A Comparative Study on Autumn Diets of Sympatric Alpine Musk Deer and Alashan Red Deer in the Helan Mountains: Postprint

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Abstract

Fecal samples of sympatric Alpine musk deer (Moschus chrysogaster) and Alashan red deer (Cervus alashanicus) in the Helan Mountains were collected during autumn, and their autumn diets were investigated using fecal microscopic analysis. Composite fecal samples (n=40) were collected from the active ranges of each species along with plant reference materials. Data were processed and calculated using the frequency conversion method to determine the autumn diet composition and proportional contributions of sympatric Alpine musk deer and Alashan red deer in the Helan Mountains. The results revealed that Alpine musk deer consumed plants from 20 families and 30 species (or genera) during autumn, with Lonicera caerulea (11.96%), Astragalus chingianus (10.17%), Salix characta (8.32%), Spiraea fruticosa (6.82%), and Leptodermis ordosica (6.18%) comprising the main food items. Alashan red deer consumed plants from 12 families and 29 species (or genera) during autumn, with Stipa (22.15%), Ulmus glaucescens (21.14%), Poa (16.90%), Potentilla parvifolia (11.62%), and Populus davidiana (10.00%) serving as the primary dietary components. Nine food species overlapped between the two species, with a niche overlap index of 83.75%. The Shannon-Wiener index, Pielou evenness index, food niche breadth index, and maximum species diversity index for Alpine musk deer during autumn were all higher than those for Alashan red deer.

Full Text

Preamble

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A Comparative Study of Autumn Diets of Alpine Musk Deer (*Moschus chrysogaster*) and Alashan Red Deer (*Cervus alashanicus*) in the Helan Mountains, China

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Abstract

Fecal samples of Alpine musk deer (*Moschus chrysogaster*) and Alashan red deer (*Cervus alashanicus*) were collected in the Helan Mountains to study their autumn feeding habits through microscopic fecal analysis. Fecal and plant samples were collected from the habitats of both species, yielding 40 composite samples for each. Diet proportions were processed using the frequency conversion method.

The results showed that the autumn diet of Alpine musk deer comprised 30 species from 20 families, with main foods including *Salix characta* (11.96%), *Lonicera edulis* (10.17%), *Astragalus* spp. (8.32%), *Spiraea* spp. (6.82%), and *Leptodermis ordosica* (6.18%). The diet of Alashan red deer consisted of 29 species from 12 families, dominated by *Stipa* spp. (22.15%), *Potentilla* spp. (21.24%), *Ulmus glaucescens* (18.90%), *Potentilla parvifolia* (12.92%), and *Populus davidiana* (10.00%). The two species shared nine food plant species, with a niche overlap index of 83.75%. The Shannon-Wiener index, Pielou evenness index, food niche breadth index, and maximum species diversity index were all higher for Alpine musk deer than for Alashan red deer.

Keywords: Alpine musk deer; Alashan red deer; diet composition; autumn; Helan Mountains

Introduction

Competition for resources among sympatric species is a central focus of community ecology research. Numerous studies have demonstrated that competition is a primary factor driving differential resource utilization among species, leading to morphological and behavioral divergence [1-4]. Both Alpine musk deer and Alashan red deer are key species in the Helan Mountains forest ecosystem and are listed as national first-class and second-class protected wildlife, respectively.

The Helan Mountains represent the northernmost distribution of Alpine musk deer in China. Due to habitat fragmentation and illegal hunting, the population has become extremely rare, making research on its status and conservation urgently needed [5]. Alashan red deer (*Cervus alashanicus*) is currently restricted to the Helan Mountains at the border of Ningxia and Inner Mongolia, representing the only viable population of this subspecies in China [6-7]. Based on morphological characteristics related to plant consumption and ruminant physiological traits, Alpine musk deer are classified as concentrate selectors, while Alashan red deer are intermediate between concentrate and roughage feeders [8-11]. Both species inhabit the montane coniferous forest zone of the Helan Mountains, suggesting potential food competition. In northern regions, autumn is a critical period for herbivores to accumulate energy reserves for winter, with both species feeding primarily on herbs within forests and at forest edges [12-15]. This study investigates the autumn diets of sympatric Alpine musk deer and Alashan red deer to provide a scientific basis for more effective conservation of these two rare species.

1. Study Area

The Helan Mountains are located between the Yinchuan Plain and Alashan Plateau (38°21 -39°22 N, 105°44 -106°42 E), extending nearly north-south for approximately 250 km with elevations typically ranging from 2000–3000 m. The range is bounded by the Maowusu Desert to the east, the Ulan Buh Desert to the north, and the Tengger Desert to the west, serving as a boundary between temperate desert and temperate desert-steppe ecosystems and holding significant geographical importance in northwest China [16].

Vegetation shows clear vertical zonation. From foothills to the main peak, four vertical belts are recognized: (1) Montane sparse forest-steppe zone at 1400-1600 m; (2) Montane coniferous forest zone in the mid-montane and subalpine regions at 1600–2000 m; (3) Subalpine shrub and meadow zone at 1900–3100 m; and (4) The zone around the main peak at 3100–3556 m [17]. The area experiences a typical continental climate with mountainous characteristics, with mean annual precipitation of 2000 mm and mean annual temperature of -0.8°C. Autumn climate is notably variable, with unstable weather, strong winds, and early frosts leading rapidly into winter [18-19].

2. Methods

2.1 Plant and Fecal Sample Collection

Common methods for studying herbivore diets include stomach analysis, direct observation, indoor feeding trials, and fecal microhistological analysis [20]. Many scholars consider fecal microhistological analysis to be accurate for determining food composition and more suitable for Chinese herbivores than other methods, as it yields relatively precise results and facilitates sampling.

We selected several valleys where Alpine musk deer and Alashan red deer were concentrated in autumn and established transects from valley mouths to ridges, covering all habitat types and elevation ranges for both species. Fresh feces were collected along transects based on color, moisture, and drying degree as freshness criteria. Species identification relied on external morphology and size of fecal pellets. Ten pellets were collected from each fecal pile into sample bags with associated data including collection time, location, and habitat type. Due to the extended collection period required to obtain adequate sample sizes for statistical analysis, we ultimately collected 40 composite fecal samples for each species. During fecal collection, all plant species encountered along valley transects were collected in duplicate—one set for reference slide preparation and another for species identification.

2.2 Microscopic Slide Preparation

Collected reference plants and fecal specimens were pulverized in a grinder and sieved through a mesh screen. Samples were placed in petri dishes with sufficient dissociation solution (NaClO) to ensure complete immersion. After approximately 3–5 hours, when cell structures became clear, contents were transferred to a mesh sieve for rinsing, then placed in clean petri dishes. Temporary mounts were prepared to verify cell morphology clarity before staining with safranin for 30 minutes. After staining, samples were rinsed, excess water removed with filter paper, and permanent slides prepared with Canada balsam and labeled. Each reference plant and composite fecal sample yielded 2–3 slides for examination.

2.3 Microscopic Examination

Each slide was examined at 100× and 400× magnification. Identifiable plant epidermal fragments were recorded in each field of view. The frequency of each plant species in composite fecal samples was converted to average density (D) of identifiable epidermal fragments per field using the formula F = 100(1 - e), where F is frequency. Density was then converted to relative density (RD) as: RD = (D of each plant / sum of D for all plants) × 100%, representing the dry weight proportion of each plant in the diet. All slides were photographed with a digital microscope camera for archival purposes [21-23].

2.4 Data Analysis

Shannon-Wiener index (H), Pielou evenness index (J), and niche breadth index (B) were calculated to analyze autumn diet composition diversity:

- Shannon-Wiener diversity index: H = -ΣP lnP , where P is the proportion of fragments of plant i
- Evenness index: J = H /H   , where H   = lnS (S = number of plant species in feces)
- Niche breadth index: $B = 1/\Sigma P^{2}$

- Schoener overlap index: $D = 1 - \frac{1}{2}\Sigma|P - P|$, where P and P are percentages of shared plants in each species' diet

3. Results

3.1 Autumn Diet of Alpine Musk Deer

Alpine musk deer consumed 30 plant species from 20 families in autumn. Main foods included *Salix characta* (11.96%), *Lonicera edulis* (10.17%), *Astragalus* spp. (8.32%), *Spiraea* spp. (6.82%), and *Leptodermis ordosica* (6.18%). Legumes and composites constituted the bulk of the diet, accounting for 43.45% of autumn food intake. The remaining families contributed varying proportions. By growth form, shrubs comprised 46.52% of the diet, herbs 31.80%, large fungi 7.10%, trees 14.55%, and mosses 0.02%.

3.2 Autumn Diet of Alashan Red Deer

Alashan red deer consumed 29 plant species from 12 families in autumn. Primary foods were *Stipa* spp. (22.15%), *Potentilla* spp. (21.24%), *Ulmus glaucescens* (18.90%), *Potentilla parvifolia* (12.92%), and *Populus davidiana* (10.00%). Grasses (Poaceae) dominated at 43.45% of the diet, followed by Ulmaceae (21.14%) and Rosaceae (13.93%). By growth form, grasses accounted for 43.45%, trees 31.14%, shrubs 17.31%, non-grass herbs 4.34%, and mosses 3.42%.

shows the complete diet composition for both species.

3.3 Dietary Comparison

The niche overlap index between the two species was 83.75%, indicating substantial dietary overlap. However, key differences existed: red deer heavily consumed *Stipa* spp., which musk deer avoided entirely, while musk deer favored *Lonicera edulis*, which red deer ate only minimally. Nine plant species were shared, but in markedly different proportions. Musk deer exhibited higher Shannon-Wiener diversity, Pielou evenness, niche breadth, and maximum species diversity indices than red deer (Table 2).

compares food diversity indices and niche breadth between the species.

4. Discussion

4.1 Autumn Diet of Alpine Musk Deer

Shrubs and herbs constitute the bulk of Alpine musk deer autumn diet. Musk deer primarily consume tree leaves and fallen foliage, feeding on most shrub species available. While *Berberis* and *Potentilla glabra* are highly preferred foods [24], their autumn consumption was low due to limited availability. Alpine musk deer inhabit high-elevation montane coniferous forests (2700–3100 m) [30].

Their relatively small body size prevents access to tall trees, making shrubs and herbs the primary food source. This demonstrates high dietary adaptability. We observed that as autumn food abundance declined, musk deer increasingly consumed tannin-rich foods like *Lonicera edulis* and *Berberis ordosica*, reflecting adaptive responses to seasonal environmental changes [25-27].

4.2 Autumn Diet of Alashan Red Deer

Herbs and trees are the main autumn foods for Alashan red deer. Cui et al. [17] reported that Alashan red deer winter diet comprised few plant categories, while Chang et al. [5] found summer diet included 29 species with substantial *Picea crassifolia* consumption. Our results show autumn consumption of numerous grasses like *Poa* spp. Seasonal differences in diet primarily reflect the species' seasonal migration from high-elevation summer ranges to low-elevation winter ranges [28-29], which changes foraging habitats and consequently plant species consumed. This seasonal dietary generalization demonstrates strong environmental adaptability during autumn and winter [17].

4.3 Autumn Food Overlap Between Species

The high Schoener overlap index of 83.75% indicates substantial dietary overlap between sympatric Alashan red deer and Alpine musk deer in autumn. However, marked dietary differences exist: red deer heavily consumed *Stipa* spp. while musk deer favored *Lonicera edulis.* These differences likely reflect habitat segregation, with red deer primarily foraging in temperate coniferous forests at 2000–2300 m and consuming more trees and grasses, while musk deer foraged in subalpine shrublands at 2700–3100 m [30]. Red deer foods like *Potentilla parvifolia* and *Stipa* spp. predominantly occur on sunny slopes, whereas musk deer foods like *Lonicera* and *Spiraea* are more common on shady slopes. Body size differences also contribute: musk deer' s smaller stature limits tree foraging, while shrubs and herbs are more accessible. This reflects a compensatory mechanism common among sympatric species, where differential resource use in one dimension (e.g., space) reduces competition in others (e.g., food) [31-33]. Despite spatial proximity, distinct resource utilization patterns demonstrate niche partitioning and compensatory mechanisms in this sympatric ungulate assemblage.

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Note: Figure translations are in progress. See original paper for figures.