



Original Research Paper/Review Paper

Influence of Anthropogenic Disturbances on Wildlife Behavior, Reproductive Success, and Population Persistence

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Key Words	Abstract
Anthropogenic disturbance, Wildlife behavior, Reproductive success, Population persistence, Human-wildlife interactions, Habitat disturbance, Animal movement ecology, Conservation biology, Species adaptation, Biodiversity threats.	Human activities now pervade virtually all wilderness areas, and a wealth of evidence demonstrates that non-lethal disturbances, including recreation, roads, noise, and infrastructure development, can have significant impacts on animal behavior, negatively affect reproductive success, and potentially jeopardize the long-term persistence of populations. This review collates global meta-analyses and empirical studies of animal behavior in order to describe the nature of animal responses to humans, potential fitness costs of these responses, and demographic outcomes associated with the costs. Behavioral responses to human disturbance include alteration of patterns of movement, sizes of home ranges, and time of day when activities take place, and more than two-thirds of movement responses are larger than 20%. Nocturnality is increasingly selected in mammal species exposed to human disturbance, and the mean selection ratio is 1.36 in 62 mammal species across six continents. Responses to human presence are costly in terms of fitness, because disturbed large ungulates experience higher levels of predation due to disturbed habitat use; bird species and other taxa show very diverse responses to different types of disturbances at different times and with different life histories.

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Introduction

While human infrastructure expansion, recreation, and resource extraction continue to encroach on what remains of wildlife habitats, wildlife populations will experience more and more behavioral disturbances, short of habitat destruction or lethality, that alter the ways in which animals allocate energy, behave, and reproduce. In contrast to habitat destruction that eliminates resources, behavioral disturbance occurs indirectly via mechanisms where animals view humans as predators and react accordingly by showing vigilance, avoiding contact with humans, modifying their movements, or changing their activity times, all of which incur energetic or opportunity costs. Whether or not these behavioral changes result in reduced reproductive success and survival is a fundamental but largely unanswered question in the field of behavioral and conservation ecology. In this paper, we review current global meta-analyses and case studies of the mechanisms linking human disturbance to wildlife behavior and population dynamics.

Behavioral Responses to Human Disturbance

Movement and Space Use

According to a worldwide meta-analysis, which reviewed 208 studies of 167 species in both terrestrial and aquatic environments, human disturbance causes changes in animals' movement throughout the world, with more than 66 % of 719 examples of the effect showing that a shift in movement by 20 % or more occurred,

an increase of movements being on average 70 %, and a decrease - 37 % (Doherty et al., 2021). The interesting observation made by scientists was that human disturbances caused not only by habitat modifications, like logging and agriculture, but also caused by direct human activities such as recreation and hunting, were more potent (Doherty et al., 2021).

Temporal Activity Shifts

Other than the spatial responses, the wildlife species also make behavioral changes based on when they are active in order to minimize the chances of running into humans. A meta-analysis carried out on 76 papers involving 62 mammalian species on six continents established that there was an increase in nocturnal behavior by an average multiple of 1.36 times in relation to the presence of humans; this behavior was consistent across continents, habitat type, taxa, and disturbances, including hunting, recreation, and construction (Gaynor et al., 2018). Though increasing activity at night will lower the chance of meeting people, there will be some repercussions on food acquisition and thermoregulation due to the unnatural change in activity pattern.

Sources of Variability in Behavioral Response

In spite of the presence of the aforementioned consistent large-scale patterns, however, the extent of the reaction to human disturbance, as well as the direction in which the reaction moves, differs greatly from study to study. A study of the determinants of this variation found that the reactions of wildlife to human disturbance are

determined by a complicated array of interactions, involving aspects like the nature of the disturbance, its predictability, time of occurrence relative to vulnerable points of the lifecycle like reproduction, and individual characteristics of the species, such as body mass and previous exposure to disturbance (Tablado & Jenni, 2017).

Social Behavior at the Spatial-Social Interface

In addition to movement and timing, human disturbance changes the social aspects of animal behavior. According to a literature review on the spatial-social interface in animals, the risk posed by human disturbances affects the interactions of group-living animals in terms of their decision to balance social behavior and vigilance behavior, which are linked to each other and can affect each other in a way that is not easily detectable when analyzed independently (Gaynor et al., 2024). According to the same review on the spatial-social interface, while sometimes the effects of human disturbances can be buffered through the spatial-social interface, in other cases these disturbances are magnified through it, thus posing new conservation challenges which cannot be understood by analyzing the impacts on the movement and activity pattern of animals (Gaynor et al., 2024).

Consequences for Reproductive Success and Individual Fitness

While the relationship between behavioral responses to disturbances and associated fitness costs has typically been poorly understood relative to behavioral responses, recently

reported case studies now provide strong evidence for this connection. In one study, using a long-term GPS telemetry monitoring of woodland caribou living in forests in Quebec, Canada, it was observed that individuals residing in ranges with a history of recent anthropogenic disturbances related to deforestation and road construction exhibited a higher risk of predator-related mortality, and those caribou that died because of predator attack were characterized by having a more disturbed habitat prior to their death than those surviving (Leblond et al., 2013). Such observation provides support for the idea of disturbance being similar to predation in the way of affecting habitat choice of organisms and unintentionally exposing them to predators (Leblond et al., 2013). Reproduction in the same study proved to be more ambiguous, with no effect of the composition of the home range on the reproductive rate of females (Leblond et al., 2013).

Implications for Population Persistence

In relation to the population as a whole, however, the negative consequences of human disturbance in terms of behavior and fitness may occur via multiple compounding mechanisms. When disturbance creates increased predation danger, which has been found in caribou, or creates increased energetic demands due to higher rates of movement or nocturnal activities in general, then the end result could be survival and/or reproductive success that falls below the rate required for the maintenance of a population, especially where there are already smaller or fragmented populations involved (Gaynor et al.,

2018; Doherty et al., 2021; Leblond et al., 2013). In addition to this, the context dependence of behavior has been observed in relation to multiple studies, implying that the consequences will differ from one species or habitat to another, and so some disturbed populations will not experience any real harm in terms of their demographics while others, particularly those lacking in behavioral plasticity or already being fewer in number, will be at greater risk of experiencing population decline (Tablado & Jenni, 2017).

Discussion

All of these points contribute to the creation of a conceptual framework where anthropogenic disturbance is a widespread, non-lethal stressor that has the potential to influence the behavior of wildlife around the world and, in well-established instances, to result in fitness and survival costs (Gaynor et al., 2018),3,4]. The universality of the behavioral reactions like higher levels of nocturnality and changes in movement in many dozens of animal species and across all continents suggests that they are common reactions to humans, not individual ones (Gaynor et al., 2018; Doherty et al., 2021). On the other hand, high levels of the contextual nature of the reactions to disturbances warn us against making automatic assumptions about their population-level consequences; the same kind of disturbance can have a big effect on the behavior of one species while having no impact at all on the behavior of another (Tablado & Jenni, 2017). Due to interactions between behavioral pathways, such as spatial and social ones, which can mitigate or exacerbate

consequences of disturbances, estimations that are based on only one pathway, for example, movement or activity, may be either overestimated or underestimated. These differences have important implications for wildlife management practices because it is better to use approaches that are based on the sensitivities of certain species, the life history periods of their sensitivity and the types of human activities involved, as opposed to using disturbance threshold approaches across the board. The caribou example also shows cases where the impacts of disturbance are expected to be particularly relevant to the survival of the species and thus deserve more focused management attention (Leblond et al., 2013).

Conclusion

Anthropogenic disturbances have been shown to significantly impact wildlife behavior, consistently leading to an increase in nocturnality and modifications in movement patterns even in the absence of habitat destruction. The fitness consequences of such responses are known in at least some systems in which they have been investigated, with increased risks of predation in large herbivores inhabiting disturbed environments being one such example, although the degree of this effect varies from system to system. Due to the potential for behavioral modifications to occur prior to population declines, conservation efforts must recognize that non-lethal anthropogenic disturbance is itself a threat to population viability.

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