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НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

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This monograph shall inform you about up to date methodologies and recent results in landscape research. It is intended as a guide for researchers, teachers, students, decision makers, stakeholders interested in the topic of landscape science and related disciplines. It provides information basis for decision makers at various levels, from local up to international decision bodies, representing the top level of landscape science in a very short form.

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Chapter III/34: STABLE ISOTOPE ANALYSIS TO STUDY DIETARY BEHAVIOR OF SYMPATRIC EQUIDS IN THE DZUNGARIAN GOBI

**ABSTRACT.** We used sequential stable isotope analysis of tail hair to study dietary behaviour of three sympatric equid species, the re-introduced Przewalski’s horse (*Equus ferus przewalskii*), the khulan (*Equus hemionus*), and their potential pasture competitor the free ranging domestic horse (*Equus caballus*). We used stable isotope analysis on tail hair to study dietary behaviour of three sympatric equid species. We found that both horse species are predominantly grazers, suggesting a high potential for pasture competition in winter, while khulan switch seasonally between grass dominated diet in summer and mixed grass-browse diet in winter. Analysis of historic tail hair samples from the same area showed similar switching pattern in historic (pre-extinction) Przewalski’s horses as in extant and historic khulan. This dietary shift in Przewalski’s horse from being a summer grazer to a year-round grazer nowadays, is best explained by a release from human hunting pressure.

**KEYWORDS:** desert landscape, Dzungarian Gobi, khulan, pasture competition, Przewalski’s horse, stable isotope analysis

**INTRODUCTION**

In historic times, two wild equid species, the Przewalski’s horse (*Equus ferus przewalskii*) and the Asiatic wild ass (khulan, *Equus hemionus*), roamed the Eurasian steppe. But by the end of the 1960s, the Prze-
Przewalski’s horse had been driven to extinction in the wild and the range of khulan became severely restricted to the least productive habitats. However, the Przewalski’s horse survived in captivity and reintroductions since the 1990s have brought the species back to parts of its native range in the Dzungarian Gobi in Mongolia and northern China where they again overlap with khulan, and in addition, share their habitat with a third equid species, the free-ranging domestic horse (Equus ferus). This makes the Dzungarian Gobi a unique environment, because overlap zones of different equid species are rare. Equids have a very similar size and body shape and seem to occupy very similar ecological niches [1], and little work has been done to understand the resource use and physiological adaptations that explain their distribution.

Since continuous observations of free-ranging equids are almost impossible to conduct in this remote and harsh environment, we applied an indirect approach using stable isotopes. Analysis of stable isotopes in animal tissues (e.g., bone, hair, feather, muscle, blood) has become a preferred tool to study dietary ecology. The underlying principle of the isotope approach is that animal tissues reflect the isotope composition of diet and water consumed. Carbon isotopes (expressed as $\delta^{13}C$ in $\%e$) are particularly useful to address dietary ecology of herbivores due to a clear difference of $\delta^{13}C$ values between $C_3$ and $C_4$ plants as a result of different photosynthetic pathways followed by the respective plant groups [2]. To date most studies have focused on species from North America, Africa and Europe, with only a handful of studies carried out on species from Asia. In the cold dry steppes of the Gobi, grasses primarily follow the $C_3$ pathway, and most shrubs and semi-shrubs follow the $C_4$ pathway, thus allowing separation between browsing and grazing herbivores (plants with a third photosynthetic pathway, namely CAM, are rare in the Gobi [3]).

Other light stable isotopes can provide additional information on diet ($\delta^{15}N$, $\delta^{34}S$), as well as on physiological status (e.g., starvation) and water use efficiency ($\delta^{18}O$, $\delta^{15}N$, $\delta^{34}S$), or geographical location ($\delta^{18}O$, $\delta^{15}N$, $\delta^{2}H$), and most shrubs and semi-shrubs follow the $C_4$ pathway. Hair presents an ideal matrix for the isotope analysis, because it grows continuously and is metabolically inert after formation [4], [5]. A long tail hair is particularly suitable as it presents a chronological time series of isotope information covering a time window of up to several years [6]. Provided a good sample preservation, this information can be retrieved from the hair even hundreds of years after the death of the animal.

We thus used stable isotope analysis of sequentially cut tail hair to draw inferences about multi-year diet seasonality, isotopic dietary niches and physiological adaptations of the three sympatric equid species, the re-introduced Przewalski’s horse, the khulan, and their potential pasture competitor the free-ranging domestic horse in the Dzungarian Gobi. Specifically, we asked: Do they feed as grazers, browsers or mixed-feeders? Do they compete for the same resources? Are there any potential differences in physiological adaptations among species? In addition, stable isotope analysis of historic museum samples from the same area enabled the comparison of pre-extinction and extant reintroduced Przewalski’s horses. Here we asked: Is the dietary behaviour of the extant reintroduced Przewalski’s horses the same or different as the behaviour of their historic pre-extinction counterparts?

MATERIAL AND METHODS

The habitat of the Dzungarian Gobi is characterized by an arid (<100 mm/year), cold-temperate climate with a summer precipitation peak. The landscape consists of desert-steppe, semi-desert, and desert drylands dominated by Chenopodiaceae (shrubs and semi-shrubs) which follow a $C_4$ photosynthetic pathway and Asteraceae, Tamaricaceae and Poaceae, which follow a $C_3$ pathway. Alpine meadows above 2000 m are primarily dominated by $C_3$ grasses and forbs. We collected and analysed tail hair samples from six extant Przewalski’s horses, khulan and domestic horses in the Dzungarian Gobi (SW Mongolia) and samples from six historic Przewalski’s horses and three khulan, sampled in the Dzungarian Gobi between 1889 and 1898 (SW Mongolia and N China; kept in museum collections of the Zoological Institute of the RAS, St. Petersburg and Zoological Museum of the Moscow Lomonosow State University in Russia). All samples were cleaned, cut into 1 cm increments and analysed for carbon and nitrogen isotope values in the IZW Berlin, Germany (with precision better than 0.1‰ for both isotopes; calibrated to international standards). $\delta^{13}C$ values of historic samples were corrected for the Suess effect. We calculated the contribution of browse and grass in the diet of each individual using the dual mixing model of [7], based on our own vegetation isotope data (with mean $\delta^{13}C$ values of -25.5±1.3‰ for $C_3$ and -13.5±0.5‰ for $C_4$ plants), and literature fractionation factors for horses (2.7‰ for C and 1.9‰ for N) [8], [9]. Species specific isotope dietary niches were estimated following a Bayesian approach based on bivariate, ellipse-based metrics using SIBER implemented in the R package SIAR [10], [11]. For details on methodology see [3], [12].
RESULTS AND DISCUSSION

Extant equids. Results of the stable isotope analysis showed that even in the arid Gobi, both horse species are predominantly grazers that include browse in their diet only under extreme environmental conditions (e.g. dzud winter), whereas khulan are highly seasonal, switching between grass dominated diet in summer and mixed grass-browse diet (including up to 65% browse) during the critical nutritional bottleneck in winter (Fig. 1).

The isotopic dietary niches of both horse species were almost identical, did not differ with season, and were smaller and narrower than in khulan. Winter and summer isotopic niches of khulan, on the other hand, were completely separated, with spring and autumn niches lying in between. Higher δ15N values in khulan suggest higher water use efficiency, which may be one reason why khulan can exploit pastures further away from water. Our results suggest that the differences in foraging adaptation facilitate the coexistence of horses and khulan in the same habitat, but the high degree of isotopic niche overlap of both horse species indicates a high potential for pasture competition in winter, highlighting the need to severely restrict grazing of domestic horses on the range of the Przewalski’s horses.

Pre-extinction Przewalski’s horses The analysis of historic tail hairs of pre-extinction Przewalski’s horses showed a clear difference in the isotopic dietary composition, with clear seasonality in the diet of historic but not in extant Przewalski’s horses. This seasonality followed the same pattern as observed in the extant (Fig. 1) as well as historic khulan, i.e. grazing in summer and mixed feeding in winter. Due to the high proportion of browse in their diet in winter, historic Przewalski’s horses had much broader core isotopic dietary niches than their extant reintroduced conspecifics (Fig. 2).

We explain this dietary shift in Przewalski’s horses by a release from human predation. Until recently, both the Przewalski’s horses and khulan have been heavily hunted as game and persecuted as pasture competitors. Nowadays both species are fully protected, but whereas the newly returned Przewalski’s horse has become a much appreciated iconic national flagship species, attitudes towards khulan remain ambivalent [13]. This changed positive attitude allows the reintroduced Przewalski’s horses to feed on the scarce, grass dominated pastures alongside local people and their numerous livestock whereas their historic conspecifics (like the historic and extant khulan), were forced into less productive habitats dominated by browse during the resource poor winter season.

CONCLUSIONS

1. Both extant horse species are grazers, whereas khulan are highly seasonal, switching between being grazers in summer, and mixed-feeders in winter.
2. Differences in foraging adaptation facilitate the coexistence of horses and khulan in the same habitat, but the high degree of isotopic niche overlap of both horse species indicates a high potential for pasture competition when resources are scarce.
3. Stable isotopes revealed the dietary change from pre-extinction to reintroduced Przewalski’s horses, which could not be detected by any other analytical means.

4. A changed, positive societal attitude enabled reintroduced Przewalski’s horses in the Dzungarian Gobi to return from a suboptimal diet including elevated levels of browse in winter to a more optimal year-round grazing diet.

5. Stable isotope analysis is an excellent tool to study various aspects of animal ecology of extant and/or (pre-)historic species with a great potential to answer myriad other questions related to diet, food-web structure, migration or physiology of animals inhabiting Central and East Asia.

**Figure 2** – Isotopic dietary niches of the Przewalski’s horses and khulan in the Dzungarian Gobi, clearly indicating a dietary shift from historic to extant Przewalski’s horses and the lack thereof in khulan [12].

**REFERENCES**


Chapter III/35: POPULATION-ECOLOGICAL, MORPHOLOGICAL AND GENETIC CHARACTERISTICS OF WILD REINDEERS IN WEST TAIMYR

Глава III/35: Популяционно-экологическая, морфологическая и генетическая характеристика диких северных оленей Западного Таймыра

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ABSTRACT. In the conditions of increasing influence of anthropogenic factors on wild reindeer population of Western Taimyr and their habitat, a reduction of the census size, a decrease in reproductive capacity, a change in spatial distribution and calving sites, and negative tendencies in sex and age structure are observed. Currently, this population is characterized by a relatively high level of genetic diversity, which indicates its good adaptation to the environment. However, the continuing impact of these factors on this population and its habitat can cause a decrease of its census size to a critical state (up to complete extinction) and loss of unique genes, which negatively affects the level of genetic diversity.