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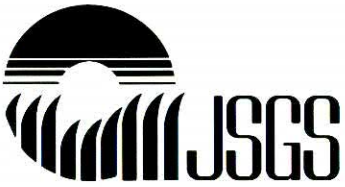

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Isotope ecology of Yak in Tibet-Transhimalaya alpine rangelands

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The main chemical elements of plant biomass (carbon, oxygen, hydrogen and nitrogen) show strong variation in isotope composition ($^{13}C/^{12}C$; $^{15}N/^{14}N$; $^{2}H/^{1}H$; $^{18}O/^{16}O$) at a wide range of spatial and temporal scales. As "you are what you eat, isotopically" (DeNiro & Epstein 1978 *Geochmica Cosmochimica Acta*), these signals are ingested with feed, imprinted in the body of herbivores and propagated in food chains. The isotopic patterns originate from a different behavior of isotopes in physical and chemical processes which are controlled by environmental conditions and biological properties of organisms and ecosystems. The $^{15}N/^{14}N$ ratio differs between legumes and non-legumes, with the $^{15}N/^{14}N$ ratio of non-legumes mainly depending on the ^{15}N of soil nitrogen which is influenced by nitrogen inputs, precipitation and soil pH. The $^{18}O/^{16}O$ and $^{2}H/^{1}H$ ratio of rain and snow water is affected by the temperature of droplet formation and leads to strong seasonal, latitudinal and altitudinal variation of meteoric waters. The ^{13}C composition of plants depends on the $^{13}C/^{12}C$ ratio of atmospheric CO_2 (which decreases in concert with increasing atmospheric CO_2; Suess effect) and differs between photosynthetic types (C_3, C_4). At a finer scale the $^{13}C/^{12}C$ ratio of C_3 plants responds to drought and altitude. The hair and horn of grazers – such as cattle, yak or alpine ibex – are virtually ideal trackers of isotopic signals in grassland vegetation: they are chemically uniform (composed of keratin), laid down progressively during growth and remain unaltered thereafter. Hence, hair and horn form isotopic chronologies which record environmental cues and the behavioral ecology of grazers.

To our best knowledge, the present work is the first stable isotope study of yak in Tibet-Transhimalaya alpine rangelands. The work addresses the following questions: (1) Are there systematic isotopic patterns along the length of hair and horn? Do isotopic signals present evidence for (2) ontogenetic effects or (3) nutritional stress? (4) Do transhumant yak show recurrent seasonal patterns of isotope signals which match predictions from migration along altitudinal gradients? (5) How do isotopic signals compare with signals observed in sheep and cattle kept at different altitudes in the Alps? (6) Is there evidence for drought effects on vegetation? And, finally, does drinking water isotope composition differ between contrasting sites in the Tibet-Transhimalaya region? Samples were obtained in two regions: Ladakh (India), and Yushu and Menyuan (Qinghai/China), with the Yushu and Menyuan sites both having a resident and a transhumant herd of yak. River water, used as drinking water by yak, was obtained in Ladakh and Yushu. Finally, the horn of a 16 years-old yak was used for a detailed inspection of longitudinal and transversal isotopic patterns.

Hair from animals sampled in different years demonstrated sections with matching isotopic patterns which allowed estimation of hair growth rates. Such information is useful for assigning isotopic patterns to seasons and years. The horn revealed systematic isotopic variation within (^{13}C and ^{15}N) and between (^{13}C) year rings. The ^{15}N variations were particularly evident in the 2nd, 3rd, 4th and 5th year of the animals' life. The $^{15}N/^{14}N$ ratio was low in the oldest section of horn annuli, high in the center part, and decreasing in the young part. We predict that this pattern records variation in the ^{15}N of soils in ecosystems which were visited during seasonal migration patterns. The ^{13}C in newly formed horn annuli decreased with animal age, partly due to the Suess effect. Interannual variation in horn-^{13}C may have resulted from interannual variation in rainfall/drought incidence. River water from Ladakh agreed closely with the global meteoric water line, while samples from Yushu presented evidence of evaporation effects, perhaps related to snow melt in upstream regions. A full account of all analyses will be presented in the paper. Overall, the data demonstrate that horn and hair isotope data can help us to reconstruct their behavioral ecology and environment of yak.

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