

Natural diet and food habitat use of the Tarim red deer, *Cervus elaphus yarkandensis*

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Abstract In order to determine the natural diet and food habitat use of Tarim red deer (*Cervus elaphus yarkandensis*), a study was carried out in Qiemo, Xinjiang, China from October 2000 to June 2001. Direct observation combined with faecal analysis method was used to determine the natural diet of red deer. 15 different species of plant were identified as food items. Among them, 13 species of plants were identified in winter diet and 9 species in summer. Red deer consumed a wider range of species in winter because of their nutrient requirement as well as the shortage of food and the scarcity of high-quality forage in the study area. *Phragmites communis*, *Glycyrrhiza inflata* and *populus diversifolia* were frequently present in the deer's diet whenever in winter and summer. Among them, *Phragmites communis* was the most abundant plant in the area and was included in the deer's diet. Observation on food selection frequency of captive Tarim red deer showed that *Populus diversifolia* was the first preferred species. However, this food was limited in the study area. Five food habitat types were found in the study area according to plant association: (1) *Phragmites communis*-*Tamarix ramosissima* association, (2) *Tamarix ramosissima*-*Halostachys caspica* association, (3) *Tamarix ramosissima*-*Phragmites communis* association, (4) *Populus diversifolia*-*Phragmites communis* association, (5) Burned area. Among them, *Phragmites communis*-*Tamarix ramosissima* association (reed meadow and reed marsh) was preferred to other types within the study area whenever in summer and winter. Dense reed cover could reduce the chance of detection from predator and obstruct attack from predator. Furthermore, under the cover of the reed, Tarim red deer was protected from direct solar radiation during the hours of

hot day in summer. The reed meadow and marsh was preferred, presumably because the red deer could minimize their movements while searching for food, water and cover.

Keywords: Tarim red deer, *Cervus elaphus yarkandensis*, diet, food habitat, Tarim Basin.

The red deer (*Cervus elaphus*) is a member of the *Cervidae*. There are 8 subspecies of red deer in China, three in Xinjiang. Altai wapiti (*C.e. sibiricus*) occurs in Altai Mt. in northern Xinjiang. Tian-Shan wapiti (*C.e. songaricus*) occurs in Tianshan Mountain area in middle and western Xinjiang. Tarim red deer, (or Tarim red deer) (*C.e. yarkandensis*) occurs along rivers valley in Tarim Basin in southern Xinjiang^[1]. *C.e. yarkandensis* is classified as endangered species by IUCN and is included in the China Red Data Book of Endangered Animal. It is a special desert dweller member of the red deer families, very little is known about its biology, ecology, diet and feeding behaviour.

Tarim red deer is endangered everywhere in Tarim Basin. This endangered situation is thought to be due to the extension of agricultural land, overgrazing by domestic animals, oil exploitation and fawns catching^[2-4]. Among them, fawns catching is believed to be the most important reason, affecting the population of *C.e. yarkandensis*^[4]. In the past 40 years, several studies have documented its distribution^[2,5], status^[1] and habitat^[6]. Yet, our knowledge of diet and food habitat use in Xinjiang, China remains unknown. However, it is important to understand the diet and food habitat characteristics that determine suitability for Tarim red deer and their distribution in the landscape, because these characteristics will influence the management and conservation of this species.

Natural diet and food habitat use of the Tarim red deer were conducted from 2000—2001. At present, various methods have been adopted to study the natural diet of herbivores: (1) direct observation^[7,8]; (2) stomach contents analysis^[9,10]; (3) faecal analysis^[11,12]. The present study examines the natural diet of a wild population of *C.e. yarkandensis* by the technique of faecal analysis and direct observation. The following report provides some preliminary data on natural diet and food habitat use of Tarim red deer in the Cheerchen river valley, Tarim basin, Xinjiang, China

1 Study area

Field work was conducted in Qiemo County along Cheerchen river valley, Xinjiang, China. The studied

ARTICLES

area (38°22'N, 85°45'E) is a natural plain oasis along lower reach of Cheerchen river, which is located in the southeastern edge of Tarim Basin and surrounded by famous Taklimakan Desert. Topography of the area is flat. Soil is predominantly saline. The climate is arid and warm in summer, cold in winter (24.8°C on average in July, and -8.7°C on average in January). The mean annual rainfall is 18.6 mm, mostly falling in summer.

In general, the vegetation in the study area is typical tugai (tugai is a complex of forest, bushes and meadows in the river valleys of desert in Asia). Based on the topography, depth of water table and salt content of soil, the vegetation can be divided into four types: (1) desert open riparian forest, dominated by the popular tree (*Populus diversifolia*) and tamarisk bush (*Tamarix ramosissima*). Intensive timber harvesting created a sparsely distributed popular trees, where the common herbaceous plants are reed (*Phragmites communis*), *Glycyrrhiza inflata*, *Poacynum hendersonii*. (2) *Tamarix ramosissima* bush, characterized by sparsely or dense *Tamarix ramosissima*, where the common plants are *Halostachys caspica*, *Phragmites communis*, *Poacynum hendersonii*, *Karelinia caspia*, *Lycium ruthenicum*, *Glycyrrhiza inflata*. (3) salinization grassland, characterized by reed, where the other plants are *Tamarix ramosissima*, *Populus diversifolia*, *Lycium ruthenicum*, *Poacynum hendersonii*. (4) burned area, characterized by dense reed, where *Poacynum hendersonii*, *Glycyrrhiza inflata*, *Typha angustifolia*, *Asparagus neglectus* can be found.

2 Methods

2.1 Diet selection analysis

The faecal analysis method^[12,13] was used for examining food items. Samples of plants present in the area (21 species) were collected and identified. A reference collection from different parts of all plants was conducted. 39 different samples of Tarim red deer faeces were collected and prepared for microscopic examination. These samples were collected in the winter and summer respectively in order to study the difference of food items of red deer between winter and summer. We took one pallet in each faeces sample. They were broken apart by agitating with water at low speed in a household blender. The fragment we got were boiled in a 20% nitric acid solution for 3 minutes, placed on slides, covered as faeces sample. Five slides were prepared of

each faeces sample. The same method was used to make five plant slides for each of 21 species of plant sample.

We took five sub-samples from faeces and plant sample respectively, placed on slides, covered and examined under 100 times microscope. Each sub-sample was identified at 20 random microscope fields. Total of 100 microscope fields were identified in faeces sample and plant sample. Compared to the plant sample, we can identify the species in the faeces sample. Frequency of occurrence of each species was determined from the existing times in 100 microscope fields. Direct observations of red deer feeding in this area were also used to verify the selection of certain plants and habitat use by recording the twigs and leaves, which show evidence of having been nipped by Tarim red deer.

2.2 Selection frequency of food

Red deer feeding preference was recorded by observing the captive Tarim red deer in a deer farm in the summer in 1995. Four adult deer (2 male and 2 female) were housed in an open pen and supplied with a shelter and drinking trough with fresh water inside and keep no feeding one day. The fresh leaves and young branch of five main species of plant of food items (*Populus diversifolia*, *Phragmites communis*, *Glycyrrhiza inflata*, *Poacynum hendersonii* and *Tamarix ramosissima*) were weighted and feed to the deer. We kept observing from 10:00 am to 18:00 pm. Consumed species and frequency were recorded.

2.3 Food habitat use

We described the food habitat of Tarim red deer. According to the topography, depth of water table and vegetation characteristics, we divided the food habitat of red deer into five types. At each type, ten 10 m × 10 m and ten 1 m × 1 m samples quadrat were established. Plant species composition, plant cover and vegetative cover were recorded. In each type, the active marks including footprint chain, lying marks, and nip marks were recorded.

3 Results

3.1 Natural diet of Tarim red deer

Faecal analysis revealed that Tarim red deer in the wild feed on a variety of plants. 9 species were identified in summer faeces samples, and 12 species were identified in winter faeces samples. The percentage of

their occurrence in red deer faeces was shown in Table 1. Remains of *Phragmites communis* was found mostly frequently in the faeces both in winter and summer, and appeared to comprise the major part of the diet. *Halostachys caspica*, *Glycyrrhiza inflata*, *Tamarix ramosissima*, and *Populus diversifolia* were also represented in the winter diet, and *Glycyrrhiza inflata*, *Poacynum hendersonii*, *Populus diversifolia* and *Asparagus neglectus* were also represented in the summer diet, but occurred less frequently.

Table 1 Diet composition of Tarim red deer in Cheerchen river valley

| Plant species | Frequency of occurrence in winter faeces (%) | Frequency of occurrence in summer faeces (%) |
|-----------------------------|--|--|
| <i>Phragmites communis</i> | 77.1 | 87.6 |
| <i>Halostachys caspica</i> | 37.8 | – |
| <i>Glycyrrhiza inflata</i> | 34.6 | 34.6 |
| <i>Tamarix ramosissima</i> | 34.5 | 5.0 |
| <i>Populus diversifolia</i> | 22.7 | 21.6 |
| <i>Poacynum hendersonii</i> | 13.3 | 26.4 |
| <i>Cynanchum sibiricum</i> | 7.6 | 10.2 |
| <i>Acorus calamus</i> | 5.4 | – |
| <i>Karelinia caspia</i> | 4.3 | 15.2 |
| <i>Aeluropus litoralis</i> | 3.9 | – |
| <i>Lycium ruthenicum</i> | 2.0 | – |
| <i>Alhagi sparsifolia</i> | 1.0 | – |
| <i>Asparagus neglectus</i> | – | 20.4 |
| <i>Scorzonera</i> sp. | – | 1.4 |

3.2 Selection frequency of food

The consumed frequency of 5 plants by Tarim red

deer was showed in Table 2. The *Populus diversifolia* was the most favorite species. The *Tamarix ramosissima* was not touched during the whole observation. According to the selection frequency and consumed amount, the order of food preference by red deer is *Populus diversifolia* > *Phragmites communis* > *Glycyrrhiza inflata* > *Poacynum hendersonii* > *Tamarix ramosissima*.

3.3 Food habitat use of Tarim red deer

Five plant associations are distributed in the study area, according to the depth of the water table and salt content of the soil (Table 3): (1) *Phragmites communis*-*Tamarix ramosissima* association, characterized by dense *Phragmites communis* (1–2 m high) with sparsely distributed *Tamarix ramosissima*. Plant cover is dense, giving the area a meadow or marsh. The water table is very high. There is permanent surface water in some of the area. (2) *Tamarix ramosissima*-*Halostachys caspica* association, characterized by sparsely distributed *Tamarix ramosissima* bush. The understory is open with a few *Halostachys caspica* stands between the bushes. The soil here is saline. (3) *Tamarix ramosissima* - *Phragmites communis* association, characterized by dense *Tamarix ramosissima* bush with sparsely distributed *Phragmites communis*. The water table is very high and permanent surface water can be seen in some of the area, giving the area a marsh. (4) *Populus diversifolia*-*Phragmites communis* association, character-

Table 2 Consumed frequency of 5 main species of plant of food items by 4 captive Tarim red deer in Cheerchen river valley, 1995

| No. of deer | Time | Consumed frequency of 5 plants species | | | | |
|---|-------------|--|----------------------------|-----------------------------|-----------------------------|--------------------|
| | | <i>Glycyrrhiza inflata</i> | <i>Phragmites communis</i> | <i>Poacynum hendersonii</i> | <i>Populus diversifolia</i> | <i>Tamarix</i> sp. |
| 1 | 10:00–13:00 | 3 | 4 | 2 | 5 | 0 |
| | 13:00–15:00 | 0 | 0 | 1 | 2 | 0 |
| | 15:00–18:00 | 1 | 3 | 2 | 7 | 0 |
| 2 | 10:00–13:00 | 2 | 3 | 2 | 5 | 0 |
| | 13:00–15:00 | 1 | 2 | 0 | 0 | 0 |
| | 15:00–18:00 | 2 | 4 | 2 | 5 | 0 |
| 3 | 10:00–13:00 | 4 | 5 | 1 | 10 | 0 |
| | 13:00–15:00 | 0 | 0 | 0 | 2 | 0 |
| | 15:00–18:00 | 3 | 2 | 0 | 6 | 0 |
| 4 | 10:00–13:00 | 4 | 3 | 1 | 6 | 0 |
| | 13:00–15:00 | 1 | 0 | 0 | 1 | 0 |
| | 15:00–18:00 | 3 | 2 | 3 | 1 | 0 |
| Total consumed frequency | | 24 | 28 | 14 | 50 | 0 |
| Percent of total consumed frequency (%) | | 20.7 | 24.1 | 12.1 | 43.1 | 0 |
| Consumed amount (kg) | | 2.8 | 3.8 | 2.2 | 4.7 | 0 |

ARTICLES

Table 3 Habitat type of Tarim red deer along Cheerchen river.

| Plant association and species composition | Species coverage (%) | Vegetative coverage (%) |
|--|----------------------|-------------------------|
| <i>Phragmites communis</i> - <i>Tamarix ramosissima</i> | | |
| <i>Phragmites communis</i> | 81.0 | 94.4 |
| <i>Tamarix ramosissima</i> | 13.0 | |
| <i>Poacynum hendersonii</i> | 0.2 | |
| <i>Asparagus neglectus</i> | 0.2 | |
| <i>Tamarix ramosissima</i> - <i>Halostachys caspica</i> | | |
| <i>Tamarix ramosissima</i> | 21.0 | 39.11 |
| <i>Halostachys caspica</i> | 17.0 | |
| <i>Phragmites communis</i> | 0.9 | |
| <i>Poacynum hendersonii</i> | 0.09 | |
| <i>Karelinia caspia</i> | 0.09 | |
| <i>Lycium ruthenicum</i> | 0.03 | |
| <i>Tamarix ramosissima</i> - <i>Phragmites communis</i> | | |
| <i>Tamarix ramosissima</i> | 75.0 | 89.2 |
| <i>Phragmites communis</i> | 10.0 | |
| <i>Poacynum hendersonii</i> | 2.0 | |
| <i>Glycyrrhiza inflata</i> | 2.0 | |
| <i>Asparagus neglectus</i> | 0.2 | |
| <i>Populus diversifolia</i> - <i>Phragmites communis</i> | | |
| <i>Populus diversifolia</i> | 10.0 | 80.0 |
| <i>Phragmites communis</i> | 30.0 | |
| <i>Tamarix ramosissima</i> | 15.0 | |
| <i>Glycyrrhiza inflata</i> | 10.0 | |
| <i>Poacynum hendersonii</i> | 8.0 | |
| <i>Karelinia caspia</i> | 7.0 | |
| Burned area | | |
| <i>Phragmites communis</i> | 54.0 | 77.8 |
| <i>Poacynum hendersonii</i> | 9.5 | |
| <i>Glycyrrhiza inflata</i> | 6.8 | |
| <i>Acorus calamus</i> | 4.0 | |
| <i>Allium</i> sp. | 1.5 | |
| <i>Acroptilon australe</i> | 1.5 | |
| <i>Asparagus neglectus</i> | 0.5 | |

ized by sparsely standing *Populus diversifolia* trees. The understory consists of *Phragmites communis* and *Lycium ruthenicum*. (5) Burned area. The area was burned before. The tree and bush were scarce. The

common species are *Phragmites communis*, *Poacynum hendersonii* and *Glycyrrhiza inflata*.

In these five types, *Phragmites communis*-*Tamarix ramosissima* association was preferred both in summer and winter. In addition, *Tamarix ramosissima*-*Halostachys caspica* association and *Populus diversifolia*-*Phragmites communis* association were also more used than other types (Table 4).

4 Discussion

4.1 Natural diet of Tarim red deer

Faecal analysis revealed that Tarim red deer took a variety of plants in the wild feed. They feed on 9 species of plant in summer and 12 species of plant in winter (Table 1). 3 more species were found in the food item of red deer in winter. Belovsky (1978) and Westoby (1974) thought that herbivores would specialize when resource levels were high and generalize when they were low^[14,15]. We think that foraging strategies of Tarim red deer will change with resource abundance. Red deer consumed a wider range of species in winter because of their nutrient requirement coupled with the shortage of food and the scarcity of high-quality forage in winter in the study area.

Most of red deer in Europe and America are mixed feeders^[16-20]. Red deer in Cheerchen river valley are also mixed feeders, which consume 1 species of tree (*populus diversifolia*), 1 species of bush (*Tamarix ramosissima*), 6 species of forb and 1 species of grass (*Phragmites communis*) in summer and 1 species of tree, 3 species of bush (*Tamarix ramosissima*, *Lycium ruthenicum* and *Halostachys caspica*), 6 species of forb and 2 species of grass (*Phragmites communis* and *Aeluropus litoralis*) in winter. Such general food composition is consistent with another subspecies — Bokharan deer (*C.e.bactrianus*) in the former USSR. There, the Bokharan deer occurs in the similar environment and their basic food is the woody, shrubby and herbaceous vegetation of low-lying land^[21]. In general,

Table 4 Statistics of active marks of Tarim red deer in each habitat

| Habitat types | Footprint chain | | Lying marks | | Nip marks | |
|--|-----------------|--------|-------------|--------|-----------|--------|
| | winter | summer | winter | summer | winter | summer |
| <i>P.communis</i> - <i>T.ramosissima</i> | 23 | 13 | — | 2 | — | 1 |
| <i>T.ramosissima</i> - <i>H. caspica</i> | 6 | 3 | — | — | — | — |
| <i>T.ramosissima</i> - <i>P.communis</i> | 2 | — | 2 | 3 | — | — |
| <i>P.diversifolia</i> - <i>P. communis</i> | 4 | 7 | 2 | — | — | 1 |
| Burned area | 1 | 3 | — | — | — | — |

grasses provide a more completely digestible source of energy and browse contains more protein^[17]. We think that grass is an important source of digestible dry matter and, hence, energy, and browse appeared to be a better source of protein.

Examination of the faeces showed that 14 species of plants were included in the Tarim red deer's diet, which were available in the area. However, only one of them, *Phragmites communis*, represents the most important food items in their diet whenever in winter and summer. Such result is consistent with the study on *C.e. bactrianus* in former USSR. There, reed played a considerable role as food all the year round^[21]. *Phragmites communis* is the most abundant species in the study area, forming an important community in 4 of five habitat types (Table 3). It provides a good source of food for red deer. In the five main species of plant of food items, *Phragmites* is the second preferred species (Table 2). We think that keeping the *Phragmites* from overgrazing by livestock is important for red deer conservation in the study area.

Populus diversifolia was found in the food items of Tarim red deer and it is one of the important food species both in winter and in summer (Table 1). It was found fourth frequently occurring in summer food and fifth in winter. However, in the five main species of plant of food items, *Populus diversifolia* is the first preferred species (Table 2). Similar report in the middle Amu Darya in former USSR showed that another species of popular — *Populus pruinosa* leaves is the favorite food of Bokharan deer all the year round^[21]. Before 1950, there is still large area of *Populus diversifolia* forest in the study area. We think that *populus diversifolia* maybe play a more important role as food of Tarim deer. However, intensive timber harvesting beginning in the 1950s along with harsh natural environment conditions created a sharp decrease of popular sources. Tarim deer in the study area have to feed on more *Phragmites*.

Tamarix ramosissima was found second least frequently occurring in the faeces in the summer in Cheerchen river valley. However, it was fourth frequently occurring in winter (Table 1). Bannikova (1971) reported that Bokharan deer prefer *Tamarix* sp. in winter and tamarisk shoots is one of the two basic food for the Bokharan deer in winter in the lower Vakhsh in former USSR^[21]. In our food selection frequency observation, the Tarim deer did not select *Tamarix* in summer (Table 2). *Halostachys caspica* was found

second most frequently occurring in the faeces in the winter. It was not found in the faeces in summer (Table 1). We think that Tarim red deer in cheerchen river valley usually do not select *Tamarix* and *Halostachys caspica* as a food in summer when food sources are abundant. Such halophytic plants were used only in winter when food source is limited.

4.2 Food habitat use of Tarim red deer

During our field survey, we found that *Phragmites communis-Tamarix ramosissima* association (reed meadow and reed marsh) was preferred to other types within the study area whenever in summer and winter. We think that dense cover of reed can reduce the chance of detection and obstruct attack from predator. Furthermore, under the cover of the reed, Tarim red deer are protected from direct solar radiation during the hours of hot day in summer. The reed meadow and marsh were preferred, presumably because the red deer could minimize their movements while searching for food, water and cover, thus maximizing their energy efficiency.

In addition, we found that *Tamarix ramosissima* bush and *Populus diversifolia-Phragmites communis* association were used more often in winter. We think that Tarim red deer feed on *Tamarix ramosissima*, *Halostachys caspica* and *Populus diversifolia* in the Tamarisk bush and *Populus diversifolia-Phragmites communis* association during winter. Furthermore, in the open habitat, red deer can get direct solar radiation and heat during cold winter day.

Burned area was preferred by red deer both in summer and winter though its area is very limited in the study area. We think that deer have opportunity to select more species of herbaceous plants in the burned area (Table 3). Furthermore, we think that the plants grow on burned area can provide more nutrition. Some studies showed that herbaceous plants growing on burned area contain more crude protein^[22–25], less crude fiber^[22,23,26]. Thus, the food digestible rate is increased^[27]

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ARTICLES

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