Vegetation composition and distribution on the northern slope of Karlik Mountain to Naomaohu basin, East Tianshan Mountains

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Abstract: This paper reports the characteristics of plant flora in the region of the northern slope of Karlik Mountain to Naomaohu basin, based on field investigation of the vegetation and referring to relevant literature. The results show that the flora of the study area mainly consists of communities of single species or a limited number of species, genera and families. The flora composition is marked by the phenomenon of dominant families and genera; the temperate element occupies a dominant position, while in terms of the genera the Tethys element is an important component. Areal-types of the species are dominated by the floral element of Asian Central-part with xerophytic characteristic, and the life-forms of plants are mainly perennial and herbaceous. These characteristics reflect that the compositions of the species in this region possess both ancient and young elements. Analysis of the relationship between the species composition, plant community diversity and altitude gradient, we found that the structure of the vegetation has an obvious vertical distribution. The lower and higher altitude areas, where the climate conditions are relative inclement, are mainly occupied by the plant communities with simple structure and single dominant population, while the species richness in the mid-altitude area increases with favorable temperature and precipitation. Consequently, the species diversity and evenness indices show single-peak distribution with increasing elevation (about < 2500 m), while the dominance indices decrease in elevation from 500 m to 2500 m and increase in elevation of > 2500 m.

Keywords: Karlik Mountain to Naomaohu basin; vegetation; composition; distribution

1 Introduction

Vegetation composition is a natural synthesis of plant family, genus and species in one region. The characteristics of vegetation composition and its development can be recognized through recording plant species and analyzing their geographical elements (Pan, 1997, 1999). Therefore, this is a basic research for eco-environmental management and biodiversity protection (Ren and Tao, 2002; Zhang *et al*., 2006). In related research, understanding of plant life-forms and their geographical origin has revealed the vegetation and vegetation-environment relationships in this region (Dong *et al*., 1996). The habitat heterogeneity caused by changing altitude and landform can result in the changes in vegetation composition, community diversity and vegetation structure on the terrain unit. Because the altitude and landform can influence the reallocation of resources of water, heat, sunlight and soil nutrients, that are important factors influencing vegetation patterns, the distribution of vegetation is usually formed on the basis of different altitudes and terrains (Chen and Liu, 1997; Yang *et al*., 2005). Some researchers have studied the vegetation composition of the Tianshan Mountains (Editorial Committee of Flora of Xinjiang, 1996; Mijit and Xu, 2000), and analyzed the diversity of plant communities on the southern slopes and on the mid-section of the northern slopes (Feng *et al*., 2005; Hu *et al*., 2007). Based on field investigation in the region of the northern slope of Karlik Mountain to Naomaohu basin, in the east of the

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Tianshan Mountains and studying related literature, this paper discussed the composition and distribution of vegetation under the influence of altitude, in order to provide data for the study of the vegetation composition and structure in the Tianshan Mountains and adjacent areas. A second objective of the study was to provide a scientific basis for environmental protection, sustainable utilization of biological resources and implementation of sustainable development within the region.

2 Study area and methods

The region of the northern slope of Karlik Mountain to Naomaohu basin is located in eastern Xinjiang, in the northeast of the Tianshan Mountains, with the geographical coordinates of 42°54′–44°29′N and 93°35′–96°23′E (Fig. 1). The elevation of the whole Karlik Mountain is relatively low in the Tianshan Mountains and the piedmonts in the south, north and east of the mountain join the surrounding gobi and sand deserts. One hundred and twenty two glaciers are located in the Karlik Mountain, 49 of which are situated on the northern slopes, in the Dabaiyanggou, Ketuoguolegou and Turgangou gullies. In the mid 1980 these 49 glaciers covered a total area of 49.29 km^2 and had an ice volume of 2.63 km^3 (Lanzhou Institute of Glaciology and Geocryology of Chinese Academy of Sciences, 1986). The melt-water and alpine precipitation are the main sources of surface water and groundwater recharge in this region.

The climate in the study area varies greatly from the mountain land to the basin. The annual average temperature ranges from –6ºC to 11ºC and annual temperatures range from 40ºC to –40ºC. The annual temperature-accumulated in the period of $\geqslant$0ºC (i.e. $\sum \geqslant 0$ºC) is 1,800ºC–4,600ºC and the annual total sunlight is 2,500–3,300 hours. The annual precipitation is low and unevenly distributed, with 74% of rainfall occurring in May to August, with a decreasing trend from southwest to northeast. The annual precipitation is over 300 mm in the southern mountain and about 100 mm in the middle basin. In the Naomaohu basin the annual precipitation is only 19 mm. The average annual evaporation is 2,000–4,400 mm, and the non-frost period is less than 175 d. The soil types in this region include gray brown desert soil, brown soil, chestnut soil, meadow soil, subalpine meadow soil and solonchak.

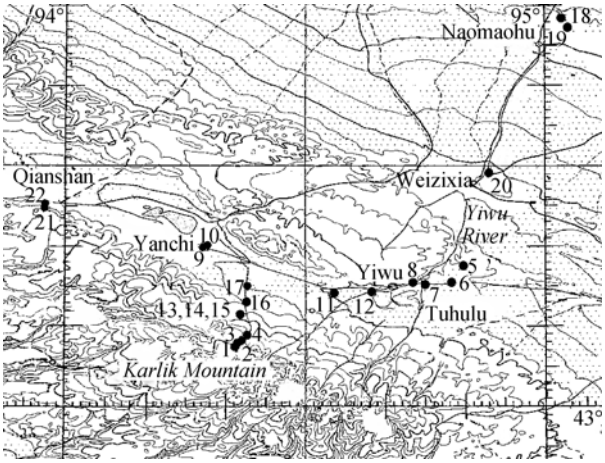

Fig. 1 Geomorphological types and sampling sites in the study area

The vegetation in this region shows a vertical, zonal distribution, but the vertical, zonal spectrum is incomplete. Compared with other mountains on the northern slopes of the Tianshan Mountains, the boundary between steppe and meadow are higher on Karlik Mountain. The vegetation distribution is as follows: (1) desert vegetation is distributed on the low mountains, hills, plains and deserts below an elevation of 1,900 m; (2) steppe vegetation is distributed in the range of 1,900–2,800 m; (3) alpine and sub-alpine meadows and a small expanse of alpine grassland are found at 2,800–3,600 m.

Species' statistics in this study are based on our field observations and the related literatures (Editorial Committee of Flora of Xinjiang, 1996; Mijit and Xu, 2000). The investigation of vegetation used the sampling method of Yue *et al*. (1999), which was to choose representative vegetation plots according to the habitat conditions and types of vegetation in which to set up quadrats. Twenty two sampling quadrats were set up to systemically measure the characteristic parameters of plants. Quadrats of 5 m × 5 m were chosen for shrubs and 1 m × 1 m for herbs. At each site, we recorded the species category and presence, plant height, vegetation cover and habitat factors (altitude, slope direction, geomorphology and soil type), and we also collected plant samples for further species identifications.

3 Composition and geographical components of the flora

Steppe and desert vegetation types predominate in the region of the northern slope of Karlik Mountain to Naomaohu basin. According to the field work and literature, 47 families, 188 genera, 345 species have been recorded in this study area (including subspecies and variant species, Table 1). Of these species, 133 species in 93 genera of 33 families were observed in the field and 212 species in 138 genera of 41 families are recorded in the literature. These species respectively account for 29.19% of the total families, 21.44% of the total genera and 8.45% of the total species in Xinjiang (Feng and Pan, 2004).

3.1 Composition and geographical components of the family

In terms of the floristic composition, the numbers of the genera and species within the big and main families possess the dominance and play an important role in the vegetation composition and community structure. The families of Gramineae, Compositae, Chenopodiaceae and Leguminosae respectively contain more than 10 genera in each family (Table 2) and these

Table 1 Elements of the floristic composition in the study area

Type		No. of families	Percentage in total family (%)	No. of genera	Percentage in total genera (%)	No. of species	Percentage in total species (%)
Pteridophyta		1	2.13	1	0.53	1	0.29
Gymuospermae		3	6.38	4	2.13	7	2.03
Angiospermae	Dicotyledoneae	35	74.47	141	75.00	238	68.99
	Monocotyledoneae	8	17.02	42	22.34	99	28.70
Total		47	100	188	100	345	100

Table 2 Compositions of the species, genera and families in the study area

Name of families	No. of genera	No. of species	Name of families	No. of genera	No. of species
Equisetaceae	1	1	Convolvulaceae	2	4
Ephedraceae	1	4	Primulaceae	2	4
Pinaceae	2	2	Iridaceae	1	4
Cupressaceae	1	1	Orchidaceae	2	3
Gramineae	30	65	Tamaricaceae	2	2
Compositae	27	47	Geraniaceae	2	2
Chenopodiaceae	14	20	Scrophulariaceae	2	2
Leguminosae	11	20	Apocynaceae	2	2
Cyperaceae	4	17	Plantaginaceae	1	2
Polygonaceae	5	15	Juncaginaceae	1	2
Ranunculaceae	7	14	Rubiaceae	1	2
Rosaceae	3	13	Plumbaginaceae	1	2
Cruciferae	7	11	Papaveraceae	1	2
Gentianaceae	4	11	Juncaceae	1	2
Caryophyllaceae	6	10	Asclepiadaceae	1	2
Umbelliferae	7	7	Urticaceae	1	1
Crassulaceae	5	6	Caprifoliaceae	1	1
Boraginaceae	5	6	Malvaceae	1	1
Zygophyllaceae	3	6	Campanulaceae	1	1
Salicaceae	2	6	Cynomoriaceae	1	1
Labiatae	4	5	Valerianaceae	1	1
Liliaceae	2	5	Portulacaceae	1	1
Solanaceae	4	4	Potamogetonaceae	1	1
Saxifragaceae	3	4			

families account for 8.51% of the total families. The families of Cruciferae, Umbelliferae, Ranunculaceae and Caryophyllaceae respectively include 6–9 genera and also account for 8.51% of the total families. There were 20 families with few-genera (2–5 genera in each family), such as Polygonaceae, Cyperaceae, Rosaceae, Primulaceae, and these families account for 42.55% of the total families. Nineteen families only contain one genus, and they account for 40.43% of the total families. Thus it can be seen that the plant families in this region are mainly concentrated on single-genus and few-genus families, which accounts for 82.98% of the total families.

In the study area 11 families contain 10 or more species, such as the Gramineae, Compositae, Cyperaceae, and they account for 23.4% of the total families in the study area. The most of them are the dominant species in the plant communities. Five families contain 6–9 species. These are the Umbelliferae, Zygophyllaceae, Crassulaceae, Boraginaceae and Salicaceae. Twenty one families, including the Liliaceae, Ephedraceae, Plantaginaceae, contain 2–5 species, and account for 44.68% of the total families. Ten families, such as the Urticaceae, Valerianaceae and Cynomoriaceae, contain only one species in each family, and represent 21.28% of the total families. The single-species' and few-species' families are the main parts of the local flora, which is thought to relate to the inclement environment in the study area. In some families only a few species can well adapt to harsh environments, so that the species in the flora tend to concentrate on a few big families, leading to the remarkable phenomenon of dominant families.

The quantity and types of dominant and typical families have an important effect on the flora of a region. Usually, the dominant family contains many species and fills a major part of plant communities, while the typical family is the representational family in a flora and has a quantitative predominance with a high proportion of species in China or in the world (Pan, 1997; Dang and Pan, 2002; Zhang *et al*., 2009). In this region, the families containing over 10 species occupy 23.4% of the total families and 70.43% of the total species. Obviously, they are the dominant families but not the typical families in the study area. The percentage of dominant families, compared with that in Chinese flora, varies from 1.22% to 10% and the average is 3.59%. Therefore, we chose the families with over 3.59% in Chinese flora as the typical family. According to the ratio ordination, they are Chenopodiaceae, Polygonaceae and Gramineae. The Chenopodiaceae and Polygonaceae are also the typical families of Xinjiang (Pan, 1997).

The geographical components of families for the seed plants in the study area can be divided into 7 types:

(1) Cosmopolitan distribution. They are Gramineae, Compositae, Chenopodiaceae, Leguminosae, Cruciferae, Umbelliferae, Ranunculaceae, Caryophyllaceae, Polygonaceae, Labiatae, Cyperaceae, Rosaceae, Gentianaceae, Pinaceae, Cupressaceae, Primulaceae, Scrophulariaceae, Plantaginaceae, Liliaceae, Juncaceae, Campanulaceae, Portulacaceae, Orchidaceae and Potamogetonaceae.

(2) Pantropic distribution. It is Asclepiadaceae.

(3) Tropic to temperate distribution. They are Boraginaceae, Zygophyllaceae, Crassulaceae, Solanaceae, Convolvulaceae, Ephedraceae, Iridaceae, Urticaceae, Plumbaginaceae and Cynomoriaceae.

(4) Tropic to subtropic distribution. They are Geraniaceae, Malvaceae, Apocynaceae and Rubiaceae.

(5) Subtropic to temperate distribution. They are Salicaceae and Tamaricaceae.

(6) Temperate distribution. They are Papaveraceae, Caprifoliaceae, Valerianaceae and Saxifragaceae.

(7) Temperate to Frigid distribution. It is Juncaginaceae.

The percentage of geographical components above is shown in Table 3.

The statistical result of the families indicates that the plant flora is mainly composed of 24 cosmopolitan distributed families that account for 52.17% of the total families in the study area. The next most common is the temperate components that include the

Table 3 Geographical components of the families for the seed plants in the study area

Type	Cosmopolitan	Pantropic	Tropic to temperate	Tropic to subtropic	Subtropic to temperate	Temperate	Temperate to frigid
Number	24	1	10	4	2	4	1
Percentage (%)	52.17	2.17	21.74	8.70	4.35	8.70	2.17

tropics to temperate, subtropics to temperate, temperate, and temperate to frigid families. They have 17 families with 36.96% of the total families and 77.27% of non-cosmopolitan families, indicating a temperate characteristic of the plant flora in the study area. The quantity of true tropic and tropic to subtropic distributed families is few, only accounting for 10.87% in the total families. In the study area, the dominant families and typical families are all the wide distributed families, reflecting the inclemency and asperity of the climate. In the region of the northern slope of Karlik Mountain to Naomaohu basin, the desert climate not only controls the areas of the low mountains and hills but also dominate the mid-mountain zone with an elevation of 2,300–2,500 m. The arid desert environment indicates that many families of the temperate components can occur in this region but could not form the dominant families, and only the wide-spread cosmopolitan families can occupy the absolute predominance with their giant species system and adaptive abilities in this inclement environment (Pan, 1997).

3.2 Composition and geographical components of the genera

The genus composition in the plant flora are mainly composed of single-species' and few-species' genera (containing 2–5 species), and these two types of genera account for 96.28% of the total genera in the study area (Table 4). In terms of the quantity of species in a genus in the study area, only one genus includes more than 10 species, that is *Carex* (13 species). There are 6 genera with 6–9 species, and they are *Potentilla* (9 species), *Stipa* (9 species), *Polygonum* (8 species), *Gentiana* (8 species), *Artemisia* (8 species) and *Poa* (7 species). The genera with 2–5 species are *Salsola* (5 species), *Thalictrum* (4 species), *Clematis* (3 species), *Aster* (2 species), totalling 62 genera. There are 119 genera that only include one species, such as the *Aconitum*, *Glaux*, *Lonicera* and *Koenigia*. The value for the ratio of genera to species in the study area is 0.54, which is higher than that for the whole of Xinjiang (0.21).

In the study area, the plant flora originated from a variety of sources. Various components converged and mingled here, then developed and evolved under this special geographical environment, leading to the complicated characteristics of the plant flora.

(1) Temperate elements

The geographical components of the flora mainly consist of the temperate element, accounting for 109 genera, which is 70.32% of non-cosmopolitan genera. This indicates that the flora in this region is an integral part of Angala Flora, and this distribution characteristic corresponds with the geographical position of the study area. That is, the region of the northern slope of Karlik Mountain to Naomaohu basin is located in the northwest of China and its latitude belongs to a temperate zone, so a lot of temperate genera are developed here.

Of the types of temperate distribution, the genera and species of the North Temperate and their variation have the largest number, which dominates the plant flora, accounting for 153 species of 79 genera. These account for 42.25% of the total genera and 44.48% of the total species. The genera number of old world temperate elements and their variation is just less than that of the temperate distribution, which has 21 genera and account for 11.23% of the total genera in the study area. The temperate Asia element in the temperate distribution has 7 genera and 11 species, and the species of the herbs are more than that of the woods.

(2) Tethys elements

The Tethys elements, including the Mediterranean, West Asia to Central Asia and the Central Asia elements, account for 34 genera, occupying 18.18% of the total genera and 21.94% of non-cosmopolitan genera. The Mediterranean and West Asia to Central Asia elements are inferior to the Cosmopolitan and

Table 4 Composition of the species and genera in the study area

No. of species in genera	No. of genera	Percentage in total genera	No. of species	Percentage in total species
⩾10	1	0.53	13	3.77
6–9	6	3.19	49	14.20
2–5	62	32.98	164	47.54
1	119	63.30	119	34.49
Total	188	100	345	100

North Temperate distribution, yet occupying an important position in the flora composition. Of these two types, most of the species are xeromorphic-mesophic and xeromorphic plants and they are the main composition of the desert steppe, desert and some azonal vegetation. The Central Asia distribution only contains 11 species belonging to 9 genera, and most of them are xeromorphic or super-xerophic herbs and woods and are the significant component of desert vegetation in this region.

(3) Cosmopolitan elements

The cosmopolitan elements have 32 genera and 92 species in this region and they mainly belong to cosmopolitan families. It is because genera with the wider ecological amplitude can survive in the inclement environment of the study area.

(4) Tropics and East Asia elements

The study area is so far from the tropical and subtropical regions that tropics elements can not adapt well to the climate. Eight genera are distributed in this region and account for 4.28% of the total genera and 5.16% of the non-cosmopolitan genera. The genera of the East Asia elements are the least in all geographical components, comprising just 4 genera accounting for 2.14% of the total genera and 2.58% of the non-cosmopolitan genera.

3.3 Composition and geographical components of the species

The plant geographical distribution in the region of the northern slope of Karlik Mountain to Naomaohu basin belongs to the Asian Central-part Desert Subkingdom, and then forms the plant geographical elements that are dominated by the types of the arid Asian Central-part. The following distribution types of plant species were recorded by the Xinjiang Review Term of the Chinese Academy of Sciences (1978).

(1) The Asian Central-part elements. The desert and steppe, composed by the elements with xeromorphic characteristics, can better represent the characteristics of the arid vegetation in the Asian Central-part.

(2) The Central Asia elements. This element is widely distributed on the plains and mountains of the desert regions of inland Asia.

(3) The north temperate elements. The north temperate elements occupy a certain position in the flora of the study area.

(4) The Mediterranean, West Asia to Central Asia elements. This distribution type is the typical representative of Tethys elements of origin, and these species are the main components of the desert vegetation (Dong *et al*., 1997).

(5) The Old Continent temperate elements. The distribution areas of these elements are mainly the regions of the middle and high latitude in Eurasia, and they are also the temperate and subtropics regions.

(6) Other elements. The other elements in this region are mainly cosmopolitan species.

3.4 Compositions of life forms and endemic components

Plant life-form can reflect the characteristics of ecology and biology in the process of plant evolution, and the same life-forms show that the plants have the similar needs or adaptive abilities to the environment. In the study area, the precipitation is meager and the climate is aird to extremely arid and the winter is cold with the lowest temperature of –44ºC. Therefore, most species can not accomplish the whole process of growth and development during the period of a year. In this region the perennial herb is a dominate life-form, and the number can account for 239 species occupying more than 50% of the total species. This phenomenon indicates that the young elements of the species formation in the region are the results of long-term adaptation to the arid natural environment (Feng and Pan, 2004). There are 50 woody species (mostly shrubs) in the study area and these shrubs are mainly composed of Ephedraceae, Rosaceae, Leguminosae, Polygonaceae, Chenopodiaceae, Zygophyllaceae. The quantity of tree species in this region is few but the position in the vegetation is very important. For example, *Larix sibirica* and *Picea schrenkiana* are the dominant species of the coniferous forests and shrubs in the mid mountains and subalpine, while *Populus euphratica* and *Haloxylon ammodendron* are the main components of the desert regions and they play a vital role in protecting the regional eco-environment.

Endemic genera of Chinese plants are poorly represented in this region with only *Elachanthemum*. However, there are 14 endemic species of Xinjiang plants, belonging to 14 genera and 10 families, and accounting for 5.22% of the total endemic species in Xinjiang (Feng *et al*., 2003). These endemic species are as follows: *Saussurea pulviniformis*, *Seriphidium*

borotalense, *Ligularia xinjiangensis*, *Bidens leptophylla*, *Lagochilus lanatonodus*, *Arenaria meyeri*, *Ranunculus hamiensis*, *Rhodiola telephioides*, *Salsola junatovii*, *Androsace squarrosula*, *Calligonum pumilum*, *Agropyron sinkiangense*, *Leymus yiunensis* and *Iris curvifolia*.

4 Plant community and species diversity

4.1 Plant communities

The vegetation in the region of the northern slopes of Karlik Mountain to Naomaohu basin is mainly of the steppe and desert types. We chose the species with importance values ＞10% as the indices for distinguishing the plant communities (Feng *et al*., 2005), and thus 18 plant communities were identified in this region (Table 5).

4.2 Species diversity

The habitat condition and the ecological characteristics of species influenced by habitat determine the differences in species diversity between the different plant communities. Past research has indicated that Pielou evenness index (J_{si}), Shannon-Wiener diversity index (H) and Simpson dominance index (C) have a preferable representation in describing species diversity between plant communities (Qian *et al*., 2007, 2008; Zhang *et al*., 2009). Figure 2 shows the distribution of species diversity indices between different plant communities. Among them, the varying range of Pielou evenness indices is smaller, which reveals that the species distribution in the plant communities of the study area is even, while the varying ranges of the other two indices are larger. The varying trend of the species diversity index basically accords with that of the evenness index. However, the dominance index shows an opposite trend to them. The plant communities with higher species richness have higher diversity and evenness indices, while their dominance indices are low. For instance, sites 13, 21, 11 and 7 belong to the sub-alpine meadow in the mountain ecosystem and the steppe desert, or the river-floodplain meadow and meadow steppe in the mountain and desert ecotone, and all have higher species diversity and evenness indices. Compared with them, the diversity and evenness indices of the plant communities in the desert ecosystem, with simple structure, few species and consisting of super-xerophytes and salt-tolerant plants,

Table 5 Plant communities and their characteristics in the study area

Vegetation types	No. of sites	Community types	Vegetation characteristics
Desert	5	*Ephedra przewalskii+Zygophyllum xanthoxylon + Sympegma regelii*	The dominant species are mainly composed of super-xerophytic shrubs and semi-shrubs, and the companion species are the xerophytic perennial graminaceous grass.
	6	*Reaumuria soongorica + Sympegma regelii*	
Steppication desert	20	*Iljinia regelii-Zygophyllum pterocarpum*	
Desertification steppe	11	*Caragana pumila + Ajania fruticulosa-Stipa tianschanica*	
	17	*Artemisia* sp. + *Stipa saucasica subsp.desertorum + Lagochilus diacanthophyllus*	
Mountain steppe	16	*Stipa saucasica subsp.desertorum-Arenaria meyeri*	Perennial and xerophytic bunchgrasses are dominant, and also xerophytic or xerophytic-mesophytic forbs.
	22	*Stipa sareptana + Carex enervis*	
Meadow steppe	21	*Potentilla bifurca + Melica transsilvanica + Carex stenocarpa*	
Subalpine meadow	13	*Androsace dasyphylla + Inula aspera*	The plant communities which occur on the humid alpine mid-zone are mainly composed of the mesophytic, graminaceous grass and forbs.
	14	*Carex liparocarpos + Inula aspera*	
	15	*Poa attenuate + Aconitum rotundifolium + Stellaria uda*	
Alpine meadow	1	*Waldheimia glabra + Lagopsis eriostachys + Silene karaczukuri*	The vegetation is composed of cold tolerant, perennial mesophyes with low grass layer and simple structure.
	2, 4	*Carex* sp.+ *Polygonum viviparum*	
	3	*Halerpestes sarmetosa + Poa attenuata*	
Wetland meadow	8, 12	*Blysmus sinocompressus + Glaux maritime + Halerpestes ruthenica*	The swamp meadow mainly dominated by the hygrophilous plants, accompanied by mesophytic perennial herbs.
Salinized meadow	7	*Caragana pumila + Clematis songarica-Achnatherum splendens*	The dominant species are salt-tolerant xerophytic, xerophytic-mesophytic graminaceous grass and forbs, and also have some salt-tolerant shrubs.
	9, 10	*Nitraria sibirica-Achnatherum splendens*	
	18, 19	*Phragmites australis* subsp. *australis*	

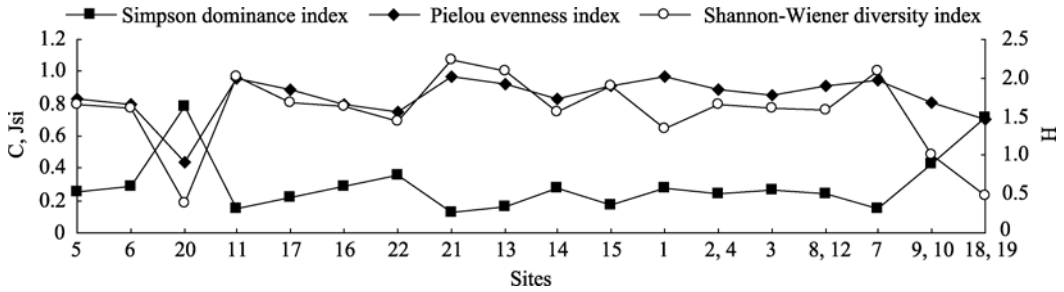

Fig. 2 Species dominance, evenness and diversity of the plant communities in the study area

are all low. Desert ecosystem sites in Fig. 2 are 20, 9, 10, 18 and 19, whose plant communities are mainly composed of a single or few dominant species, such as the *Iljinia regelii*, *Zygophyllum pterocarpum*, *Phragmites australis* subsp. *Australis* and *Nitraria sibirica*.

4.3 Community diversity pattern under the influence of environment gradients

An altitudinal gradient contains the gradient effects of many environmental factors. The altitudes in the study area increased from 500 m to 3,525 m and the variation in altitude brings important influences on the spatial distribution of plants. Figure 3 reveals the variation of species diversity in plant communities with increasing altitudes. The diversity and evenness indices of the species show the single-peak distribution with the rise in elevation. That is, the indices decrease in elevation from 500 m to 2500 m and increase in elevation of > 2500 m, and in the mid altitude zone reached their peak-values. The dominance index shows an opposite trend, first decreasing and subsequently increasing from the low to high altitude sites.

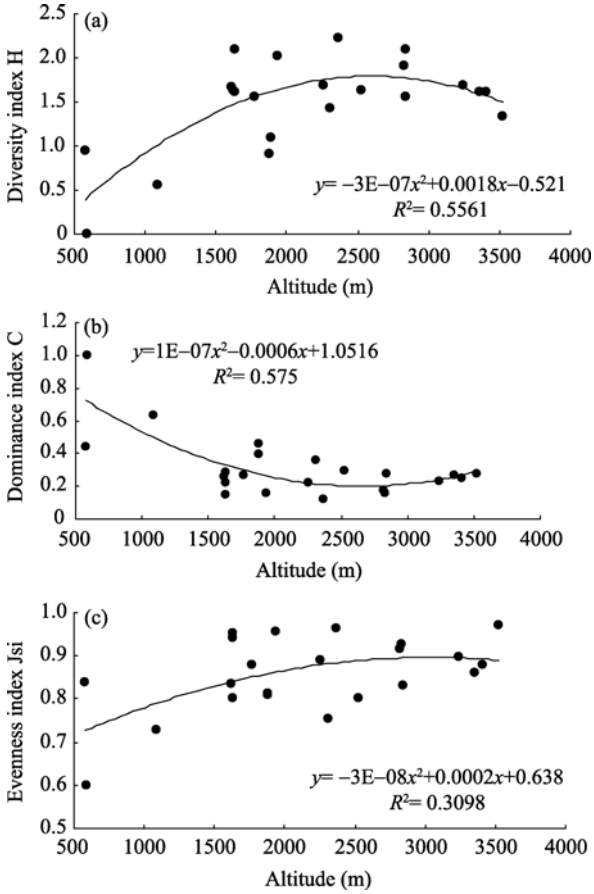

Fig. 3 Variation in community species diversity indices along an elevation gradient in the study area

5 Discussion and conclusion

The region of the northern slope of Karlik Mountain–Naomaohu basin lies on both the massif of the Junggar Basin and the geologic fold-uplift belt of the Tianshan Mountains. Its plant geography belongs to the Asian Central-part Desert Subkingdom, and the particular environment decides the formation, development and distribution of the plant flora. In the study area there are 345 species belonging to 47 families and 188 genera in all, among which Pteridophyta contains one species of a genus in a family; Gymuospermae includes 7 species of 4 genera in 3 families; and Angiospermae has 337 species of 183 genera in 43 families. Compared with other sections of the Tianshan Mountains, the species diversity in this region is relatively poor, related to the arid to extremely arid continental climate. In the plant flora, the families with single-species and few-species are the main parts of the composition. The species of dominant families account for 70.43% of the total species. The genera, with single-species and few-species, account for 96.28% of the total genera. The dominant plant life-form in this region is herbaceous perennials with 239 species, accounting for more than 50% of the total species, which indicates that the plant communities contain a lot of

young components. The characteristics of the plant flora are both old and young, which is a typical temperate attribute. In the composition of the families and genera for carpophytes, the temperate component is dominant, and the Tethys elements are important components, while the percentage of the tropics and East Asia elements are much smaller. The distributing types of the species are mainly the elements of the Asian Central-part, which has xerophytic characteristics.

The distribution of species is the result of many ecological processes related to the climate, community productivity and other factors. An altitudinal gradient contains varying climatic factors such as temperature, humidity and sunlight, and the change of these factors with increasing altitude is 1000 times as fast as that of the latitudinal gradient. With increasing elevation the species diversity shows a negative correlation and a single-peak distribution, which is usual. The single-peak pattern commonly appears in arid and semi-arid regions (Tang and Fang, 2004). The changes in species diversity along the altitudinal gradient (Fig. 3) reflect the difference of the species components between the plant communities brought about by the substitution of species at the different elevations, and the vertical pattern of the diversities. With increases in altitude, the species diversity and evenness indices show single-peak patterns, and the dominance index decreases first and then increases. This is due to the difference of the climate at different altitudes, as well as the result of long-term adaptation and evolution of the species to environmental factors. The low altitude desert zone is mainly restricted by low precipitation and its climate is arid to extremely arid. Xerophytic shrubs and a few species of herbs with low richness exist there. However, this low diversity does not imply poor stability within the system; it is those communities with simple structure and single dominance that can have higher stability (Li *et al*., 2008). In the high altitudinal zone of cold climate, its vegetation mainly belongs to types that are cold-tolerant, so the species diversity is also not high. The species diversity can reach a maximum value at the mid altitudinal zone because of the favorable allocation of heat, temperature, precipitation and other environmental factors, as well as the optimum in environment resources with a higher utilizing efficiency. From the aspect of human disturbance, the desert ecosystem in the low elevation area is easily affected by human activities. For instance, in the field investigation we found that the steppe desert zone in the front of Karlik Mountain exhibits the signs associated with overgrazing and land reclamation without programming. This is also a reason for the low species diversity and evenness indices in this region. Except for the climate and human activities, other factors can also influence the distribution of species diversity. Related research (Ru *et al*., 2006) indicated that differences in the development phase of plant communities and the fluctuation in species diversity can result from differences in landform, slope gradient, slope aspect and habitats variations caused by environmental factors (e.g. differences in soil depth, soil organic matter and soil moisture). In summary, the species diversity in the region of the northern slope of Karlik Mountain to Naomaohu basin is relatively small, and the plant flora mainly consist of single-species and few-species families and genera. The temperate element is the dominant distribution type of plant species. The Areal-types of the species, with xerophytic characteristic, are dominated by the elements of the Asia Central-part, and the perennial herb is the main plant form. Therefore, the plant flora in this region is not only ancient but also young. The species composition, vegetation community diversity and succession reflect the influence of changing environmental factors at different altitudes. That is, the lower and higher altitudinal zones, whose climate conditions are relative inclement, mainly contain plant communities with simple structure and a single dominant species, while in the mid altitudinal zone, the species richness is increased because of the favorable environmental conditions. However, few species can adapt to the arid to extremely arid climate in this region, so the diversity of the plant communities composed of such species is also low.

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