Indirect effects of environmental policy on predator behavior and local economy on the Tibetan plateau

Key Words: feeding behavior, hidden Markov model, human-wildlife conflict, movement, stochastic dynamic programming, Tibetan brown bear, Tibetan plateau, *Ursus arctos pruinosis*

Introduction: Indirect effects of species loss are well documented within biological communities, but have rarely been extended to examine human-wildlife interactions. An integrative understanding of cascading effects on coupled socioecological systems is needed to explore complexities and feedbacks between ecology, policy, and local peoples. My proposed study will contribute to this theoretical framework by examining the impacts of environmental policy on the ecology of a Tibetan predator and the resulting consequences to local communities.

In the high grasslands of the Tibetan plateau, government programs to exterminate the plateau pika (*Ochotona curzoniae*) are being conducted under the assumption that pikas compete with livestock, diminishing rangeland productivity [1]. This lagomorph is a keystone prey species on the Tibetan plateau for mammalian and avian predators [1] and therefore plays an integral role in maintaining healthy ecosystem dynamics. Between 2007 and 2009 alone, the Chinese government poisoned pikas across approximately 320,000 km^2 of the plateau [2]. While studies are underway to determine the effects of pika extirpation on livestock and grassland dynamics [3], an in-depth study examining the loss of this key prey item on carnivores is lacking. The Tibetan brown bear (*Ursus arctos pruinosis*), an endangered subspecies, relies on pikas as a food source and may be especially vulnerable to their decline. Pikas have been found in up to 78% of bear scats [4] and comprise as much as 60% of their diet [5]. In other regions, studies show that carnivores increase home range size, daily straight-line movements, and hunting efforts when faced with a sudden decline in their primary prey resource [6]. Preliminary studies indicate that brown bears are less abundant in areas where pikas are poisoned [7]; however, more empirical evidence is needed to understand the mechanisms underlying these apparent changes in local abundance by investigating spatial and behavioral responses of bears to pika extirpations.

The intent of government pika extirpation programs to increase livestock productivity may have paradoxically resulted in unforeseen negative impacts on pastoralists. Bears that are nutritionally stressed from the loss of a primary food source are potentially more likely to target human food stores. While human-bear conflicts have increased concurrently with large-scale pika extermination [8], no study has explicitly examined the relationship between poisoning and bear raids. Recent human-bear conflicts in Tibetan communities have resulted in destruction of property and loss of food supplies, often costing families more than their annual income [8]. The federal government prohibits shooting bears, preventing pastoralists from protecting their supplies. Other preventative measures have so far been too costly to implement effectively [8].

Hypotheses: This study will examine how the extirpation of a keystone prey species influences bear behavior and may indirectly affect pastoralist communities. I will test the following hypotheses on the impacts of regional pika poisoning:

- **H1**: Energy demands for bears will lead to the use of larger home ranges, more linear movement, and increased time spent traveling;
- **H2**: Bears will supplement their diet with a greater diversity of food resources, including increased consumption of vegetation and human food stores; and
- **H3**: Economic trade-offs between increased livestock productivity and damage caused by nuisance bears will result in a higher cost-benefit ratio to local pastoralists.

Research Plan: The study area will be the alpine grasslands of Qinghai Province, People's Republic of China. I will monitor the Qinghai bear population for three years. Monitoring efforts will be concentrated in regions where pikas have been extirpated as well as regions that have not been poisoned to develop baseline home range, movement, and behavioral models. I will select study areas with similar environmental conditions beyond pika extirpation to minimize natural variation in bear movements and feeding behavior. I will live-trap bears with leg snares [9] to fit them with Argos GPS collars, collect hair samples for stable isotope analysis (SIA) [10], and measure internal state via bioelectrical impedance analysis (BIA) [11]. I will collect fecal samples along transects in each study area. I will use cluster data from the GPS collars to locate pika colonies frequented by bears and calculate functional pika density. Tibetan brown bears are a second-class key protected species in China [6], so I will obtain permission to trap these animals from the Qinghai Ministry of Forestry. In order to ensure the success of these methods, I will be collaborating with local Tibetan brown bear experts Dr. Dajun Wang (Peking University) and Dr. Li Sheng (Smithsonian Conservation Biology Institute), as well as Dr. Marc Foggin, founder of Plateau Perspectives (an environmental NGO in Qinghai province).

To test **H1**, I will perform a movement analysis incorporating directionality, straight-line distances, and home ranges with respect to discrete feeding patches of pika colonies and human food stores. I will construct a hidden Markov model (HMM) to detect behavioral states of bears given reduced feeding patch density. HHMs link behavioral and habitat data to uncover hidden processes underlying movement patterns and predict responses to environmental change [12]. Behavioral states will be classified as feeding, resting, or traveling.

To test **H2**, I will compare dietary diversity and composition between the study populations from SIA and scat samples. Stochastic dynamic programming (SDP) will be used to model feeding decisions and the likelihood of a raid given internal state, availability of resources, and human population density. SDP allows for the prediction of optimal foraging behavior under specified bioenergetic and environmental constraints [13].

To test **H3**, I will record all human-bear conflicts, associated economic losses, and changes in livestock productivity in pastoralist communities from interviews [8], as well as the status of nearby pika colonies. I will construct a cost-benefit analysis to test if pika extirpation results in net economic gains or losses to local pastoralist communities.

Intellectual Merit: This interdisciplinary research will expand our understanding of coupled human-wildlife systems as they relate to ecological function, policy, and local economy. My study will also contribute to ecological theory by analyzing and predicting impacts of local keystone prey species loss on spatial ecology and resource selection in predators.

Broader Impacts: I will work with Plateau Perspectives to train Tibetan field assistants and organize a regional workshop to discuss opportunities for co-management of human-wildlife conflicts. I will inform policy on bear and pika management by presenting my results to the Qinghai Environmental Protection Bureau. To reach the scientific community, I will make my results available to the IUCN Bear Specialist Group, present my research at professional meetings, and publish my findings in peer-reviewed scientific journals. I will share my experiences with students by speaking at California middle and high schools about how animals respond to environmental disturbance and on interdisciplinary methods of conservation biology.

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