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Review paper

Hearing sensitivity in context: Conservation implications for a highly vocal endangered species

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ABSTRACT

Hearing sensitivity is a fundamental determinant of a species' vulnerability to anthropogenic noise, however little is known about the hearing capacities of most conservation dependent species. When audiometric data are integrated with other aspects of species' acoustic ecology, life history, and characteristic habitat topography and soundscape, predictions can be made regarding probable vulnerability to the negative impacts of different types of anthropogenic noise. Here we used an adaptive psychoacoustic technique to measure hearing thresholds in the endangered giant panda; a species that uses acoustic communication to coordinate reproduction. Our results suggest that giant pandas have functional hearing into the ultrasonic range, with good sensitivity between 10.0 and 16.0 kHz, and best sensitivity measured at 12.5–14.0 kHz. We estimated the lower and upper limits of functional hearing as 0.10 and 70.0 kHz respectively. While these results suggest that panda hearing is similar to that of some other terrestrial carnivores, panda hearing thresholds above 14.0 kHz were significantly lower (i.e., more sensitive) than those of the polar bear, the only other bear species for which data are available. We discuss the implications of this divergence, as well as the relationship between hearing sensitivity and the spectral parameters of panda vocalizations. We suggest that these data, placed in context, can be used towards the development of a sensory-based model of noise disturbance for the species.

Contents

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1. Introduction

The large-scale transformation of the acoustic landscape by human activities may have significant consequences for wildlife (Francis, 2015; Francis and Barber, 2013; Shannon et al., 2015), as noise can readily permeate regulatory boundaries and can be detected in even the most remote protected areas (Barber et al., 2010). While the nature and severity of noise impacts is dependent upon the interaction of acoustic, biological, and abiotic environmental factors, this complexity should not preclude the development of predictive, mechanistic models that integrate key aspects of species biology and environmental parameters (Southall et al., 2007). Given the rapidly increasing footprint of noise-generating human activities, estimating impacts, predicting consequences, and developing targeted mitigation strategies may be essential to species and habitat conservation (Francis and Barber, 2013).

Hearing is the selective filter through which animals integrate acoustic signals, cues and inadvertent environmental sounds that promote successful reproduction and survival (Blanchet et al., 2010). However, hearing can also be a non-selective entryway through which audible noise may influence or impede communication (Bee and Swanson, 2007), or act as a disturbance (Shannon et al., 2015); ultimately influencing successful reproduction or survival. Thus, hearing sensitivity is a fundamental aspect of an animal's vulnerability to anthropogenic noise (Gerstein and Gerstein, 1999; Hastie et al., 2015). Because of this fundamental role in noise perception, data describing a species' hearing capacity should be a key component of models that predict noise impacts (Erbe and King, 2009; Gerstein and Gerstein, 1999), and efforts should be made to integrate audiometric data with data describing other aspects of species' acoustic ecology and the environmental soundscape (i.e., consider audiometric data 'in context', Ellison et al., 2011 and Southall et al., 2007). Here we model the integration of hearing sensitivity and the spectrographic characteristics of vocalizations of an endangered Ursid, the giant panda (*Ailuropoda melanoleuca*); exploring potential areas of acoustic vulnerability.

The Ursidae share a number of ecological and life history characteristics (Stirling and Derocher, 1990), however, they also diverge widely in the topography of their habitat – a factor which can shape the evolution of both signal design and hearing sensitivity (Morton, 1975) – and the use of acoustic signals for communication and survival (Jackson et al., 2010). Together, these factors suggest that hearing capacity may be varied among bear species, especially for those exhibiting dramatic differences in these characteristics and in the relative evolutionary distance between them (Kutschera et al., 2014; Stirling and Derocher, 1990). From a conservation perspective, this is important because differential hearing capacity will impact both the susceptibility to noise disturbance (Delaney et al., 1999), and the validity of extrapolating confamiliar hearing capacity from one species to the next. To date, the polar bear (*Ursus maritimus*), a relatively recently-evolved species of bear, is the only other Ursid for which audiometric data are available (Owen and Bowles, 2011).

The endangered giant panda (*Ailuropoda melanoleuca*) relies on acoustic communication for successful reproduction (Kleiman and Peters, 1990). Courtship and breeding are coordinated through multimodal signaling, however acoustic signals are prominent, especially during the peri-ovulatory period (Owen et al., 2013). The vocal repertoire of adult giant pandas ranges from intensity-graded agonistic vocalizations (Nie et al., 2012) to information-rich affiliative vocalizations (Kleiman and Peters, 1990). For example, characteristics of female chirps vary according to female reproductive stage (Charlton et al., 2010a), and characteristics of bleats contain information about male androgen levels and size (Charlton et al., 2011, 2012, 2009b), female age (Charlton et al., 2009b) and the identity of male and female callers (Charlton et al., 2009a,c). Male copulation calls convey information regarding mating success (Keating, 2011). Cubs emit a range of vocalizations that elicit discrete behavioral responses from mothers (Baotic et al., 2014) and may be essential for cub survival. Indeed, the vulnerability of highly altricial cubs during the denning period is well documented (Zhu et al., 2001), and den abandonment and cub mortality as a result of disturbance are of concern for all conservation dependent species of bear (Linnell et al., 2000).

The majority of free-ranging pandas inhabit wildlife reserves (State Forestry Administration, 2015), however, human pressures on habitat are intense and increasing. Further, climate projections indicate that within 50 years, these reserves may no longer hold suitable bamboo stands for giant pandas and populations may shift outside reserve boundaries in search of appropriate habitat (Tuanmu et al., 2012). These range shifts will increase the potential for giant pandas to be in increased proximity to human activities, thus exposing them to a suite of potentially disturbing acoustic stimuli (Zhu et al., 2013).

We used behavioral psychoacoustic techniques to measure hearing thresholds across frequencies and generate the first comprehensive audiogram for the species. We compare our findings to the audiogram of the polar bear (Owen and Bowles, 2011), to the relative spectral energy of adult and cub vocalizations, and to published data of the fundamental frequencies of cub and adult vocalizations (Baotic et al., 2014; Keating, 2011). We also discuss the implications of the panda's hearing