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RESEARCH ARTICLE

Soundscape conservation

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Abstract We argue that soundscapes possess both ecological and social value and that they should be considered natural resources worthy of management and conservation. In this paper we bring together diverse bodies of literature that identify the human and ecological benefits provided by soundscapes. Sense of place, cultural significance, interactions with landscape perceptions, and wildlife wellbeing are a few of the values ascribed to soundscapes. The values and benefits of soundscapes are motivation to advance soundscape conservation and management. Given that soundscape conservation is new, we present a summary of conservation principles that need to be considered in soundscape conservation planning. These include the need to set goals, identify targets, assess condition, identify and manage threats, and conduct monitoring of the soundscape. We also argue that soundscape conservation needs to consider the soundscape within the larger mosaic of the landscape that is occupied by humans—a perspective provided by landscape ecology. We describe several different kinds of soundscapes that need to be conserved, such as natural quiet, sensitive, threatened, and unique soundscapes, and the ways that conservation planning can protect these for the future.

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Introduction

Human domination of natural habitats has resulted in the loss of biodiversity (Vitousek et al. 1997; Chapin et al. 2000; Perrings et al. 2010; Rands et al. 2010). The loss of species is so significant that some have concluded that we are experiencing the sixth extinction event (Pimm et al. 1995; Wilson 1999). In the recent past, biodiversity conservation has become not only a new discipline, but also a global priority and research agenda item (Soulé 1985; UNEP 1992; Sutherland et al. 2009). With the loss of habitat and biodiversity, areas lose their natural sounds (Wrightson 2000; Pijanowski et al. 2011a). Natural sounds have been referred to as an endangered resource as the ability to experience them becomes increasingly rare (Jensen and Thompson 2004).

In addition to the world losing natural sounds, our planet is gaining in the temporal and spatial reach of human-generated sounds (Schafer 1994). Human-generated sounds can include motorized transportation, such as global air travel, sounds from industrial and domestic machines, road noise due to friction, the sounding of bells, sirens, alarms, and human voices. Sometimes these sounds are subjectively deemed noise by a listener (Truax 1999). The ever expanding

transportation systems for aircraft, railways, and highways contribute to some of the most ubiquitous sources of noise (Miller 2002). Human-generated sounds continue to spread to even remote, natural areas (Berglund et al. 1999; Wrightson 2000). While most attention has been on regulating individual sources of noise, such as those from airports, little attention has been given to conserving the natural acoustic environment, or natural soundscape, and its positive associated values.

Some researchers (i.e. Schafer 1994; Krause 2002) and natural resource agencies (i.e. National Park Service 2006) have begun to recognize soundscapes as resources. By treating soundscapes as resources, a new approach for conservation and management can be developed; one that is fundamentally different from incrementally regulating noise sources. In order to create a rationale for soundscape conservation, the associated values of this resource need to be clearly identified and linked in meaningful ways within the larger social-ecological system. Understanding soundscape values strengthens the motivation and justification for conservation and management actions. It has been recognized that conservation needs to be guided by a set of principles, a common vocabulary, and a classification system that allows managers and scientists to set goals and determine how management practices alter outcomes (e.g., Soulé 1985; Groom et al. 2006). Advancing soundscape conservation will require a similar set of guidelines organized around a classification system that identifies high priority soundscapes.

The purpose of this paper is to present an argument that soundscapes are natural resources worthy of conservation. First, we define soundscapes as natural resources. Second, we posit that soundscapes possess certain values, socially and ecologically, and therefore need to be conserved. Third, we provide a framework for soundscape conservation derived from principles of landscape ecology (e.g., Wiens 2009) and conservation biology (e.g., Groom et al. 2006).

Defining soundscapes as natural resources

The soundscape concept was formalized in the 1970s by R. Murray Schafer, a composer and researcher interested in the acoustic environment. He defined soundscapes as "any acoustic field of study" including the acoustic elements of actual environments or more abstract environments such as musical compositions (Schafer 1994, p. 7). Schafer founded the multidisciplinary study of acoustic ecology. Acoustic ecology emphasizes the human system: human perceptions and the value of listening. Truax (1999), a colleague of Schafer's, defines acoustic ecology as the study of the effects of the relationship between humans and the soundscape emphasizing individual responses and perceptions. Three soundscape features and the way we perceive them were categorized by Schafer (1994): keynote sounds, sound signals, and soundmarks. Keynote sounds are the background tones of an environment that are directly influenced by geography and climate including wind, water, animals, vegetation, and geological features. These sounds are not listened to consciously, but may deeply imprint on a person's sense of place. Sound signals, in contrast to keynotes, are listened to consciously, since typically they convey information or warnings (e.g., train whistles, car horns, or ambulance sirens). Soundmarks, like landmarks, are sounds unique to specific locations. Unique soundscapes can then be defined as soundscape patterns that allow places to be differentiated (O'Connor 2008).

Through our perceptions of and interactions with soundscapes, humans construct meaning and understanding of their surroundings (Truax 1999). Thompson (2002) described the relationship between the soundscape resource and the human listener as a cultural construction. As Thompson (2002) eludes, humans derive different benefits from soundscapes based on their personal frame of reference, from more analytical to emphasizing the aesthetic, and the interactions with the surrounding environment. Some of the socially important values that are ascribed to soundscapes include creating a sense of place, providing cultural and historical heritage values, interacting with landscape perceptions, and connecting humans to the nature. Additionally, how humans perceive environmental quality based soundscapes raises important resource considerations (Sonyerd 2004). Since humans utilize soundscapes for different cultural and social benefits or services, they represent a resource (Kraft 2007).

Soundscapes also are an ecological resource. While identified and recognized by humans, soundscapes are utilized by a variety of wildlife species. Krause (2002)

contributed to the definition of soundscapes referring to them as all of sounds present in an environment at a given time. Krause grouped sounds into three categories: biophony (sounds from non-human organisms), geophony (geophysical sounds) and anthrophony (human-generated sounds). In his Acoustic Niche Hypothesis, Krause (1987) posited that soundscapes can provide available acoustic niches for vocalizing species and that stable and healthy ecosystems exhibit soundscapes with complex and discriminate use of frequency and temporal acoustic niches. If the soundscape is composed of anthrophony, such as low frequency motorized sounds, the previously available niches may be filled masking species vocalizations or other sounds important for species survival (Barber et al. 2010). By vocalizing species communication filling a niche, these natural sounds in the landscape essentially represent a functional component of an ecosystem (in sensu Chapin et al. 1997; Hooper et al. 2005). Alteration of either species composition and/or the soundscape through modification of the acoustic properties could impact the functioning of ecosystems. Thus, management of soundscapes needs to consider specific sounds, as well as all sounds collectively.

Some government agencies have identified that sounds should be managed. Internationally, the European Commission adopted a directive on the assessment and management of noise (European Union 2002; King et al. 2011). The policy objectives include assessing noise conditions in urban areas, as well as "open country" or other noise sensitive areas to preserve quiet areas (European Union 2002). The U.S. National Park Service (NPS) identifies soundscapes as a resource and considers all of the natural sounds within parks and their interactions to encompass the natural soundscape (NPS 2006). NPS management policies address the protection and management of soundscapes, similar to other park natural resources, stating, "the Service will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise), and will protect natural soundscapes from unacceptable impacts" (2006, p. 56). Recognizing the interactions between soundscapes and landscapes is important for site-specific conservation activities. Indeed, parks and protected areas illustrate this concept well, since park soundscapes are expected to reflect the wildlife, geophysical features, or other elements being protected (Mace et al. 1999).

Pijanowski et al. (2011b, this issue) further elaborated on the connection between sounds and landscapes by defining soundscape ecology as all "biological, geophysical, and anthropogenic sounds that emanate from a landscape and which vary over space and time reflecting important ecosystem processes and human activities." This definition identifies soundscapes as an audible reflection of the landscape and indicates the social and ecological significance of this resource. We build on the importance of this resource within the context of associated values.

Understanding soundscape values

The motivation for natural resource conservation and caring has been linked to the values associated with the resources (Rolston 1988; Harmon and Putney 2003; Sagoff 2004). For this paper, value is defined as "that which has worth: something of merit, something estimable- whether or not such worth is assigned or recognized by people" (Harmon 2003, p. 13). Natural resource values have been described also as benefits (Steins and Edwards 1999) and ecosystem services (MEA 2005). The environmental philosopher Holmes Rolston III states that objective values within nature are "discovered, not generated by the valuer" (1988, p. 116). Discovered values within nature are referred to as intrinsic values. Once discovered, intrinsic values can be appreciated by people thereby gaining instrumental value, or that which serves a purpose. Instrumental values can be tangible providing a product or economic benefit. Other instrumental values are intangible. Several types of intangible values have been identified for natural resources including: recreational, cultural, spiritual, therapeutic, identity or sense of place, existence and bequest values, research and monitoring, educational, and artistic (Harmon 2003). In this paper we review many of these same values as they are applied to natural soundscapes.

Soundscape ecology as an emerging science recognizes the importance of understanding interactions and feedbacks between humans and soundscapes (Pijanowski et al. 2011b, this issue). Evidenced in the conceptual diagram of soundscape processes, the soundscape is linked to features of the natural environment, such as biodiversity and landforms, and

human systems (Fig. 1). Utilizing a social-ecological context the importance and value of soundscapes for both humans and wildlife can be considered. We recognize that how wildlife and humans perceive and respond to sounds will vary. Similarly, individual human perceptions and responses to sounds also are not universal. With this in mind, we acknowledge that different social and ecological research approaches are necessary to understand these dynamics.

Landscapes and soundscapes can be directly perceived by humans and wildlife. Soundscapes are perceived with our sense of hearing, whereas landscapes are perceived visually or through our other senses. Being in this "perceptible realm," soundscapes are a direct connection between humans and natural systems (Gobster et al. 2007). In Fig. 2 we demonstrate the process of human perceptions of soundscape patterns and resulting values and potential behaviors. Humans are able to perceive, evaluate the experience, form attitudes, and strengthen or create values from the soundscapes that they experience. These values can influence the form of human behaviors in regards to soundscapes (Fig. 2; see Ajzen 1991 for more on behavior theory). An individual's behaviors are also influenced by many other factors, such as knowledge and education (Rogers 2003). By understanding soundscape values and providing information and educational opportunities, it is possible to have individuals change their behavior toward this resource (Harmon 2003). Soundscape conservation measures and management are more likely with a shared understanding of the multitude of soundscape values.

We present the following values associated with soundscape quality in this paper: human health and wellbeing, wildlife impacts, sense of place, landscape interactions, and ecological integrity values (Table 1).

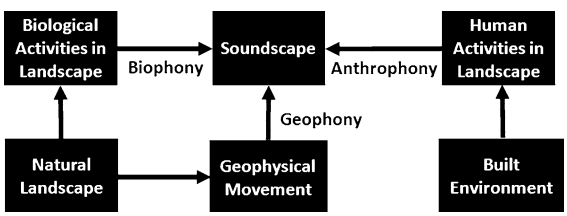

Fig. 1 Soundscape system emphasizing the main sources of sound (modified from Pijanowski et al. 2011b)

Human and wildlife wellbeing

In soundscapes degraded by noise pollution, the benefits of healthy soundscapes for human and wildlife wellbeing become readily apparent. A large body of literature documents the effects of noise exposure on human physical and mental health (Staples 1996; Passchier-Vermeer and Passchier 2000). Auditory health research has established clear relationships between decibel level exposure and associated hearing loss (Passchier-Vermeer and Passchier 2000). Other health effects from chronic noise exposure have been found to include stress, annoyance, cardiovascular effects in adults, sleep disturbance, and decreased task performance (Evans et al. 1995; Bronzaft et al. 1998; Stansfeld and Matheson 2003). Children exposed to chronic noise have a higher likelihood of reading deficits and declines in other academic tasks (Evans and Maxwell 1997; Haines et al. 2002). Quality of life impacts for people in noisy areas has been assessed by researchers, as well (Staples 1996; Bowles and Schulte-Fortkamp 2008). Noise detracts from human wellbeing and other values, such as peace and tranquility (Sonyerd 2004; Pheasant et al. 2010). There is strong evidence that human health and wellbeing are impaired when exposed to degraded soundscapes raising issues of rights to access a healthy acoustic environment (Berglund et al. 1999; Brainard et al. 2004).

Degraded soundscapes have been found to negatively affect some species of wildlife, as well. Motorized transportation noise has been found to mask, or limit the perception, of acoustic signals (Slabbekoorn and Ripmeester 2008). Acoustic masking has many important implications for wildlife, such as prey location, predator avoidance and interspecies communication (Barber et al. 2010). Species have responded in various ways to urban noise, such as abandoning the area and making vocal adjustments by shifting amplitude or frequency of their songs (Patricelli and Blickley 2006; Slabbekoorn and Ripmeester 2008). One study found that robins changed their singing time to evenings when the city was quieter (Fuller et al. 2007). Additionally, noisier areas irrespective of habitat quality have been found to have reduced bird density and diversity (Reinjen et al. 1997; Stone 2000). Anthrophony in the soundscape can also decrease the listening area for species interfering with communication and predator

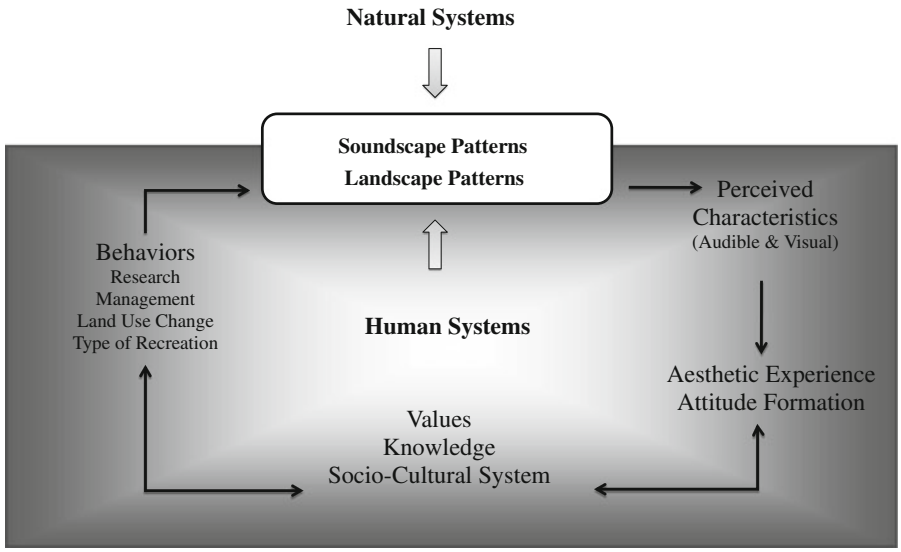

Fig. 2 The connections between perceived soundscapes, their associated values, and human behaviors (after Gobster et al. 2007)

Table 1 Soundscape values and derived benefits of quality soundscapes

Soundscape values	Associated benefits from soundscapes
Human wellbeing	Improved human health and welfare, reduced stress, improved quality of life, and equitable access to quality soundscapes
Wildlife wellbeing	Ability to hear predators, improved prey detection, improved vocalizing species communication, decreased stress, reduced need for vocalization modifications
Sense of place	Cultural, historical, and natural locations convey unique sounds that meaningfully connect humans to that place
Landscape interactions	Human expectations of the visual surroundings match the soundscape, increased aesthetic appreciation and evaluation of place and experience
Ecological integrity	Using soundscapes to monitor ecosystem function and sustainability, using biophony as an indicator of biodiversity, using soundscape recordings to research effects of land use change

detection (Barber et al. 2010). Francis et al. (2011) found that habitat occupancy and nest predation was reduced in the gray flycatcher in areas containing noisy gas well compressors. While the impacts of noise are not the same for all species, the research thus far indicates that soundscape quality is an important consideration for wildlife conservation and management.

Soundscapes and sense of place

Soundscapes have been referred to as an element of sense of place (Schafer 1994; Fisher 1999). Sense of place is defined as a collection of symbols, values, feelings and meanings ascribed to a specific place (Williams and Stewart 1998). Some researchers have proposed that the construction of sense of place is developed from place specific attributes emphasizing the physical landscape features (Stedman 2003). In recognition that the visual environment is not the only thing influencing sense of place, others have claimed soundscapes are an acoustic manifestation of place (Fisher 1998). Fisher (1998) stated, "many sounds of nature, e.g., the sounds of oceans or rivers or the forest canopy or weather events vary significantly from place to place, from time to time, and with each instance" (p. 168). Schafer recognized the relationship between soundscapes and sense of place stating, "every natural soundscape has its own unique tones and often these are so original as to constitute soundmarks" (1994, p. 26). Even our home environment has sounds that we perceive to create an acoustic sense of place (Westerkamp 2002).

The human perception and emotional response to an area are based on sensory inputs so both visual (landscapes) and auditory (soundscapes) among the other senses would interact to establish a sense of place (Williams and Stewart 1998). Perceiving soundscapes requires what Schafer calls being an "earwitness" or being aurally aware of the acoustic environment (1994). Though, as Schafer (1994) indicated, humans are increasingly disconnected with their soundscapes. Low-fidelity (lo-fi) soundscapes, often urban, are comprised of human-generated sounds that mask other sounds. Frequently the urban listener is unable to perceive low level sounds, distant sounds, and is surrounded by so many sounds that acoustic information is lost or ignored (Schafer 1994; Wrightson 2000). In contrast, soundscapes that can be clearly perceived and have low levels of noise are referred to as high-fidelity (hi-fi) soundscapes (Schafer 1994). Hi-fi soundscapes allow individual sound sources to be heard providing the listener with information about their surroundings, such as distance from the sound source and connection to the environment.

Most natural soundscapes are quintessentially hi-fi in which humans can clearly perceive and connect with natural sounds (Fisher 1999). Natural and rural soundscapes are elicited often in writing to evoke a sense of place (Leopold 1989; Schafer 1994; Olson 1997). Earwitness accounts in literature are evidence of a human connection to place through the audible. One earwitness example is from the narrative travels of Alexander von Humboldt writing about a tropical forest in Cuba:

> when we lend an attentive ear to the most feeble sounds transmitted through the air, we hear a dull vibration, a continual murmur, a hum of insects, filling, if we may use the expression, all the lower strata of the air…These are so many voices, proclaiming to us that all nature breathes
> (von Humboldt and Bonpland 1852, p. 199).

Another famous naturalist, E.O. Wilson, has indicated that this attention to nature elucidates values in the natural world claiming that when we allow our senses to experience nature, "even the small details grow in significance" (Wilson 1984, p. 103).

Cultural and historical soundscapes are also valued for creating a sense of place. Unique heritage sites reflecting historical and cultural places are impacted by changes in the soundscape (O'Connor 2008). O'Connor (2008) recognizes that aesthetic values increasingly pressured and threatened by accelerated social and physical change, so too are unique soundscapes. Sounds and sound patterns define and distinguish places from one another. Soundscapes in Japan are viewed as a part of the country's cultural heritage. Japanese Environmental Protection Agency developed a guidebook titled: *100 Soundscape of Japan: Preserving Our Heritage* (Torigoe 2003). This effort was meant to raise awareness of and preserve Japan's natural and cultural soundscape heritage. In terms of soundscape heritage and conservation, there is a need to consider sound as a positive or inherent factor of place-making.

Soundscape and landscape interactions

The associated connection between sense of place and acoustics has been explored in two other fields: landscape preference research and the emerging field of acoustic ecology. Landscape research on preferences, values and planning traditionally has emphasized visual aesthetics and quality (Zube 1987; Adams et al. 2006). As described earlier, soundscapes can be considered auditory landscapes, in which the listener evaluates and makes sense of the environment. As Farina and Belgrano (2006) indicate in their eco-field hypothesis, acoustic cues are another layer to understanding the landscape for auditory species. The early and innovative work of Southworth (1969) investigated the "sonic" environment of Boston. He claimed that the city's character and individuals' perceived evaluation of the visual landscape could be improved through changes to the soundscape. Research on landscape perception and evaluation has found that sounds influence the landscape values (Mace et al. 1999). In fact, humans seem to have a preference for the sounds of nature (Fisher 1999). Several studies have compared urban and natural settings and found that the preferred sounds in both of these environments were natural sounds of birds and water (Carles et al. 1999; Zhang and Kang 2007; Irvine et al. 2009; Pilcher et al. 2009).

Initial valuation studies emphasized the sound characteristics (e.g., decibel level, frequency, and percent time audible) (Miller 2008). While it is important to understand these components, studies

have not been able to consistently correlate quality of experience or annoyance with sound pressure level in field studies (Kariel 1990; Tarrant 1995). The impact of noise sources on visitors in natural settings has found that loudness alone does not predict annoyance (Kariel 1990). In fact, Kariel (1990) found that mechanical or motorized noises at low decibel levels could still be annoying and intrusive to people's experiences. Other factors might be better determinants for sound and landscape evaluations, such as the appropriateness of the sound within the landscape and individuals' expectations and recreational goals (Kariel 1990).

Recreation studies have documented that people who seek out areas for natural quiet and solitude have more negative experiences or increased annoyance due to noise (Gramann 1999). For instance, wilderness recreationists have been found to be more sensitive to aircraft noise than other types of recreationists (Tarrant 1995; Fidell et al. 1996). Overall, mechanized or other noises that do not naturally occur in a landscape can affect people's experiences and evaluations. The aesthetic appreciation of natural sounds has implications for biodiversity and protected area conservation.

Soundscapes and ecological integrity

Acoustic monitoring has been used for identifying the occurrence of individual species with better results than other sampling methods (Acevedo and Villanueva-Rivera 2006; Celis-Murillo et al. 2009). Using soundscape recordings to monitor biodiversity or individual species, especially in the tropics, has potential to improve efficiency and understanding of wildlife. Some researchers have used the acoustic signals from biophony to serve as a proxy for biodiversity estimates (Reide 1993; Sueur et al. 2008; Pijanowski et al. 2011a). Assessing acoustic diversity spatially and temporally can aid in conservation efforts for landscapes and biodiversity. Additionally, Pijanowski et al. (2011a) demonstrated that acoustic diversity and temporal acoustic patterns of soundscapes can be compared across multiple land use types. The expectation that soundscapes acoustically represent landscapes has led to the hypothesis that soundscapes can offer insights into ecological quality or integrity of an area (Krause 2002; Krause and Gage 2003; Pijanowski et al. 2011a). Soundscapes as indicators of environmental integrity can be applied at a variety of spatial and temporal scales.

Our research on Tippecanoe Soundscapes (Pijanowski et al. 2011a; Villanueva-Rivera et al. 2011) has focused on frequency band analysis of spectrograms. Figure 3 demonstrates the use of acoustic gap analysis based on the research in Tippecanoe County agricultural landscapes. Using this analysis, we found that sounds in the 6–9 kHz range were absent in agricultural landscapes, representing a possible gap in soundscapes that are normally occupied by certain kinds of insects (e.g., cicadas, katydids). Using this or other analyses, soundscape monitoring can serve as a rapid bioassessment tool employed to detect shifts in ecosystem function (Sueur et al. 2008; Pijanowski et al. 2011a).

Soundscape research is early in its development and may have great potential for understanding the world beyond just the visual interactions. While valuing soundscapes for their research and monitoring benefits can promote soundscape conservation, we hope that soundscape research and its clear links to biodiversity and landscapes will be able to further those conservation efforts, as well. In order to advance soundscape conservation and soundscape research, we propose the use of traditional conservation planning principles grounded in biodiversity conservation and landscape ecology disciplines.

A soundscape conservation framework for public lands

Traditional conservation planning principles

We argue that the conservation of soundscapes can benefit by following basic principles being applied to the conservation of biodiversity (e.g., Noss and Cooperrider 1994; Soulé and Sanjayan 1998; van Jaarsveld et al. 1998; Margules and Pressey 2000; Groves et al. 2002; Brooks et al. 2006; Groom et al. 2006; Lindenmayer and Hunter 2010). Additionally, we propose the following principles: consider managing soundscapes at landscape (e.g., Wiens 2009), and potentially, at global scales (e.g., Whittaker et al. 2005; Turner et al. 2007), consider various ecological and social values associated with different kinds of soundscapes as discussed here (Gobster et al. 2007), and be consistent with public area soundscape resource

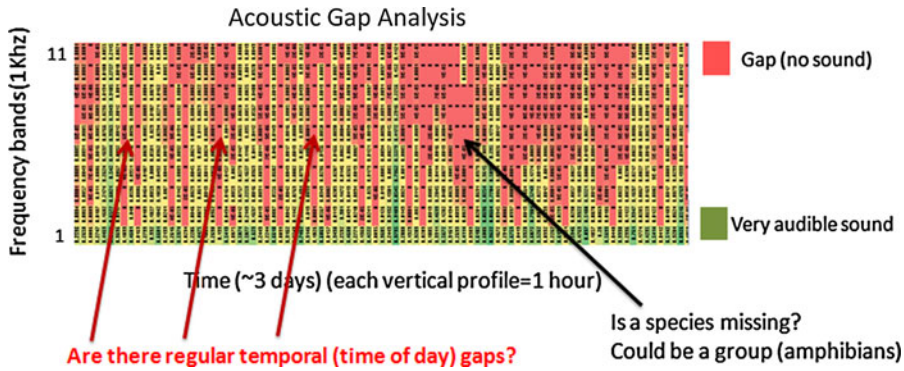

Fig. 3 Assessment of frequency gaps at a location. Each vertical bar represents the amount of sound occurring in a 15-min recording started at the beginning of each hour. Approximately 3 days of recordings are represented here for an agricultural landscape in Tippecanoe County, Indiana USA. Note that gaps may occur at specific times of the day indicating that an organism is missing. Gaps in the dawn or dusk chorus may be especially important

management goals that are being proposed by natural resource agencies, such as the NPS (NPS 2006).

Many conservation biologists recognize that several key elements are needed to protect and preserve biodiversity. A first common step is to identify the *target* for conservation (Groves et al. 2002). In general, historically, this has included the need to target certain ecosystems (e.g., tropics, savannas), specific taxonomic groups, or species of a particular status (e.g., endangered). Many conservation biologists recognize that surrogates (e.g., particular habitats) for these targets need to be assessed across large regions, perhaps even globally. Soulé and Sanjayan (1998), Margules and Pressey (2000), Groves et al. (2002), among others, recognize establishing *management goals* or objectives for conservation as a key element in any conservation planning process. Goals need to be established so that they are measurable and are responsive to policy actions. *Assessment* of current areas for their ability to maintain targets, especially those features which are being managed, is also important (Groves et al. 2002). Assessment needs to be long term and be constantly reviewed. Pressey et al. (2003) argue that the ability to maintain targets requires the identification of *threats* to the persistence of targets long term and to develop mitigating polices that reduce these threats. Finally, *monitoring* programs are needed (Noss 1990; Margules and Pressey 2000) that ensure that goals are being met and that adjustments in the management of threats to targets are not needed. The basic conservation planning activities of defining targets, setting goals, identifying and managing threats, and conducting continuous monitoring and assessment can be applied to soundscape conservation as well.

Soundscapes worthy of protection

Specific management actions we are proposing depend on the type of soundscape that needs to be protected. Although more research is needed to create a comprehensive classification of soundscapes worthy of protection, eight different kinds of soundscapes are presented here that we believe represent a breadth of soundscapes that hold ecological and/or social value (Table 2). The typology was derived using conservation biology concepts reflective of this "value-laden" science where soundscape types that have significant value are identified (Groom et al. 2006). Some of the types of soundscapes identified may need to be protected from future threats or need to be restored due to current impacts and degradation (Groom et al. 2006). Soundscape type values and additional reasons for inclusion in this typology are provided in the descriptions below and in Table 2. The soundscape types and reasons for inclusion are not mutually exclusive. In some cases the soundscape types could be interrelated reflecting a mosaic of different landscapes and values. As soundscapes are linked to landscapes, these soundscape types could be associated with public and/or private lands. Potential conservation planning activities for each type of soundscape and their associated landscape is provided in Table 2.

Table 2 Soundscape types and conservation planning principles

Soundscape type	Example(s)	Value(s)	Threat(s)	Management goals	Monitoring
Natural quiet soundscapes	Remote areas in parks, wilderness areas, volcano craters	Landscape interactions, experiencing solitude, sense of place, wildlife wellbeing	Anthrophony and biophonic invasive species that are loud	Protect area from human generated noise, especially low frequency sounds that can travel far or dispersed recreational noise	Monitor for changes in ambient sound levels
Sensitive soundscapes	Bird breeding habitats	Wildlife wellbeing, ecological integrity	Anthrophony and biophonic invasive species that mask native sounds	Protect area from human generated noise	Monitor for presence of keynote sounds that are critical to ecosystem function
Threatened soundscapes	Predominately high fidelity soundscapes that undergo increases in anthrophony, airport development, deforestation for agriculture	Ecological integrity, wildlife wellbeing, human wellbeing	Excessive noise, land use change	Mitigate excessive noise, improve technologies of sound producing object(s), limit additional noise intrusions	Monitor for anthrophony and biophony levels
Unique soundscapes	Forest elephants in Congo salt wetland	Wildlife wellbeing, sense of place, loss of these would be irreplaceable, global heritage value	Loss of appropriate habitat to generate unique characteristics of soundscape, human generated noise, biophonic invasive species	Identify unique areas and establish strict guidelines to protect both landscape and soundscape from alteration	Monitor for the presence of the unique sounds
Recreational soundscapes	Northern Minnesota lakes, off-road vehicle use areas in western rangelands	Landscape interactions, sense of place, connecting humans with nature	Human generated noise, loss of landscapes that create natural sounds	Protect area from activities that are incompatible with sounds created by certain types recreation	Monitor for specific types of sounds that are recreational in nature; protect those landscapes that support organisms that produce soundmarks of high recreational value
Representative soundscapes	Desert soundscape, taiga soundscape, grassland soundscape, coral reef soundscapes	Ecological integrity and research, global heritage—preserve natural soundscapes in ecosystems around the world, sense of place	Loss of habitats/ ecosystems, climate change	Protect soundscapes from threats from anthrophony and biophonic invasions, protect landscapes from land use changes	Monitor for selected representative soundscapes, determine natural ambient composition of these soundscapes (frequency, temporal patterns, etc.)

Table 2 continued

Soundscape type	Example(s)	Value(s)	Threat(s)	Management goals	Monitoring
Cultural soundscapes	City markets, church bells in small town, coastal areas with foghorns	Sense of place, cultural and historic values related to sounds	Loss of the sound generating objects (foghorns, church bells), increase in anthrophony	Recognize culturally identifying sounds, identify targets, maintain high fidelity soundscapes	Monitor culturally significant soundmarks and associated soundscapes
Everyday soundscapes	Rural soundscapes that contain typical vocalizing organisms such as birds, amphibians and insects City soundscapes	Human wellbeing, sense of place	Low frequency anthrophony, long term increases in the level and occurrence of anthrophony	Reduce identified noise sources and conduct acoustic mapping and qualitative research to identify issues and targets	Monitor for excessive sound levels across communities and assess the presence of biophony

Natural quiet soundscapes

Natural quiet soundscapes are already recognized by the NPS (1995) as soundscapes that need to be protected. The NPS defines natural quiet as the natural ambient sounds heard within a park unit (NPS 1995). These sound conditions are typically at very low A-weighted decibel sound levels (dBA). For instance, reported natural quiet conditions at parks ranged from 40 to 10 dBA compared to suburban and urban settings that can range from 40 to 80 dBA respectively (NPS 1995). In some significant instances the soundscape could have an absence of human perceptible sounds, such as within a volcano crater (NPS 1995). Natural quiet soundscapes can be contrasted with naturally loud soundscapes, where the ambient sound levels are higher due to increased geophony or biophony. Unlike naturally loud soundscapes, natural quiet soundscapes are more sensitive to impacts. Recognizing the impacts of anthrophony, the European Union (2002) considers quiet soundscapes as those lacking noise from traffic, industry, and recreational activities. Termed biophonic invasions by Pijanowski et al. (2011b), invasive or non-native vocalizing wildlife species also can impact soundscapes by masking native vocalizations or, as in the case of the coqui frog (*Eleutherodactylus coqui*) invasion in Hawaii, generate sound when there was quiet (Raloff 2003).

As indicated previously, natural sounds are valued by people and are important aspects of natural area and wilderness experiences (Gramann 1999). Natural quiet soundscapes are especially important for wildlife species that have evolved to communicate in these acoustic environments. Monitoring for anthrophony and any increases in ambient sound levels would be necessary. Given the continuous expansion of roads into rural areas and the increase in number and spatial extent overflights, these types of soundscapes are a conservation priority.

Sensitive soundscapes

Sensitive soundscapes are part of landscapes that provide ecological or biological functions that could be impacted due to anthrophony. A key example of this is landscapes that provide habitat for threatened or endangered species that rely on acoustic communication and cues. In these soundscapes any introduction of noise into the landscapes could negatively impact the occurrence of natural sounds that are important to the survival of the species. Depending on the types of biodiversity supported in the area, the overall ecosystem functioning could be impacted by an increase in noise. Breeding habitats for endangered bird species that rely on acoustic communication would be an example of sensitive soundscapes.

Threatened soundscapes

Threatened soundscapes would be those that were predominantly naturally quiet or high fidelity, but

have undergone land use changes or have increased anthrophony resulting in lower fidelity soundscapes. These landscapes would be increasingly exposed to high levels of sound that could negatively impact ecological integrity. Land use and transportation system changes can have a number of different impacts on wildlife species and humans, as well. The level of impairment for the threatened soundscapes needs to be monitored for long-term temporal and spatial impacts, as well as cumulative effects due to habitat loss. For example, a new airport located near a wildlife area could introduce noise levels that mask animal communication necessary for breeding, while also reducing available habitat that decreases biodiversity and biophony. Threatened soundscapes differ from sensitive soundscapes in that the species impacted by the acoustic changes are not necessarily endangered; rather noise levels and soundscape composition is such that natural sounds are interfered with and natural biological activities could be impacted. Research on threatened soundscapes can provide additional insight into how ecological integrity is reflected in the soundscape for both wildlife and humans.

Unique place-specific soundscapes

Every soundscape is indeed unique in that it is likely that at any given location in the world, the composition and volume of sounds will differ from all others. However, there are some soundscapes, because of the unique composition of sounds or volume (loud or almost silent), that should be protected. The sounds of elephants bellowing in the tropical rainforests surrounded by rock outcrops in the Congo are unique; the reverberations created by the surrounding landscape produce a soundscape that is not likely to be found anywhere else. The sounds of geysers erupting at Yellowstone National Park are another example of a unique soundscape worthy of protecting from noise intrusions. Unique place-specific soundscapes, if lost, could be irreplaceable.

Recreational soundscapes

Due to high recreational demand, some soundscapes require special management consideration for conservation. Recreational soundscapes may include areas that have natural ambient sounds reflective of the landscapes, such as waterfalls, wind through grasslands, or unique animal calls (e.g., loons), but also have moderate to high levels of recreational activity. These soundscapes host sounds from human motorized recreation activities, such as motorboats, off-road vehicles, air tour overflights, or associated recreation sounds, such as camp generators, vehicle traffic, chainsaws, or music. While these areas might currently be managed for multiple-uses, the loss of natural sounds requires careful monitoring of these soundscapes. Natural landscapes that become dominated by anthrophony should consider a revision of management goals to incorporate soundscape targets.

Representative soundscapes

These are soundscapes that reflect or represent a suite of landscape or ecosystem types. Representative soundscapes can serve as indicators for ecosystem and landscapes health, similar to indicator species used for conservation efforts (Groom et al. 2006). The biophony, geophony, and anthrophony of representative soundscapes can be researched and monitored for long-term temporal changes, such as impacts due to climate change. Spatial variations between landscape types and their soundscapes can be compared to provide information on sensitivity and resilience. Identifying areas with high ecological integrity to serve as representative soundscapes will be the most challenging, but landscape ecologists and conservation biologists can provide candidate locations for acoustic recording. The additional benefit of representative soundscape monitoring is that the soundscapes of a suite of ecosystems will be recorded for our global acoustic heritage.

Cultural soundscapes

Cultural soundscapes are socially defined soundscapes that have cultural, historical, spiritual, or aesthetic values associated with them. These can be natural or human dominated soundscapes. Generally, cultural soundscapes are those that tie people strongly to a place and that possess unique soundmarks. It has been argued that identifying soundmarks can help build community and preserve the natural and cultural heritage that makes locations unique (Schafer 1994; Torigoe 2003). Sounds of wind through unique landscape features, the sounds emanating from

historical battlefields during a reenactment, church bells that sound across a valley, fog horns produced along coastal areas, the sounds of a market in an urban area all represent soundscapes that may hold special cultural values for people (Schafer 1994). The greatest threats to cultural soundscapes are their homogenization due to anthrophony and the loss of unique soundmarks (Schafer 1994; Wrightson 2000).

Everyday soundscapes

Everyday soundscapes are those where we live, work, and visit frequently. These soundscapes provide our auditory link to the environment daily. For instance, rural soundscapes that contain typical vocalizing organisms such as birds, amphibians and insects at audible levels provide the keynotes and rhythms that residents have become customized to hearing (Schafer 1994). Special composition of dawn or dusk chorus or nighttime sounds may be very important. These soundscapes create a sense of place for people that may not even be noticed consciously. The management goal for everyday soundscapes is that areas were humans spend most of their time need to provide suitable acoustic conditions. A variety of auditory and non-auditory health impacts result from being exposed to certain sound levels (Staples 1996). Perceived environmental quality and environmental justice issues need to be taken into account for managing everyday soundscapes. Threats to these soundscapes include increasing amounts of noise and the loss of specific habitats that might contribution to the presence of biophony.

Soundscape-landscape conservation principles

The soundscape typology presented here is meant to be a first attempt at classifying different soundscapes to prioritize conservation and management. We fully anticipate the typology will change as more research linking soundscapes to social-ecological systems emerges. The current version utilizes conservation principles to identify potential goals. The conservation goals for most of the classified soundscape types emphasize maintaining the natural composition of sounds, both biophony and geophony. In some cases, managing and protecting anthrophony is an important goal, such as in some cultural and everyday soundscapes. Soundscape conservation has to be tied closely to the management of landscape as the structure of habitats influence the presence and abundance of vocal and stridulating organisms as well as affect the propagation of sounds across the soundscape (Pijanowski et al. 2011b, this issue). Management of soundscapes might occur within current protected areas, such as national parks and reserves, but also in areas with private ownership of land (e.g., everyday soundscapes). Regardless of ownership, one challenge that soundscape conservation needs to address is the management of soundscapes at landscape or larger scales.

Whittaker et al. (2005), Turner et al. (2007), Lindenmayer et al. (2008) and Wiens (2009) recognize the importance of considering ecosystem processes and human activities that occur at different spatial scales that impact management outcomes related to conservation. For example, Lindenmayer et al. (2008) and Wiens (2009) argue that areas that are under conservation management need not be managed as "stand alone" spatial units as surrounding areas contribute to the flux of individuals or species into and out of the conservation area. The surrounding areas may also be a source of many threats to the conservation area; these threats emerge as a result of various human activities in these surrounding areas. For instance, threats to park soundscapes can include sound produced by humans and the modification of the natural environment that impacts sound production, transmission, and composition. Work by Lynch et al. (2011) has shown that National Park soundscapes are under many threats either through activities within parks (e.g., visitor traffic and park infrastructure) or from sound production outside parks (e.g., overflights and road noise from areas surrounding the park).

Soundscape conservation elucidates the importance of considering spatial scale by integrating surrounding area planning as part of protected area management, since the soundscape and its impacts do not recognize boundaries. The landscape management approach, derived from landscape ecology principles outlined by Wiens (2009) can be applied to soundscapes. Figure 4 demonstrates that vocal and stridulating organisms are likely to move in and out of surrounding areas where there is likely to be much greater human activities that threaten their survival. Activities outside the conservation area that may detrimentally impact biophony in the

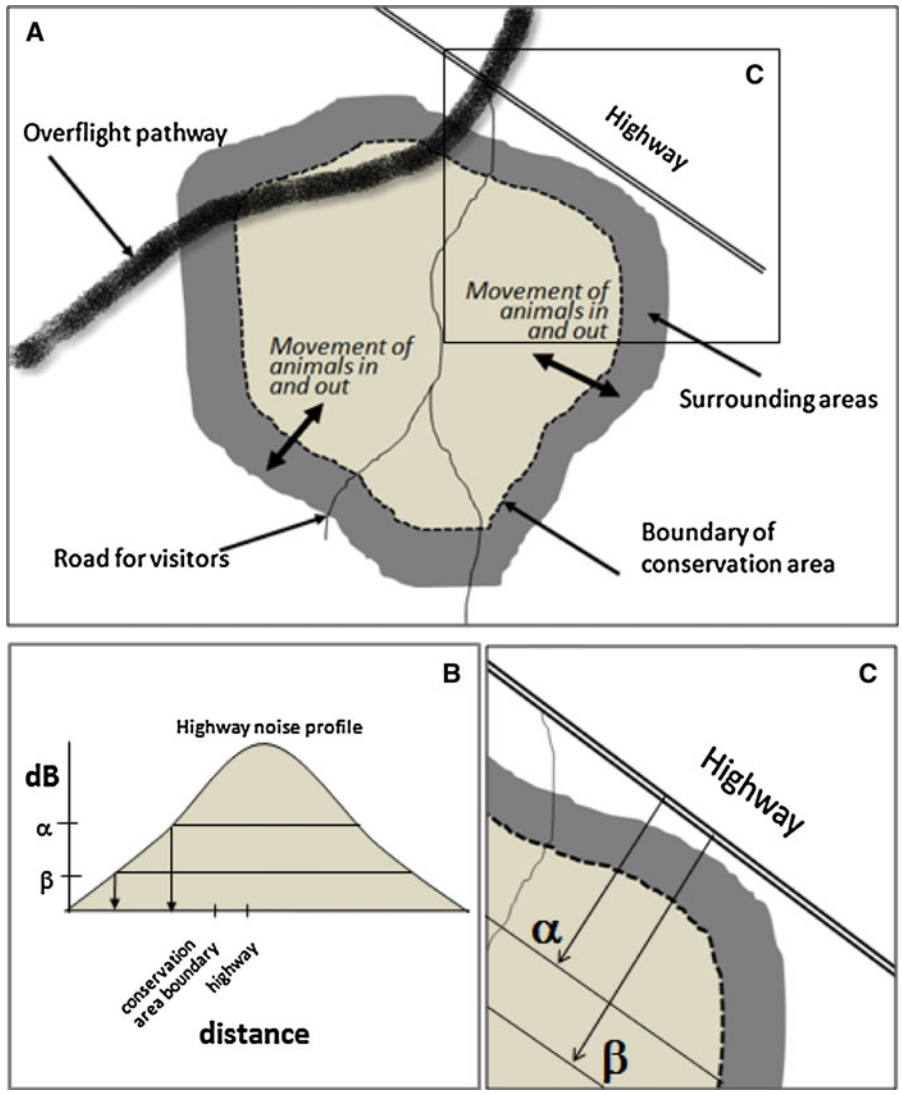

Fig. 4 Landscape perspectives of soundscape conservation (after Wiens 2009) showing **a** configuration of area of conservation, sound producing objects (e.g., roads, overflights), surrounding areas, importance of movement of animals into and out of the conservation area; **b** a road noise profile that contains the dB levels and associated travel distances of road noise for two hypothetical critical thresholds and **c** the road noise profile superimposed on the map of highway and conservation area

conservation area include road noise from surrounding areas and noise from overflights (Fig. 4a). Many activities occur in conservation areas, especially national parks like those in the U.S. National Park System (Miller 2008). Park visitor activities can include motorized recreation vehicles or visitor traffic on park roads. Factors that affect soundscapes are likely to occur at multiple scales, frequently at spatial extents larger than the conservation management unit.

In addition to spatial scales, temporal scales need to be considered in the management goals of soundscapes. Some soundscapes may need to be protected on the basis of their time-sensitive nature. Sensitive soundscapes are a key example of the need for temporal considerations. Endangered wildlife species that need to communicate at a particular time of year or day would need to have soundscape conservation measures in place to protect them. Temporal soundscape conservation can take into account rhythms that are important components of soundscapes, such as the dawn and dusk periods for birds to vocalize and announce territorial boundaries. Soundscapes in the high-latitudes occur only over a short period of time in the year. Still others might need to be protected at night as opposed to during the day as some nocturnal species might be sensitive to noise. Many soundscapes types would benefit from

management that considers time-critical periods where threats might have the greatest impact.

Monitoring at various temporal and spatial scales is a fundamental element of soundscape conservation. As indicated in Table 2, monitoring could focus on composition and/or sound levels depending upon the type of soundscape. Composition could examine the presence or absence of keynotes or soundmarks, the complexity or diversity of sounds, or whether gaps might exist (Fig. 3). Finally, research is needed that attempts to identify unaltered soundscape composition and representative soundscapes. A theoretical composition could be based on the knowledge of species that are likely to occur in an area and their acoustic niches (in sensu Krause 1987; Pijanowski et al. 2011b, this issue). Representative soundscapes used in long-term monitoring could also allow conservationists to determine how relatively slow long-term changes (e.g., climate change) might impact species composition. Sound recordings may also serve to preserve a record of biophony at a location—an acoustic fossil if the soundscape is lost.

Soundscape values and land use planning

We identified many different values associated with soundscapes and proposed a classification of soundscape types that highlight different values connected with them. As we demonstrate in Fig. 2, soundscapes are part of the perceived characteristics of the environment that affect experience, form values, and can lead to behavior change. Landscape ecologists have argued that the visual qualities of a landscape are important and that perceptions can relate to landscape values in the context of natural resource management (Zube 1987; Nassauer 1992, 1995; Gobster 1999; Gobster et al. 2007; Ode et al. 2008, 2010). Nassauer (1992) and Nassauer and Opdam (2008), among others, also have argued that policy should consider landscape appearance because people relate ecological quality to certain visual characteristics of the land. Ode et al. (2008, 2010) elaborated that visually complex landscapes are perceived more positively than homogenous landscapes; complexity is an integration of several landscape features including coherence, disturbance, naturalness and ephemera. We have presented a case that soundscapes, too, affect perceived environmental quality for humans and argue that they should be considered in policies and management, as well.

Landscape design research, in particular urban landscapes, has begun to address soundscapes as elements of the perceived environment to manage. Natural sounds, such as birds and running water, are often evaluated as the most pleasant sounds in urban areas (Zhang and Kang 2007; Irvine et al. 2009). Incorporating additional green space to provide areas for natural sounds in urban settings is a design recommendation that links landscape features and the soundscape (Irvine et al. 2009). In contrast to regulating noise in terms of a strict reduction of sound levels, soundscape conservation policy would seek to protect unique, cultural, everyday, or threatened soundscapes. Soundscape conservation design and policy would manage those soundscapes highlighting positive values and emphasizing high fidelity soundscape quality. The perceived and valued sounds of a city can be identified to enhance landscape planning and soundscape conservation efforts (Hedford and Berg 2003; Adams et al. 2006).

The values associated with natural sounds can promote the conservation of many of the other classified soundscapes types, such as natural quiet, sensitive, unique, and recreational soundscapes. Often the landscapes that are associated with these soundscapes would be predominantly natural. Planning and conservation efforts could focus on maintaining soundscapes that reflect the landscape. Some of these areas may already be protected as public parks or other designations. As we mentioned previously, another important management principle is the need to collaborate with natural resource agencies, planning commissions, and other entities that are interested in addressing soundscape conservation. Researchers can advance soundscape conservation by being consistent with soundscape conservation measures, classifications, and priority threats investigated that align with the goals of planning or management agencies working on soundscape issues. In the United States, the NPS Natural Sounds Program has been working on soundscape issues since 2000 with the passage of the National Parks Air Tour Management Act. Research projects and conservation goals for areas surrounding NPS units could be designed in consultation with the NPS to enhance soundscape conservation efforts within and around the parks.

Connecting humans with nature: an epilogue

Humans do not often see or realize the ecosystem processes and functions that are occurring around them. However, humans can hear natural sounds or see landscapes as a way of experiencing nature. Natural and unique soundscapes have a variety of different values associated with them, but natural systems need to be intact to have natural soundscapes.

More research is needed on the impacts to humans and wildlife from homogenized and simplified soundscapes. As Louv (2008) indicates, children today are less exposed to nature and therefore creating fewer connections with the natural world. Yet, there is an innate attraction of humans to natural sounds as evidenced in the multitude of values. Using this perceptible link of humans to nature could add value to conservation efforts, such as biodiversity protection and protected area establishment.

Sounds engage one of the human senses that help us experience the natural world. The recognized values of natural soundscapes discussed in this paper highlight a few motivations for their conservation. Values surrounding soundscapes still need to be better understood in order to develop appropriate management actions.

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References

Acevedo MA, Villanueva-Rivera LJ (2006) Using automated digital recording systems as effective tools for the monitoring of birds and amphibians. Wildl Soc Bull 34:211–214

Adams M, Cox T, Moore G, Croxford B, Refaee M, Sharples S (2006) Sustainable soundscapes: noise policy and urban experience. Urban Stud 43:2385–2398

Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50:179–211

Barber JR, Crooks KR, Fristrup KM (2010) The costs of chronic noise exposure for terrestrial organisms. Trends Ecol Evol 25:180–189

Berglund B, Lindvall T, Schwela DH (1999) Guidelines for community noise. World Health Organization, Geneva, p 20

Bowles A, Schulte-Fortkamp B (2008) Noise as an indicator of quality of life: advances in measurement of noise and noise effects on humans and animals in the environment. Acoustics Today 4:35–39

Brainard J, Jones AP, Bateman IJ, Lovett AA (2004) Exposure to environmental urban noise pollution in Birmingham, UK. Urban Stud 41:2581–2600

Bronzaft AL, Ahern K, McGinn R, O'Connor J, Savino B (1998) Aircraft noise: a potential hazard. Environ Behav 30:101–113

Brooks TM, Mittermeier RA, da Fonseca GAB, Gerlach J, Hoffmann M, Maoreux JF, Mittermeier CG, Pilgrim JD, Rodrigues ASL (2006) Global biodiversity conservation priorities. Science 313:58–61

Carles JL, Barrio IL, deLucio JV (1999) Sound influence on landscape values. Lands Urban Plan 43:191–200

Celis-Murillo A, Deppe JL, Allen MF (2009) Using soundscape recordings to estimate bird species abundance, richness, and composition. J Field Ornithol 80:64–78

Chapin FS III, Wlaker BH, Hobbs RJ, Hooper DU, Lawton JH, Sala OE, Tilman D (1997) Biotic control over the functioning of ecosystems. Science 277:500–504

Chapin FS III, Zavaleta ES, Eviner TV, Naylor RL, Vitousek PM, Reynolds HL, Hooper DU, Lavorel S, Sala OE, Hobbie SE, Mack MC, Diaz S (2000) Consequences of changing biodiversity. Nature 405:234–242

European Union (2002) Directive 2002/49/EC of the European Parliament and of the Council: relating to the assessment and management of environmental noise. Off J Eur Commun 189:12–25

Evans GW, Maxwell L (1997) Chronic noise exposure and reading deficits: the mediating effect of language acquisition. Environ Behav 29:638–656

Evans GW, Hygge S, Bullinger M (1995) Chronic noise exposure and psychological stress. Psychol Sci 6:333–338

Farina A, Belgrano A (2006) The eco-field hypothesis: toward a cognitive landscape. Landscape Ecol 21:5–17

Fidell S, Silvati L, Howe R, Pearsons KS, Tabachnick B, Knopf RC, Gramann J, Buchanan T (1996) Effects of aircraft overflights on wilderness recreationists. J Acoust Soc Am 100(5):2909–2918

Fisher JA (1998) What the hills are alive with: in defense of the sounds of nature. J Aesthet Art Critic 56:167–179

Fisher JA (1999) The value of natural sounds. J Aesthetic Educ 33:26–42

Francis CD, Paritsis J, Ortega CP, Cruz A (2011) Landscape patterns of avian habitat use and nest success are affected by chronic gas well compressor noise. Landscape Ecol. doi:10.1007/s10980-011-9609-z

Fuller RA, Warren PH, Gaston KJ (2007) Daytime noise predicts nocturnal singing in urban robins. Biol Lett 3:368–370

Gobster PH (1999) An ecological aesthetic for forest landscape management. Landscape J 18:54–64

Gobster PH, Nassauer JI, Daniel TC, Fry G (2007) The shared landscape: what does aesthetics have to do with ecology? Landscape Ecol 22:959–972

Gramann J (1999) The effect of mechanical noise and natural sound on visitor experiences in units of the national park system. Soc Sci Res Rev 1:1–16

Groom M, Meffe GK, Carroll CR (2006) Conservation biology. Sinauer Associates, Sunderland, MA

Groves CG, Kensen DB, Valutis LL, Redford KH, Shaffer ML, Scott JM, Baumgartner JV, Higgins JV, Beck MW, Anderson MG (2002) Planning for biodiversity conservation: putting conservation science into practice. Bioscience 52:499–512

Haines MM, Stansfeld SA, Head J, Job RFS (2002) Multilevel modeling of aircraft noise on performance tests in schools around Heathrow Airport London performance tests in schools around Heathrow Airport London. J Epidemiol Commun Health 56:139–144

Harmon D (2003) The source and significance of values in protected areas. In: Harmon D, Putney AD (eds) The full value of parks: from economics to the intangible. Rowman & Littlefield Publishers, Inc., Oxford, UK, pp 13–25

Harmon D, Putney AD (2003) The full value of parks: from economics to the intangible. Rowman & Littlefield Publishers, Inc., Oxford, UK

Hedford P, Berg PG (2003) The soundscape of two landscape settings: auditory concepts for physical planning and design. Landscape Res 28:245–263

Hooper DU, Chapin FS III, Ewel JJ, Hector A, Inchausti P, Lavorel S, Lawton JH, Lodge DM, Loreau M, Naeem S, Schmid B, Setala H, Symstad S, Vandermeer J, Wardle DA (2005) Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecol Monogr 75:3–35

Irvine KN, Devine-Wright P, Payne SR, Fuller RA, Painter B, Gaston KJ (2009) Green space, soundscape and urban sustainability: an interdisciplinary, empirical study. Local Environ 14:155–172

Jensen M, Thompson H (2004) Natural sounds: an endangered species. George Wright Forum 21:10–13

Kariel HG (1990) Factors affecting response to noise in outdoor recreational environments. Can Geographer 34:142–149

King EA, Murphy E, Rice HJ (2011) Implementation of the EU environmental noise directive: lessons from the first phase of strategic noise mapping and action planning in Ireland. J Environ Manage 92:756–764

Kraft M (2007) Environmental policy and politics. Pearson Education, Inc., New York

Krause B (1987) Bioacoustics, habitat ambiance in ecological balance. Whole Earth Rev 57:14–18

Krause B (2002) Wild soundscapes: discovering the voice of our natural world. Wilderness Press, Berkeley, CA

Krause B, Gage S (2003) Testing biophony as an indicator of habitat fitness and dynamics SEKI natural soundscape vital signs pilot program. Sequoia National Park, p 18

Leopold A (1989) A sand county almanac, and sketches here and there. Oxford University Press, Inc., New York, NY

Lindenmayer D, Hunter M (2010) Some guiding concepts for conservation biology. Conserv Biol 24:1459–1468

Lindenmayer D, Hobbs RJ, Montague-Drake R, Alexandra J, Bennett A, Burgman M, Cale P, Cullen P, Driscoll D, Fahrig L, Fisher J, Franklin J, Haila Y, Hunter M, Gibbons P, Lake S, Luck G, MacGregor C, McIntyre S, MacNally R, Manning A, Miller J, Mooney H, Noss R, Possingham H, Saunders D, Schmiegelow F, Scott M, Simberloff D, Sisk T, Tabor G, Walker B, Wiens J, Woinarski J, Zavaleta E (2008) A checklist for ecological management of landscapes for conservation. Ecol Lett 11:78–91

Louv R (2008) Last child in the woods: saving our children from nature-deficit disorder. Algonquin Books of Chapel Hill, Chapel Hill, NC

Lynch E, Joyce D, Fristrup K (2011) An assessment of noise audibility and sound levels in U.S. National Parks. Landscape Ecol (Submitted)

Mace BL, Bell PA, Loomis RJ (1999) Aesthetic, affective, and cognitive effects of noise on natural landscape assessment. Soc Nat Resour 12:225–242

Margules CR, Pressey RL (2000) Systemic conservation planning. Nature 405:243–253

MEA (2005) (Millenium Ecosystem Assessment) Ecosystems and human well-being: synthesis. Island Press, Washington, DC

Miller NP (2002) Transportation noise and recreational lands. International Congress and Exposition on Noise Control Engineering, Dearborn, MI, p 20

Miller NP (2008) U.S. national parks and management of park soundscapes: a review. Appl Acoust 69:77–92

Nassauer JI (1992) The appearance of ecological systems as a matter of policy. Landscape Ecol 6:239–250

Nassauer JI (1995) Culture and changing landscape structure. Landscape Ecol 10:229–237

Nassauer JI, Opdam P (2008) Design in science: extending the landscape ecology paradigm. Landscape Ecol 23:633–644

National Park Service (1995) Report on effects of aircraft overflights on the National Park System. U.S. Department of Interior, National Park Service, Denver, CO

National Park Service (2006) Management policies 2006. U.S. Department of Interior, National Park Service, Washington, DC

Noss RF (1990) Indicators for monitoring biodiversity: a hierarchical approach. Conserv Biol 4(4):355–364

Noss RF, Cooperrider A (1994) Saving nature's legacy: protecting and restoring biodiversity. Island Press, Washington, DC

O'Connor P (2008) The sound of silence: valuing acoustics in heritage conservation. Geogr Res 46:361–373

Ode A, Tveit MS, Fry G (2008) Capturing landscape visual character using indicators: touching base with landscape aesthetic theory. Landscape Res 33:89–117

Ode A, Hagerall CM, Sang N (2010) Analysing visual landscape complexity: theory and application. Landscape Res 35:111–131

Olson SF (1997) Listening point. University of Minnesota Press, Minneapolis, MN

Passchier-Vermeer W, Passchier WF (2000) Noise exposure and public health. Environ Health Persp Suppl 108(S1):123–131

Patricelli GL, Blickley JL (2006) Avian communication in urban noise: causes and consequences of vocal adjustment. Auk 123:639–649

Perrings C, Naeem S, Ahrestani F, Bunker DE, Burkill P, Caniani G, Elmqvist T, Ferrati R, Furhman J, Jaksic F, Kawabata Z, Kinzig A, Mace GM, Milano F, Mooney H, Prieur-Richard AH, Tschirhart J, Weisser W (2010) Ecosystem services for 2020. Science 330(6002):323–324

Pheasant RJ, Fisher MN, Watts GR, Whitaker DJ, Horoshenkov KV (2010) The importance of auditory-visual

interaction in the construction of 'tranquil space'. J Environ Psychol 30:501–509
Pijanowski BC, Villanueva-Rivera LJ, Dumyahn S, Farina A, Krause B, Napoletano BM, Gage SH, Pieretti N (2011a) Soundscape ecology: the science of sound in the landscape. Bioscience 61(3):203–216
Pijanowski BC, Farina A, Krause B, Dumyuhn S, Gage SH (2011b) What is soundscape ecology? Landscape Ecol. doi:10.1007/s10980-011-9600-8
Pilcher E, Newman P, Manning R (2009) Understanding and managing experiential aspects of soundscapes at Muir Woods National Monument. Environ Manage 43:425–435
Pimm SL, Russell GJ, Gittleman JL, Brooks TM (1995) The future of biodiversity. Science 269:347–350
Pressey RL, Cowling RM, Rouget M (2003) Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. Biol Conserv 112:99–127
Raloff J (2003) Hawaii's hated frogs. Sci News 163:11–13
Rands RW, Adams WM, Bennun L, Butchart SHM, Clements A, Coomes D, Entwistle A, Hidge I, Kapos V, Scharlemann JPW, Sutherland WJ, Bhaskar V (2010) Biodiversity conservation: challenges beyond 2010. Science 329(5997):1298–1303
Reide K (1993) Monitoring biodiversity: analysis of Amazonian rainforest sounds. Ambio 22:546–548
Reinjen R, Foppen R, Veenbaas G (1997) Disturbance by traffic of breeding birds: evaluation of the effect and consideration in planning and managing road corridors. Biodivers Conserv 6:567–581
Rogers EM (2003) Diffusion of innovations. Free Press, New York, NY
Rolston H III (1988) Environmental ethics: duties to and values in the natural world. Temple University Press, Philadelphia, PA
Sagoff M (2004) Price, principle, and the environment. Cambridge University Press, Cambridge, UK
Schafer RM (1994) The soundscape: our sonic environment and the tuning of the world. Destiny Books, Rochester, VT
Slabbekoorn H, Ripmeester EAP (2008) Birdsong and anthropogenic noise: implications and applications for conservation. Mol Ecol 17:72–83
Sonyerd L (2004) Hearing as a way of dwelling: the active sense-making of environmental risk and nuisance. Environ Plann D: Soc Space 22:737–753
Soulé ME (1985) What is conservation biology? Bioscience 35:727–734
Soulé ME, Sanjayan MA (1998) Conservation targets: do they help? Science 279:2060–2061
Southworth M (1969) The sonic environment of cities. Environ Behav 1:49–70
Stansfeld SA, Matheson MP (2003) Noise pollution: non-auditory effects on health. Br Med Bull 68:243–257
Staples SL (1996) Human response to environmental noise. Am Psychol 51:143–150
Stedman RC (2003) Is it really just a social construction?: the contribution of the physical environment to sense of place. Soc Nat Resour 16:671–685
Steins NA, Edwards VM (1999) Platforms for collective action in multiple-use common-pool resources. Agric Hum Values 16:241–255
Stone E (2000) Separating the noise from the noise: a finding in support of the "niche hypothesis," that birds are influenced by human-induced noise in natural habitats. Anthrozoos 13:225–231
Sueur J, Pavoine S, Hamerlynck O, Duvail S (2008) Rapid acoustic survey for biodiversity appraisal. PLoS ONE 3:e4065
Sutherland WL, Adams WM, Aronson RB, Avelin R, Blackburn TM, Broad S, Ceballos G, Côté IM, Cowling RM, da Fonseca GAB, Dinerstein E, Ferraro PJ, Fleishman E, Gascon C, Hunter M Jr, Hutton J, Kareiva P, Kuria A, MacDonald DW, MacKinnon K, Madgwick FJ, Mascia MB, McNeely J, Milner-Gulland EJ, Moon S, Morley CG, Nelson S, Osborn D, Pai M, Parsons ECM, Peck LS, Possingham H, Prior SV, Pullin AS, Rands MRW, Ranganathan J, Redford KH, Rodriguez JP, Seymour F, Sobel J, Sodhi NS, Stott A, Vance-Borland K, Watkinson AR (2009) One hundred questions of importance to the conservation of global biological diversity. Conserv Biol 23:557–567
Tarrant MA (1995) Factors affecting visitor evaluations of aircraft overflights of wilderness areas. Soc Nat Resour 8:351–360
Thompson EH (2002) The soundscape of modernity: architectural acoustics and the culture of listening in America, 1900–1933. MIT Press, Cambridge, MA
Torigoe K (2003) Insights taken from three visited soundscapes in Japan World Forum for Acoustic Ecology Symposium, Melbourne, Australia
Truax B (1999) Handbook of acoustic ecology. Cambridge Street Publishers, British Columbia, Canada
Turner WR, Brandon K, Brooks TM, Costanza R, da Fonseca GAB, Protela R (2007) Global conservation of biodiversity and ecosystem services. Bioscience 57: 868–879
UNEP, United Nations Environment Programme (1992) Convention on Biological Diversity. United Nations
van Jaarsveld AS, Freitag S, Chown SL, Muller C, Koch S, Hull H, Bellamy C, Kruger M, Enrody-Tounga S, Mansell MW, Scholtz CH (1998) Biodiversity assessment and conservation strategies. Science 279:2106–2108
Vitousek PM, Mooney HA, Lubchenco J, Melillo JM (1997) Human domination of Earth's ecosystems. Science 277:494–499
Villanueva-Rivera LS, Pijanowski BC, Doucette JR (2011) Sound 101: an introduction to acoustics for landscape ecologists. Landscape Ecol. doi:10.1007/s10980-011-9636-9
von Humboldt A, Bonpland A (1852) Personal narrative of travels to the equinoctial regions of America, during the years of 1799–1804. Henry G. Bohn, London
Westerkamp H (2002) Linking soundscape composition and acoustic ecology. Organised Sound 7:51–56
Whittaker RJ, Araujo MB, Jepson P, Ladle RJ, Watson JEM, Willis K (2005) Conservation biogeography: assessment and prospect. Divers Distrib 11:3–23
Wiens JA (2009) Landscape ecology as a foundation for sustainable conservation. Landscape Ecol 24:1053–1065
Williams DR, Stewart SI (1998) Sense of place: an elusive concept that is finding a home in ecosystem management. J For 96:18–25

Wilson EO (1984) Biophilia: the human bond with other species. Harvard University Press, Cambridge, MA
Wilson EO (1999) The diversity of life. W. W. Norton & Company, Inc., New York, NY
Wrightson K (2000) An introduction to acoustic ecology. Soundscape: J Acoustic Ecol 1:10–13
Zhang M, Kang J (2007) Towards the evaluation, description, and creation of soundscapes in urban open spaces. Environ Plann B: Plann Design 34:68–86
Zube EH (1987) Perceived land use patterns and landscape values. Landscape Ecol 1:37–45