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Protected areas and noise abatement: A spatial approach

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ABSTRACT

Protected areas have the capacity to provide an array of benefits to humans—ecosystem services. Concerning the acoustic environment, these ecosystem services are provisioned as natural soundscapes and quietness. A substantial body of literature has examined protected areas' performance in preserving soundscapes and management strategies to ensure the continued preservation of natural sounds in park settings. However, protected areas' abilities to abate noise are not understood to such a robust degree, especially concerning how noise abatement occurs at a landscape scale. Few studies have considered green space noise abatement beyond a city-scale. This study utilizes two national datasets previously employed in a study of soundscape preservation to examine what characteristics of protected areas aid in the abatement of noise at the county level. Using spatial regression models, this study represents the first assessment of conservation status, ownership, and level of access as potential determinates of abatement performance. Findings indicate that conservation status has a significant impact on noise abatement. Potential explanations for this finding are discussed, including wilderness amenity migration, habitat fragmentation, and the geographic distribution of protected areas.

1. Protected areas and noise abatement: a spatial approach

Nature provides a variety of ecosystem services that support human wellbeing. Protected natural areas, specifically, provide two fundamental functions with concern to acoustics—noise exclusion and noise abatement—which lead to the ecosystem service of quietness (Wang, Bakker, de Groot, & Wörtche, 2014). These two functions are positively related but provide intrinsically distinct benefits. Noise exclusion provides a mostly internal benefit, whereas natural sounds are preserved within the bounds of protected areas by prohibiting development and other forms of noise emission (Votsi, Kallimanis, & Pantis, 2017). Noise abatement, conversely, provides a mostly external benefit, whereas ambient noise is reduced in the surroundings of protected areas (Chen & Jim, 2008). The notable publication of the Buxton et al. (2017) contribution in *Science* concerning noise pollution in protected areas brought considerable new attention to soundscape conservation within protected areas (see Francis et al., 2017). Using two national datasets of noise propagation and protected area networks, the authors found significant levels of noise pollution permeating protected areas. This permeation, however, suggests that these same protected areas are effectively provisioning their service of noise abatement. By absorbing noise pollution at the levels reported by Buxton et al. (2017), it could be hypothesized that the services provided through noise abatement might also be significant at a national scale.

Given what is known about noise pollutions' broader impacts on human health and wellbeing (see Baliatsas, van Kamp, van Poll, & Yzermans, 2016; Passchier-Vermeer & Passchier, 2000; Votsi, Mazaris, Kallimanis, Drakou, & Pantis, 2014) there is surprisingly sparse research examining how protected areas' noise exclusion and abatement impact the developed—or developable—areas that surround them. In other words, while Buxton et al. (2017) revealed how noise permeates protected areas at a national scale, it is largely unknown how protected areas' presence and absorption of noise impacts the sound levels in their surroundings. Moreover, how the characteristics of protected areas—such as conservation status, ownership, and level of accessibility—impact noise exclusion and abatement has not yet been studied. Without an understanding of how conservation lands affect ambient sound levels, planning efforts to reduce the adverse effects of noise pollution are at a considerable disadvantage. The purpose of this research is therefore to explore how protected areas influence and abate the ambient noise of their surrounding regions, using the same two datasets employed by Buxton et al. (2017). Applying a spatial regression approach, we examine the following research question: do conservation status, ownership, and accessibility of protected areas impact sound levels at a county scale?

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1.1. Soundscape preservation and protected areas

Noise—though often used synonymously with sound—is distinguishable as undesirable, annoying, or extraneous human-caused sound (Marin, Newman, Manning, Vaske, & Stack, 2011; Newport, Shorthouse, & Manning, 2014). Some protected area management agencies, such as the U.S. National Park Service, preserve natural sounds as they would any other natural resource—such as wildlife, water quality, and unique geologic features (Dumyahn & Pijanowski, 2011). The management of these resources, including sounds, is designed to fulfill a dual mandate of providing human and ecological benefits (Newman, Manning, & Treviño, 2010; Sax, 1980). However, most land management agencies do not have formal policy associated with soundscape conservation and anthropogenic noise. The International Union for Conservation of Nature and Natural Resources (IUCN), a global body dedicated to protected area management, does not place soundscapes among the specific determinates of the conservation status of protected areas (Dudley, 2013). Despite the lack of broad formal recognition of soundscape conservation within a protected area, the science supporting protected areas' ability to preserve natural quiet is robust and growing. The majority of this research examines strategies of preserving quiet within protected area boundaries (see Miller, 2008).

1.2. Noise exclusion and protected areas

Because protected areas generally have a goal of reducing human development within their bounds, they tend to harbor and preserve natural quiet by excluding noise (Pavan, 2017). The exclusion of noise is primarily the result of limited development and limitations on human habitation. However, exclusion is also carried out through a variety of management strategies meant to limit development or its impacts, such as limiting overflights, implementing shuttle bus systems, designating "quiet zones", and limiting mineral exploration (Lynch, Joyce, & Fristrup, 2011). Hence, the general lack of noise produced by relatively undeveloped protected areas—enhanced by efforts to further reduce the amount of noise produced therein—not only leads to lower amounts of noise in protected areas, but also likely leads to lower levels of noise in the areas that encompass them—all else being equal (Manning et al., 2018). Some have questioned, however, the capacity of small parks and urban "pocket parks" to significantly provide this exclusion of noise given their size (e.g. Wilson, McGinnis, Latkova, Tierney, & Yoshino, 2016).

1.3. Noise abatement and protected areas

In addition to preserving natural quiet through noise exclusion, protected areas can also abate anthropogenic noise. Much of the research in this area has been driven by interest in how noise impacts human health, as reviewed by Passchier-Vermeer and Passchier (2000) and, more recently, by Baliatsas et al. (2016). Newport et al. (2014) also review the negative effects anthropogenic noise has on ecological health and provide a series of implications for protected area managers in reducing noise impacts. In response to these human health and conservation concerns, numerous studies examined the capacity of protected areas to absorb and abate anthropogenic noise—that is, how protected areas reduce the amount of noise pollution in a given area. Derkzen, van Teeffelen, and Verburg (2015) frame this abatement as an ecosystem service provided by green space, especially in urban areas. Derkzen et al. (2015) conceptualize these ecosystem services as either direct—green spaces absorbing noise and destructing sound waves—or indirect—vegetation reducing wind speeds and soils absorbing noise. The masking of anthropogenic noise with natural sounds in urban areas is another important service of green space—with evidence showing that even narrow vegetation belts can abate noise (Chen & Jim, 2008).

1.4. Emerging issues

In addition to soundscape conservation and noise abatement, new trends are emerging concerning land development, anthropogenic noise, and protected areas. It is unsurprising that development impacts ambient noise, however scientists recently began assessing both the sources and ecological consequences of an increasing human footprint proximate to protected areas. Concerning the sources of development, recent literature in the social sciences analyzed the various "pull factors" of development near wild areas, such as migration to areas near national parks and designated Wilderness areas (e.g. Breen, Hurley, & Taylor, 2016; Culbertson, Case, Fowler, Morgan, & Schwellenbach, 2008; Gimmi et al., 2011; Glass, 2006; Locke, 2006). This increased development on park and protected area borders raises additional concerns about soundscape conservation (e.g. Hanes, 2018; Laitos & Ruckriegle, 2013; Lynch, 2006). As development increases, habitat fragmentation is apt to follow (Pijanowski, Farina, Gage, Dumyahn, & Krause, 2011). This too can have adverse effects on soundscape conservation and green spaces' ability to abate noise (Tucker, Gage, Williamson, & Fuller, 2014). In sum, the negative noise impacts of development around protected areas are likely to interplay with the known positive effects of green space. This research seeks to shed light on these emerging issues of noise propagation by applying a large scale, spatial approach to the examination of how conservation status, ownership, and access impact sound pressure level.

2. Methods

2.1. Study area

The geographic scope of this study was limited to the eastern United States, as defined by counties lying east of the 100th meridian (Stegner, 1992). The American West, including Alaska and Hawaii, were not included in the analysis for the following reasons. First, counties tend to be much larger in the West, therefore causing inconsistencies in the data and making a distance-based spatial weight matrix infeasible due to size constraints. Second, the Eastern United States is more homogenous than the West in terms of climate and ecology, making it more suitable for this analysis (Omernik & Griffith, 2014; Ward, 1925). Counties were selected as the unit of analysis due to the availability of land development data and their manageability from a computational perspective as opposed to zip code or minor civil division.

2.2. Data

2.2.1. Sound level data

The dependent variable in our analysis is operationalized as average sound pressure level at a county level. These data were derived from a national noise dataset published by the US National Park Service Natural Sounds and Night Skies Division (2017) developed by Mennitt and Fristrup (2016). Using a random forest model (Breiman, 2001), the developers considered 115 explanatory variables from 7 categories—topography, climate, landcover, hydrology, anthropogenic, time, and control—before selecting 45 variables based on their predictive performance of sound pressure level to create a continuous raster of A-weighted sound pressure levels on a typical summer day across the United States. Data for the Eastern United States is provided at a resolution of 270 m and sound pressure level is measured in A-weighted decibels (dBA). These data were averaged across U.S. counties using ArcMap, creating the dependent variable of average dBA. Fig. 1 shows the results of this aggregation.

2.2.2. Protected area data

Given our research question of understanding how conservation status, ownership, and accessibility of protected areas influences ambient noise levels, we gathered spatial protected area data from the U.S.