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Review

Acoustic environments matter: Synergistic benefits to humans and ecological communities

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ABSTRACT

Protected areas are critical locations worldwide for biodiversity preservation and offer important opportunities for increasingly urbanized humans to experience nature. However, biodiversity preservation and visitor access are often at odds and creative solutions are needed to safeguard protected area natural resources in the face of high visitor use. Managing human impacts to natural soundscapes could serve as a powerful tool for resolving these conflicting objectives. Here, we review emerging research that demonstrates that the acoustic environment is critical to wildlife and that sounds shape the quality of nature-based experiences for humans. Human-made noise is known to affect animal behavior, distributions and reproductive success, and the organization of ecological communities. Additionally, new research suggests that interactions with nature, including natural sounds, confer benefits to human welfare termed psychological ecosystem services. In areas influenced by noise, elevated human-made noise not only limits the variety and abundance of organisms accessible to outdoor recreationists, but also impairs their capacity to perceive the wildlife that remains. Thus soundscape changes can degrade, and potentially limit the benefits derived from experiences with nature via indirect and direct mechanisms. We discuss the effects of noise on wildlife and visitors through the concept of listening area and demonstrate how the perceptual worlds of both birds and humans are reduced by noise. Finally, we discuss how management of soundscapes in protected areas may be an innovative solution to safeguarding both and recommend several key questions and research directions to stimulate new research.

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1. Introduction

The total area of protected lands worldwide has more than doubled in the last three decades and designated terrestrial protected areas now cover 18.4 million km^2 or 12.5% of the earth's land surface (Watson et al., 2014). The world's protected areas receive approximately 8 billion visits by people per year, 3.3 billion of which are in North America alone (Balmford et al., 2015). In the United States, the National Park Service (NPS) manages a little more than 10% of all protected areas and NPS's keystone parks present the most salient examples of tensions between protecting wildlife and providing for visitor enjoyment (Borrie et al., 2002). The Organic Act of 1916 (PL 39 Stat. 535) gives the NPS its mission, ' … *which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations'.* Protected areas are caught in a "park paradox" that reflects the negative covariance between visitor use and biodiversity (Runte, 1977).

Higher levels of visitor use and associated access are likely to lead to greater habitat degradation (Fahrig and Rytwinski, 2009) and it is clear that visitor transportation corridors in protected areas impose significant ecological costs (Benítez-López et al., 2010). Roadways are a dominant human footprint on earth and are rapidly expanding. Over 25 million kilometers of new roads are anticipated by 2050, a value 60% greater than the estimated 'roadprint' in 2010 (Laurance et al., 2014). Protected areas are not immune from new roads (Theobald et al., 2010; Theobald, 2010). Furthermore, use of protected areas is likely to continue, thus increasing associated impacts to the social and ecological conditions (Manning et al., 2014).

Noise from roadways and other sources is an important mediator of ecological costs (Fahrig and Rytwinski, 2009; Francis and Barber, 2013). In fact, recent evidence shows that broadcasting traffic noise in otherwise quiet habitats can experimentally induce many of the ecological effects of roads on wildlife and degrade habitat quality (McClure et al., 2013, 2016; Ware et al., 2015). Anthropogenic noise from other sources (e.g., energy sector noise - Bayne et al., 2008; Francis et al., 2009; talking visitors — Pilcher et al., 2009; Karp and Guevara, 2011; sonar and other sounds from military activities, Hatch and Fristrup, 2009) is an increasingly recognized cost of human activities; a cost imposed on both visitors (Newman et al., 2010b) and biodiversity in protected areas (Hatch and Fristrup, 2009). The potential for its influence is so great that the NPS created a new program — the Division of Natural Sounds and Night Skies — devoted to conserving the sounds of nature (Newman et al., 2013). These acoustic resources are monitored, managed and protected by mandate (Newman et al., 2013). Despite protection, NPS monitoring and modeling has shown that noise is a pervasive issue across the system (Buxton et al., 2017), yet it remains unclear how noise management integrates with or contributes to efforts to conserve critical habitats. Perhaps most importantly for conservation, it is unknown to what degree biological and ecological responses to altered acoustic conditions feedback on human experiences, and thus conservation ethic and action among citizens who visit and ultimately support the parks.

In this paper, we review literature across several disciplines that, collectively, point to the conclusion that management of acoustic resources both within and outside of protected areas is essential and that natural acoustic conditions should be thought of as a vital "ecosystem service." Additionally, thorough understanding of acoustic resources through coupled human-nature relationships will enlighten management of protected area acoustic environments. We begin by reviewing the concept of a soundscape and explain how and why natural sounds are both ecologically critical and key to human experiences in natural settings. We then provide an overview of the relevance of rising anthropogenic noise levels by describing its global reach and introduce the concept of listening area and its relevance to the effects of noise on human wellbeing and ecological systems. Finally, we conclude with a conceptual framework explaining how soundscape modification via human activities should be considered alongside other well-recognized threats to biodiversity and human wellbeing, such as climate change and chemical pollution and emphasize how soundscapes are a key element that couples human experience and ecological systems through psychological ecosystem services and individual and collective human behavior relevant to conservation.

2. Soundscapes and the role of natural sounds

Soundscapes have been defined two ways. We prefer soundscape as a perceptual construct, following the Soundscape Working Group of the International Standards Organization and recent NPS policy: the acoustic environment as perceived by a receiver (i.e., a listener), and usually a person (ISO 12913-1:2014). Previous NPS policy and Farina (2014) define soundscape as encompassing all physical acoustic phenomena. Terminological ambiguity aside, the term soundscape underscores the substantial role that sounds play in linking human and natural systems. Terrestrial soundscapes have always included sounds from wind, moving water and other abiotic sources. Familiar biological sources, such as singing birds and chorusing frogs and insects have characterized terrestrial environments since the Early Eocene, i.e., >50 million years before present (Gill, 2007; Senter, 2008). Since industrialization, however, many landscapes are increasingly characterized by anthropogenic sounds (Barber et al., 2010; Buxton et al., 2017) and copious evidence suggests that these changing soundscapes can profoundly affect human wellbeing and ecological systems.