Where to Forage When Afraid: Does Risk-Averse Behavior Compromise Use of the Foodscape?

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Heterogeneity in availability and quality of forage on the landscape constitute the foodscape within which animals make behavioral decisions in acquisition of food resources. Novel changes to the foodscape, such as human disturbance, can alter behavioral decisions by prompting behaviors that favor risk-aversion over food acquisition. Although behavioral alterations and population declines often coincide with the introduction of human disturbance, the mechanistic link between behavior and population trajectory are largely undocumented. We aimed to elucidate the pathway by which human disturbance effects ungulate populations by testing the Behaviorally Mediated Forage-Loss Hypothesis, wherein risk-averse behavior is expected to compromise use of the foodscape. We used GPS collar data and behavioral observations of migratory mule deer (Odocoileus hemionus) in three populations exposed to a gradient in energy development (Fig. 1) to evaluate habitat selection, movement patterns, and foraging in response to varying levels of forage availability and human disturbance. Subsequently, we linked animal behavior with measured use of forage relative to human disturbance, and forage availability and quality. Mule deer exhibited behaviors of risk-aversion in response to human disturbance across multiple behavioral scales. Deer avoided habitat near, selected for movements away from, and increased vigilance near human disturbance—all behaviors consistent with risk-aversion. Although use of winter food (i.e., sagebrush) increased as production of new annual growth of sagebrush increased, use of available food decreased with proximity to disturbance. Consequently, behavioral avoidance prompted loss of otherwise available forage that was 4.6-times greater than forage lost to direct habitat loss from infrastructure development (Fig. 2); thus, further reducing the capacity of the foodscape to support mule deer populations. Our findings unveil the mechanisms by which human disturbance can affect populations of large herbivores and provide a missing link between altered behavior and population declines coincident with the introduction of human disturbance.
**Figure 1.** Study area including three discrete winter ranges for mule deer in western Wyoming, USA (Sublette, North Wyoming Range, and South Wyoming Range), 2013–2015.

**Figure 7.** Predicted use of forage across winter ranges (A: Sublette, B: North Wyoming Range, and C: South Wyoming Range) in western Wyoming, USA, 2013–2015, resulting from the negative binomial GLM with value of weighted distance to disturbance set to the maximum value (“Use of Forage without Disturbance”) and with the actual values of the weighted distance to disturbance (“Use of Forage with Disturbance”).