \cdot K) / \sum F_k, F_k = N_{kp} / N_k \cdot N_p / N,$$

where N was the total number of sites; N_p , the number of sites with the presence of community i; N_k , the number of sites when the factor is in class k ; N_{kp} , the number of sites in class k with the presence of community i; k , the class order of a factor along its gradient. The diversity features of these communities on different grazed sites were compared, and the general changes of diversity features on grazing gradients were revealed. The integrated relationships of community diversity with climate aridity and stocking rate were illustrated with a schematic model.

RESULTS

1 *Species diversity features of the main steppe communities in relation to climate*

The 100 inventoride sites were clustered in 28 community-types according to their first dominant species, among which, 8 types were frequently recorded and distributed on the zonal habitat and lightly utilized. They were considered as the representative for diversity analysis. Their species richness, community evenness and diversity indices, as well as other related features were shown in table.

TABLE
Diversity and structure features of the main steppe communities in Inner Mongolia

Community Numb. name ¹⁾ of site	Species richness ²⁾		Diversity index (H)	Evenness index (E)	Height (cm)	Cover with ranges (%)	Phytomass (gDM/m ²)
	S ₁	S ₂					
STGOB 10	12.0	17.6	1.25	0.41	6.9	15 (5~25)	11.28
STBRE 3	14.5	20.0	2.06	0.65	7.0	22 (15~30)	20.92
STKRY 6	21.3	27.3	2.27	0.66	14.9	28 (15~70)	37.91
STGRA 15	27.9	33.9	1.91	0.48	26.0	47 (25~75)	125.71
STBAI 4	41.7	47.3	1.99	0.63	47.3	65 (40~90)	259.90
ANCHI 17	23.1	29.6	2.49	0.67	33.0	61 (35~95)	270.48
FISIB 5	41.8	45.4	2.78	0.70	23.3	60 (30~90)	167.39
FEDAH 3	33.3	40.7	1.99	0.43	15.3	60 (30~90)	95.20

1). The abbreviations of the community names, which are also used in Fig. 1 and Fig. 2, are as follows: STGOB—*Stipa gobica*, STBRE—*Stipa breviflora*, STKRY—*Stipa krylovii*, STGRA—*Stipa grandis*, STBAI—*Stipa baicalensis*, ANCHI—*Aneurolepidium chinese*, FISIB—*Filifolium sibiricum* and FEDAH—*Festuca dahurica*.
2). Species richness is the mean species numbers recorded in 8 m² quadrats (S₁) and in each site (S₂).

Fig. 1. Diversity features of the main steppe communities in Inner Mongolia and their relations to climate factors.

The other community-types were dominated by *Artemisia frigida*, *Agropyron cristatum*, *Cleistogenes songorica*, *C. squarrosa* and *Carex duriuscula*, etc. They were mainly the derived types of the above 8 communities by retrogressive succession under grazing influence. Their diversity features were analyzed in relation to grazing intensity.

Table suggested that *Stipa gobica* community had the lowest species richness, community evenness and diversity indices, while *Stipa baicalensis* and *Filifolium sibiricum* communities, the highest. The other communities were at moderate levels. The difference of species diversity in steppe communities were mainly correlated with environmental conditions, especially with climate factors. Fig. 1 showed the preferences of these communities on the hydrothermic plane (precipitation-temperature), which indicated that species richness (S) was positively correlated with precipitation (P) ($S = -5.1 \cdot e^{0.00627P}$; $r = 0.85$, $p = 0.001$), but negatively correlated with temperature (T) ($S = 50.9 \cdot e^{-0.225T}$; $r = 0.92$, $p < 0.001$). This suggested that the species richness decreased as climate aridity increased. The relationship between species richness in the 100 sites and climate aridity (A) could be expressed by an equation: $S = -41.81 + 48.03 e^{1/A}$, $p < 0.001$.

The diversity index of these communities had similar tendency of change on the hydrothermic plane, that is, the diversity decreased as climate aridity increased. But the location of *Festuca daturica* or *Stipa baicalensis* communities did not reflect its real preferences on precipitation and temperature gradients since they were recorded mainly on hills with relatively high altitude in the research area.

Fig. 2. Diversity and evenness features of the 5 main steppe communities in Inner Mongolia on a grazing gradient (L-lightly, M-moderately, H-heavy grazed sites).

2 Diversity features of the main steppe communities on grazing gradients

In this field inventory, we did not find the grazing series of *Stipa baicalensis*, *Festuca daturica* or *Filifolium sibiricum* communities; while the series of the other 5 communities were identified with PCA techniques, based on their species dominance and the grazing intensities estimated in each site (Li, 1991). Their diversity and evenness indices along grazing gradients were calculated and summarized in Fig. 2. It suggested that the highest diversity and evenness always appeared on moderately grazed sites for all 5 communities, which was similar to the results of other researchers in different grasslands (Bakker, 1989), and to the results of the detailed studies on the biodiversity of *Stipa grandis* and *Aneurolepidium chinese* steppe communities in two concrete grazing gradients. The high diversity at moderate levels of grazing intensity is due to the moderate grazing that prevents exclusive competition of dominant species (Grime, 1973), and at the same time, has no restrictions to the development of other species. Fig. 2 also indicated that the communities in arid habitat had larger amplitude of evenness under grazing influence than those in humid habitat.

3 An integrated schematic model on the relationships of community diversity with climate aridity and stocking rate

According to the above analysis, in a large geographical region, community diversity depended mainly on climate factors; while in a relatively small area, it was greatly influenced by animal grazing. These two crossed functions could be expressed with an integrated scheme (Fig. 3). Since the stocking rates of light, moderate and heavy grazing varied among different communities, they were standardized according to their aerial phytomass. Fig. 3 showed that the diversity increased as climate aridity decreased, and moderate grazing intensity led to a highest diversity. The stocking rates under which the community had the highest diversity increased with the increase of community phytomass, and therefore, with the increase of climate humidity.

Fig. 3. An integrated schematic model on the relationships of community diversity with climate aridity and stocking rate.

CONCLUSIONS

In the steppe region of Inner Mongolia, the geographical patterns of the species richness, community evenness and diversity of main steppe formations depended mainly on climate factors. The community diversity decreased as temperature increased or the precipitation decreased, that is, the increase of climate aridity. In a relatively small area, for a certain community, livestock grazing was the most important factors influencing diversity. Moderate grazing can prevent exclusive competition of species and lead to high community evenness and diversity.

REFERENCES

- Bakker J P, 1989. Nature management by grazing and cutting. *Geobot.* 14. Kluwer Acad. Publ., 11~17
- Daget Ph, M Godron, 1982. Analyse fréquentielle de l'écologie des espèces dans les communautés. *Collection d'écologie* 18., Masson, 107~133
- di Castri F, J R Vernhes, T Younes, 1992. Inventorying and monitoring biodiversity. *Special Issus-27, biology International*, IUBS, 28
- Grime J P, 1973. Control of species diversity in herbaceous vegetation. *J. Environ. Manage.*, Vol. 1: 151~167
- Laverenko E M. 1970. The provincial division of the subregion of 'Centre of Asia' of the Eurasian steppe region. *J. Botany*, 55(12) (in Russian)
- Li YongHong, 1991. The current situation of the steppe rangeland use in Inner Mongolia:-relationships of grassland structures with grazing. *The proceed. of the IVth Intl Range. Congr.*, Montpellier, Fance. (in press)
- Naveh Z, Whittaker R H, 1980. Structural and floristic diversity of shrublands and woodlands in Northern Israel and other Mediterranean areas. *Veget.* 41: 171~190