Reply to "Comments on 'Spatial Utilization and Microhabitat Selection of the Snow Leopard (*Panthera uncia*) under Different Livestock Grazing Intensities'"

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ABSTRACT: We thank Luxom and Sharma for their attention to and comments on our study. In recent years, livestock have been expanding into snow leopard habitat, and we conducted this study to examine the effects of that encroachment on snow leopard habitat within Wolong Nature Reserve. Specific responses to Luxom and Sharma's comments include the following: 1) Many habitat factors influence carnivore–habitat relationships at varying spatial scales, and it is difficult for any single study to address the full suite of factors acting across all scales of selection. Given this fact and the limited spatial scale of our snow leopard sign survey, we mainly focused on snow leopard space use and microhabitat selection. 2) Our results are not necessarily conflicting, but more research is required to further explain how high sign densities, concentrated space use, and weak habitat selection behaviors might relate to each other. 3) We agree that examining a gradient of grazing intensities would be preferable, but because of the difficulty in collecting sufficient field data and the nature of livestock grazing patterns in our study area, we think that dividing our survey area into high- and low-grazing-disturbance areas was appropriate. 4) The original intent of this study was to examine habitat factors and response to livestock within our study area in Wolong Nature Reserve, and we did not intend for our specific results to be used for management recommendations beyond Wolong but instead encourage similar studies to be conducted in other areas.

KEYWORDS: Ecology; Asia; Animal studies

1. Reply

The question that we wanted to address in our study was to determine whether livestock had an impact on snow leopard distribution and microhabitat selection characteristics in an applied case study. We had no desire to determine whether the effect was positive or negative, a priori. That said, we did put forth suggestions based on the results of the study. While we argue our results are meaningful, this study alone cannot be used to fully explain the relationship between livestock and snow leopards, a hot research topic requiring more research. We will reply to the comments made by Luxom and Sharma (2022) in order and as follows.

a. Reply to "Scale of consideration for studying habitat use"

Johnson's proposal in 1980 to divide the spatial scale of analysis into four classes is meaningful for wildlife research. However, the relevance of this classification system depends on the habitat factors that are examined, and the available habitat use data. To our first point, climatic factors may be of more relevance at the scale of a species' range selection whereas availability of specific food resources may be of more relevance for selection of habitat within an individual's home range. For the scale of available habitat use data, we conducted field surveys on foot to geolocate snow leopard sign in two areas that were both within a total snow leopard home range area (207 km^2 for males and 124 km^2 for females; Li et al. 2020) in size. Obviously, these data do not lend themselves to either first-order or second-order scales of habitat selection analysis. Therefore, we focused our analysis of habitat factors and scale of selection to what we defined as "microhabitat selection," which most closely matches the third and fourth orders of selection as defined by Johnson (1980). Because we did not have access to any GPS collar or other individual-level space use data for snow leopards in our study area, it does not make sense to attempt to differentiate our analysis between third and fourth orders, and we argue that "microhabitat" selection is a reasonable term in our case. Indeed, given that the area of available habitat to snow leopards in Wolong Nature Reserve has been estimated at only about 345 km^2 (Qiao et al. 2017), analyses of habitat use within Wolong are necessarily conducted at a relatively small scale of selection. We also argue that this smaller scale is not a limitation of the study but in fact highlights the importance of considering habitat factors and predator responses at more than just large spatial scales. We do agree with Luxom and

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Sharma that these larger scales are important, and that future research on snow leopards should consider multiple scales simultaneously, perhaps in a hierarchical framework (Zeller et al. 2017). In conclusion, we could not consider large scales of selection given our habitat use data and instead focused on spatial sign distribution and microhabitat selection under different densities of livestock grazing, but we agree that future research should consider snow leopard responses at multiple scales and including larger scales.

b. Reply to "Inconsistent conclusions are drawn from sign density data"

We do not think that there is a contradiction between the conclusion that snow leopard sign densities were higher in high-grazing-disturbance areas (HGDAs) and that snow leopards were more concentrated in HGDAs (Hong et al. 2021). It is important to note here that snow leopard sign density should not be mistaken for snow leopard population density. We had no way of identifying individuals, and as such, our data could not be reliably used to make inferences about population density. We made no conclusions about snow leopard population density—only that their space use appeared to be more concentrated in HGDAs. To Luxom and Sharma's point that the sign concentration results contradict the habitat selection results, although we might expect a greater selection signal to emerge from more spatially concentrated presence data because of spatial autocorrelation of the environmental data, this is not a forgone conclusion. We think that we did an adequate job of distancing sampling transects and control plots in a systematic manner to reduce potential spatial biases. The results of our resource selection functions depend on the habitat values within the plots that contain snow leopard sign versus those that do not, and the fact that snow leopard sign was more spatially concentrated in the HGDAs does not mean that the habitat data must also be more different than in the associated control plots in comparison with the sign-versus-control plots in low-grazing-disturbance areas (LGDAs).

There are a few reasons that we theorized might be driving our results, which we think remain reasonable theories. Perhaps livestock has indeed become one of the main food sources for snow leopards (Lu et al. 2019; Hong and Zhang 2021), which would concentrate snow leopard activity around livestock. Coupled with as the fact that snow leopards are likely actively avoiding areas of direct human activities associated with livestock herding/grazing, this would result in even more limited space and further concentration of space use. If snow leopards are not preying on livestock and instead targeting their normal prey sources, they may still face space use concentration because of the restriction in blue sheep distribution as a result of competition with livestock. Both these situations would result from higher livestock populations, which tracks with our results that the distribution of snow leopards was more concentrated in HGDAs. We agree that further study, likely incorporating other important habitat factors like food resources and interspecific competition, is needed to establish a better understanding of the reasons behind increased sign concentration and how it might result in less habitat selectivity.

c. Reply to "Absence of appropriate proxy for the impact of livestock grazing"

Livestock not only have direct effects on snow leopards, such as serving as a food source and possibly resulting in retaliatory killing, but also indirect effects, such as their alteration of ecosystem vegetation and thus habitat for wild species. Our research focused on the indirect effects of livestock on snow leopards through the alteration of vegetative habitat, so we selected for habitat factors such as shrubs and herbs in this study. In addition, based on the results of our survey, the density of livestock signs in the two survey areas differed substantially. We believe that using this result to set up high and low grazing disturbance areas for comparative studies was appropriate for our study goal of determining whether there is an influence of livestock on snow leopard distribution and microhabitat selection. We think that examining the effects of livestock grazing intensities along a continuous gradient, as recommended by Luxom and Sharma, is a good suggestion, but we did not have enough detailed field data to effectively do so. We hope to implement this approach in future studies.

In our paper, we conclude that there is an effect of livestock on snow leopard distribution (a concentration in space) and microhabitat selection (less selectivity of habitat factors). As to whether this effect is positive or negative at the population level, we agree that we cannot give a clear conclusion because of the limited scale of our analysis.

2. Conclusions

We thank Luxom and Sharma for providing feedback and suggestions on our research. Our current study could not be assigned to a specific spatial scale/order because of the scope of our data and habitat factors analyzed. We were mainly concerned with snow leopards' spatial utilization and microhabitat selection under different livestock grazing disturbance intensities, and we think that our data and results support the conclusions we made. The density of livestock signs differed significantly between the two survey areas we selected, and we think it was appropriate to classify them as areas of high and low livestock grazing in the context of our research questions of interest. We also argue that our results do not contradict each other but agree that more research is required to examine the potential mechanisms and relationships between them. We also agree that further habitat factors and more scales of effect should be analyzed to arrive at a greater understanding of livestock grazing effects on snow leopard habitat and populations. Last, we once again thank Luxom, Sharma, and other experts for any comments and suggestions they have had or might have on our research. We will consider them all and attempt to implement important points in our future studies.

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