The mechanistic pathways of trophic interactions in human-occupied landscapes

Field studies reveal more complicated relationships between African wild dogs, their prey, and the plants eaten by the prey than predicted by theory

By Adam T. Ford

From children’s stories to the logos of professional sports teams, images on commercial products, and the icons of conservation, few organisms capture our imagination like large carnivores. From a scientific perspective, understanding the context in which predators shape ecosystem processes is one of the most pressing endeavors in modern ecology (1). In central Kenya, large carnivores—such as leopards and globally endangered African wild dogs—prey upon antelope, which themselves limit the abundance of plants. These wildlife species vie with commercial ranchers, as well as traditional pastoralists and their livestock for limited resources (2). Together, these actors interact against a backdrop of pronounced environmental variation and the unique patchwork of trees on grassland that characterizes tropic savannas. Through my dissertation research, I combined long-term monitoring of wildlife populations, high-resolution satellite imagery, fine-scale tracking of animal movements, and a series of field experiments to quantify these interactions and their consequences for ecosystem structure.

Specifically, I discovered that impala—an abundant, deer-sized antelope—are caught between “the devil and the deep blue sea”: they must avoid the claws and teeth of their predators and the thorny and chemical defenses of their food (3, 4). Global Positioning System (GPS) tracking reveals that impala avoid areas characterized by dense tree cover (see the figure). In such areas, leopards and wild dogs more effectively attack and kill their prey, which makes tree cover “risky” when viewed through the eyes of an impala (3). However, trees are also an important food source for impala, and feeding trials showed that impala prefer trees with fewer thorns, even if these less-thorny trees are better defended with noxious chemicals (3). This combination of habitat and food preferences means that impala deplete the abundance of their preferred (and less thorny) forage in safe habitats, yet forgo access to this preferred forage in risky habitats. Consequently, an impala’s fear of being eaten increases the prevalence of thorny trees in safe areas, and safeguards less-thorny trees in risky areas.

There are three critical implications of this study (3). First, and from the perspective of a plant, there are two pathways to success—either defend yourself from herbivores by growing large thorns or thrive in areas that are risky to your enemies. Second, fear of predation and diet preference interact to shape the spatial patterning of tree species across entire landscapes (about 200 km²). Third, because the open areas in which impala aggregate for safety arise from old (>10-year) cattle corrals, traditional pastoralism plays a key role in shaping the interactions among carnivores, their prey, and plants. The implications of this last point are profound, because it demonstrates that people are inextricably embedded within this food web. Indeed, the preferred plants that impala relinquish in risky areas could be used for livestock forage, a critical ecosystem service that may help mitigate the impact of episodic droughts that plague East Africa.

Whereas fear of predation can powerfully shape ecosystems and animal behavior (3, 5), so too can the direct consumption of prey. After a 20-year absence, African wild dogs naturally recolonized areas of central Kenya and now prey upon the region’s most abundant antelope, the dik-dik. Theory predicts that this strong, top-down pressure in the food chain should trigger a trophic cascade; in other words, after wild dog recovery, herbivory by dik-dik will relent and plant abundance will increase. To test this prediction, I linked the movement and diet composition of wild dog packs with changes in the size of the dik-dik population over a 14-year period. I then identified which plants are vulnerable to browsing by dik-dik. Finally, I quantified herbivory by means of a series of replicated and controlled dik-dik enclosures, separately established before and after wild dog recovery.

There were strong, top-down effects in this food chain, but no evidence that wild dog recovery caused a trophic cascade. The population of dik-dik declined by 33% because of predation by wild dogs, and dik-dik reduced the abundance of some tree species by up to 84% (6). However, the effect of herbivory did not diminish in the presence of wild dogs (6). This finding was surprising because overall plant growth (both inside and outside dik-dik enclosures) was greater following wild dog recovery. Had experiments not been used, as often is

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Adam T. Ford

Adam T. Ford is a wildlife ecologist interested in how predator-prey interactions are shaped by human-modified landscapes. He received a B.Sc. from the University of Victoria (British Columbia), a M.Sc. from Carleton University (Ontario), and his Ph.D. from the University of British Columbia with Assistant Professor Jacob Goheen. Ford is currently a Liber Ero Postdoctoral Fellow in Conservation Science, based at the Department of Integrative Biology at the University of Guelph (Ontario). The research described in this essay sheds new light on the relationships of people, large carnivores, their herbivore prey, and plants in an East African savanna.
How trophic cascades emerge. Some key interactions between people, large carnivores, antelope, and plants in an African savanna landscape. The creation and abandonment of (A) cattle corrals creates openings in (B) woody cover. Areas of high woody cover are used by predators, like (C) African wild dogs, for hunting, which coincides with (D) the distribution of predation risk [shown here as the per-capita risk of mortality] across the landscape. As a result, prey, like (E) the impala, avoid areas of high woody cover and find safety in the open areas created by abandoned cattle corrals. The GPS-recorded movements of (F) an adult female impala, are shown by the black dots in panels (B) and (D). This animal was tracked every 20 min over the course of a year. Impala prefer and suppress the abundance of less-thorny acacia plants, like (G) Acacia brevispica, compared with thorny species like (H) Acacia etbaica. As result of impala’s risk-avoidance behavior and diet preference, (G) the proportion of stems in the tree community containing the less-thorny species is highest in the risky areas that impala avoid (see black dots tracking impala movement); whereas (I) thorny plants are more abundant in the open areas where impala aggregate (as shown by the black dots in GPS). Details of this study are described in (J).
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