PERSPECTIVE

Anthropogenic noise in terrestrial Antarctica: a short review of background information, challenges and opportunities

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Abstract

Anthropogenic noise is an inevitable by-product of human activities. However, the potential effects of human noise on terrestrial Antarctica's ecosystems have been understudied. Documented impacts encompass stress, alterations in behavioural patterns, auditory masking, and, in severe instances, mortality. This Perspective note aims to call attention to human-generated noise as potential sources of impact on Antarctic wildlife and to highlight the potential of soundscape analysis as a flexible, cost-effective tool for environmental monitoring across Antarctica, complementing other non-invasive approaches. Acoustic monitoring in terrestrial environments has been extensively used in different parts of the world to assess biodiversity, monitor populations' status and trends, and identify and monitor sources of anthropogenic disturbance. Technological advances in passive acoustic monitoring allow for the gathering of detailed information with little need of human attention, and powerful processing tools and algorithms enable researchers to analyse large collections of audio data. Cold climates limit battery-operated instruments, but solar panels in Antarctic summer trials revealed over 100 days of unattended operation, which is promising for the incorporation of acoustic monitoring in Antarctica's environmental management toolbox.

Keywords

Antarctic soundscapes; acoustic monitoring; wildlife; environmental management; marine mammals; penguins

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Abbreviation

PAM: Passive Acoustic Monitoring

Introduction

Threats posed by human impacts on Antarctic environments and values have been widely reported. These include, but are not limited to, growing human activity, including both research and tourism, pollution, the introduction of non-native species and climate change (Tin et al. 2009; Hogg et al. 2020; Lee et al. 2022; Tejedo et al. 2022). However, potential disturbances and impacts from the ever-increasing development of infrastructure and logistics have only recently gained more visibility (Brooks et al. 2019; Hogg et al. 2020). Anthropogenic noise is an inevitable by-product of human activities and its effects on wildlife and ecosystem function have been reported worldwide (Shannon et al. 2016; Berger-Tal et al. 2019; Kok et al. 2023). In Antarctica, noise may have an impact on environmental, scientific, wilderness and aesthetic values, though an interest in the effects of human noise on Antarctica's environmental values has emerged only recently.

Since the early 2000s, a growing body of research has concerned noise from anthropogenic sources in the Antarctic marine environment (Dziak et al. 2015; Shannon et al. 2016; Duarte et al. 2021), including issues such as sources and levels of anthropogenic underwater noise, and the potential for interactions and impacts on Antarctic marine wildlife. However, research on the incidence and effects of anthropogenic noise in terrestrial environments has lagged. In fact, a preliminary systematic map of scientific literature on noise in terrestrial ecosystems in Antarctica published until 2020 (Acosta 2021), identified fewer than a dozen scientific articles mentioning terrestrial anthropogenic noise as an issue to be considered when assessing the impacts of human activities.

The aim of this note is to call attention to terrestrial sources of noise derived from human activities as potential sources of impact on Antarctic wildlife. The animal groups that will be most vulnerable to airborne anthropogenic noise will be pinnipeds and seabirds. However, because some sources of anthropogenic noise from terrestrial origin can also be perceived underwater, other groups such as fish, marine mammals and invertebrates could also be impacted (Shannon et al. 2016; Kunc & Schmidt 2019). We also seek to highlight the potential of soundscape recording analyses as a flexible, cost-effective tool for environmental monitoring across Antarctica,

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complementing other non-invasive approaches such as remote sensing, unoccupied aerial vehicles and camera traps, with local acoustic information collected on the ground by autonomous devices (Sveegaard et al. 2015; Francomano et al. 2023).

The soundscape is composed of all the sounds present in a landscape. Sounds from animals and from non-biological sources, such as wind and rain, are the most notable components of soundscapes in natural environments (Pijanowski et al. 2011). Urban areas are more characterized by sounds produced by humans, which are called anthrophonies (Pijanowski et al. 2011). However, there is increasing evidence that the acoustic footprint of humans can also be seen—or rather, heard—in natural areas (Barber et al. 2010; Buxton et al. 2017; Brooks et al. 2018; Brooks et al. 2019). Human activities are almost always accompanied by noise, which may propagate to areas well beyond the line of sight of the sound source. Terrestrial environments are subject to uncontrolled and rather unpredictable sources of noise. Although human sources of noise tend to be concentrated around human settlements, human-generated noise can travel into natural or protected areas and affect the values being protected (Buxton et al. 2017; Haver et al. 2020). In Antarctica, most human activities are concentrated at or near ice-free areas, which, because of their environmental characteristics, tend to be areas of particular importance for Antarctic flora and fauna (Tin et al. 2009; Brooks et al. 2019). Anthropogenic noise could be acting synergically with other stressors in these already fragile environments.

Acoustic monitoring in terrestrial environments has been extensively used in different parts of the world to assess biodiversity (Marques et al. 2013; Stevenson et al. 2021), to monitor the status and trends of animal populations (Law et al. 2018; Appel et al. 2023) and to identify and monitor sources of anthropogenic noise (Blumstein et al. 2011; Gibb et al. 2019). Although the range of ecosystems covered by these studies has been expanding, polar regions continue to be underrepresented, and this is particularly so for Antarctica. Some notable exceptions are the acoustic data sets of Alaskan soundscapes (Çoban et al. 2022) and Arctic bird sounds (Christin et al. 2023).

Anthropogenic noise in terrestrial Antarctica: sources and potential impacts

The primary sources of human-generated noise in Antarctic settings consist of aircraft, water and land vehicles, and diesel generators (Tin et al. 2009; Tiwari 2017). Additional sources include noise generated during construction and repair activities using electric tools, as well as sounds produced by footsteps and human voices (Ziegler, unpubl. data). Empirical evidence on the impacts of noise on wildlife elsewhere demonstrates that the effects of noise manifest at different levels, with varying degrees of severity. Responses to noise exposure are often behavioural in nature, potentially altering normal behavioural patterns (Barber et al. 2010). These include changes in the type and rate of vocalizations (Duquette et al. 2021), foraging activity and efficiency (Purser & Radford 2011) and antipredator responses (reviewed by Francis & Barber 2013). Animals can also exhibit physiological responses to noise, including hearing loss, increased stress hormone levels and hypertension, as documented in previous studies (reviewed by Shannon et al. 2016). A mass mortality event among penguins on Macquarie Island was attributed to a stampede likely triggered by the overflight of a large aircraft near the bird colony (Rounsevell & Binns 1991, cited by Harris 2005). Although reports of animal deaths caused by human-generated noise are very rare, they highlight our need to better understand the impact of anthropogenic noise on Antarctic wildlife. It is important to note that physiological responses can sometimes be inconspicuous, lacking visible external effects on wildlife. Recent studies have explored how individual-level responses can scale into demographic and community-level processes (Kleist et al. 2018; Jerem & Mathews 2021; Kleist et al. 2023; Kok et al. 2023).

Acoustic monitoring in terrestrial Antarctica: opportunities and challenges

Most of the articles reviewed by Acosta (2021) share a common view that there is a significant lack of scientific data on the impacts of noise on Antarctic wildlife and allowable noise thresholds, which does not allow working under a common standard (e.g. Tiwari 2017; Brooks et al. 2018). Most of the assessments and studies on the subject have been carried out in ice-free areas and during the austral summer. Current technological advances in passive acoustic monitoring allow for the gathering of detailed information with little need of human attention, while powerful processing tools and algorithms enable researchers to analyse large collections of audio data. However, recording in extreme environments such as those found in Antarctica presents special implementation difficulties. One such difficulty is the duration of batteries. Because Antarctica is a remote continent, and access to field sites is restricted by both logistic and management issues, being able to deploy instruments and leave them unattended for the longest duration possible is particularly desirable. Cold environments impose further restrictions on battery-run instruments because the

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rate of discharge is accelerated by exposure to cold temperatures. Pilot trials throughout the summer campaign 2022/23 have proven successful, with devices left unattended for over 100 days still recording when recovered (Acevedo et al. 2023).

Final considerations

To incorporate practices for managing anthropogenic noise in the Antarctic terrestrial environment, further knowledge and research on the subject is required. This includes aspects such as the identification of noise sources, their spectral and temporal characteristics (McKenna et al. 2016), their daily and year-round patterns, their effect on wildlife and their incidence as a source of cumulative impacts (Francis & Barber 2013; Kunc & Schmidt 2019). The spatial extent of sources of noise, especially in interaction with abiotic factors, should also be a matter of study. By understanding these factors, it becomes possible to develop targeted strategies for mitigating and managing noise pollution in the region.

Research to investigate the short and longer-term impacts of noise on wildlife should ideally employ standardized methodologies and experimental approaches to ensure consistent and comparable results across different sites and species (McKenna et al. 2016; Ferguson et al. 2023). Understanding how noise affects different species, their behaviour, reproductive success, physiology and overall well-being will aid in developing appropriate management measures to protect Antarctic wildlife.

The findings from such research can play a vital role in informing the management of terrestrial anthropogenic noise, particularly through the environmental impact assessment process (Gibb et al. 2019). Incorporating noise-related considerations into environmental impact assessments could help assess and minimize the potential negative effects of human activities on the acoustic environment. Additionally, the research can contribute to the development of management plans for protected areas, especially those located near regions with high levels of human activity. Integrating noise management strategies into protected area management plans makes it possible to mitigate the impact of noise on vulnerable ecosystems and wildlife populations.

At the same time, the use of acoustic monitoring can be implemented as a valuable tool for providing information on various aspects of the Antarctic environment. PAM systems can offer insights into the behaviour and distribution of wildlife, ecosystem structure and function, and the effects of human interventions. Examples of studies using PAM to understand communicative, foraging and sexual behaviour can be readily found for a variety of taxa (Browning et al. 2017; Gibb et al. 2019) and in diverse environments (Desjonquères et al. 2020; Sugai et al. 2020; Van Hoeck et al. 2021). Several studies have also used the soundscape to scale up the acoustic behaviour of different ecosystem components and link soundscape complexity to ecosystem function and integrity (Jerem & Mathews 2021; Kleist et al. 2023; Kok et al. 2023). In Antarctica, where more traditional survey methods, such as censuses and observational studies, are particularly costly, PAM can provide long-term information on species, populations and communities with little human intervention. Building cost-effective acoustic monitoring tools into regular environmental monitoring programmes will contribute to a more comprehensive understanding of human impacts. This information could then be used to guide decision-making processes and support effective conservation measures in Antarctica. The collaborative nature of scientific activities in Antarctica fosters opportunities for developing an acoustic monitoring network in key Antarctic sites, in harmony with other efforts towards an international environmental monitoring framework that would generate synchronous observation schemes across Antarctica. This might be particularly useful to monitor trends in breeding colonies and the impact of tourism activities in highly visited—yet remote—areas.

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