

## Letter

# The role of humans in dynamic landscapes of fear

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Lethal and nonlethal human activities can have an important role in inducing dynamic landscapes of fear by instilling fear in wild animals, as underscored by Moleón and Sánchez-Zapata [1]. We believe that the dynamic landscape of fear [2] offers a useful framework for exploring the many pathways through which anthropogenic change can alter risk perception and response, with consequences for ecosystems and populations [3]. Humans exert both top-down and bottom-up pressures on biological systems, often having outsized impact on ecological processes by acting as predators, niche constructors, and ecosystem engineers [3]. Collectively, these roles alter the densities and behaviors of predators and prey, reshaping the playing field of predator-prey interactions, and altering dynamic landscapes of fear.

As Moleón and Sánchez-Zapata note [1], humans often act as predators in many ecosystems, even when our activities are neither consumptive nor even lethal [4]. Humans, similar to other predators, are influenced by many of the same natural cycles outlined in our review [2]. Rhythms of light, temperature, visibility, and other cycles influence daily activity, vacation periods, hunting seasons, and other spatiotemporal patterns of human behavior [5]; these cycles of human activity further drive well-documented changes in animal behavior [6]. Thus, humans can be situated within a dynamic

landscape of fear framework: we generate spatiotemporal patterns of perceived predation risk and constraints on prey response that vary in their degrees of predictability (see our Table 1 in [2] for examples).

However, we find it interesting to consider ways in which anthropogenic risk may qualitatively depart from expectations of a framework conceived primarily with respect to wild apex predators. Human behaviors are modulated by social norms, cultural processes, and technology [3] in ways that can decouple them from natural cycles. Phenomena, such as the ‘weekend effect’ highlighted by Moleón and Sánchez-Zapata [1], can predictably increase traffic intensity, ambient noise levels, hunting, tourism, and other leisure activities [7,8] on weekends compared with weekdays. This variation in human activity can cause animals to reduce their activity in and/or avoid areas where humans congregate during these periods (e.g., [7]). However, few studies have explored how the weekend effect and other ‘unnatural’ (but still periodic and, thus, potentially predictable) patterns of human-induced risk impact patterns of perceived risk.

Anthropogenic landscapes of fear may also differ with respect to certain uniquely human risk cues. Even predictable spatial and temporal patterns of anthropogenic risk can be difficult for wildlife to anticipate based on the unreliability of anthropogenic stimuli; for example, a human voice may be associated with risk or with safety depending on the type of human activity [4]. Spatiotemporal dissociation between threat and risk cues (e.g., hunting with firearms or traps) likewise distinguishes human from most nonhuman predation. Such nuances in anthropogenic landscapes of fear can amplify lethal and nonlethal human impacts on prey population dynamics by creating mismatch between risk and response [4].

In addition, humans have the capacity to substantially reshape dynamic landscapes of fear by changing both the players of predator-prey interactions and the arena in which they occur. Humans frequently introduce invasive species (e.g., novel predators or alternative prey) or remove or reintroduce natural predators [8]. The well-documented fear shown by wild apex predators of humans may cascade through communities by creating ‘human shields’ in which prey find refuge from predation near humans. Anthropogenic landscape modification can affect the relative hunting success of predators, and the vulnerability and perceptive capacities of prey in different places and times [9]. Pollution, such as artificial lighting, can shift diel cycles of risk from both wild predators and humans [10]. Humans can also regulate patterns of prey vulnerability by predictably altering forage availability and habitat structure via land-use change, including agricultural practices [11]. Climate warming is affecting animal behavior and reshaping temporal cues and phenology in ways that will further alter the ways in which prey perceive and respond to risk [12].

We highlight the importance of considering the extent to which human behavior is predictably regulated by natural processes and, thus, generates dynamic landscapes of fear akin to those created by predators. However, given that humans are unique in our inducement of perceived risk and our patterns of predation [4] and fill a wide range of top-down and bottom-up ecological roles [3], it is also interesting to consider how anthropogenic change may add complexity to dynamic landscapes of fear more broadly. By understanding the ways in which humans alter patterns of risk, prey perceptions, and behavioral responses, we can better manage landscapes, animal populations, and human activities to achieve desired outcomes for people and biodiversity.

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