NUTRITION AND DEMOGRAPHY

Nutritional Paradoxes in Wild Sheep, Goats, and Other Northern Ungulates

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ABSTRACT: Nutritional paradoxes, in which a conclusion about nutritional ecology seems absurd or self-contradictory but upon deeper investigation is well supported, abound for northern ungulates. The presence of nutritional paradoxes challenges management and conservation efforts to understand their complexities and nuances. To disentangle their intricacies, we evaluate nutritional paradoxes through the lens of behavioral, physiological, and life-history adaptations in northern ungulates. We scoured decades of work on nutrition and foraging ecology of northern ungulates and identified several paradoxical questions including: 1) How do ungulates obtain fats, which are essential for all animals, from plant-based diets that have essentially no fat? 2) How do ungulates achieve adequate energy and protein intake when peaks in energy and protein in forage are phenologically mismatched? 3) How do ungulates balance the cost of mineral acquisition with the cost of acquiring adequate macronutrients (e.g., carbohydrates, fats, protein)? 4) How do ungulates meet energy and protein requirements when dietary concentrations are below requirements? 5) How do individuals persist when nutrition is limiting (e.g., to meet requirements for production, growth, and survival during periods of starvation)? 6) How do populations persist when nutrition is limiting? We illustrate each of these paradoxical questions with empirical or modeled examples in wild sheep, goats, and other northern ungulates to demonstrate that the self-contradictory nature of the nutritional paradox is "solved" by the individual through behavioral and physiological adaptations, often resulting in life-history effects, which resolve the contradiction. Understanding how northern ungulates "make a living" despite these paradoxes has been a challenge for biologists because they contradict some assumed and adopted biological "laws" and hypotheses.

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