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# **Anthropogenic Noise in the Southern Ocean: an Update**



# Anthropogenic Noise in the Southern Ocean: an Update<sup>1</sup>

A Working Paper submitted by the Scientific Committee on Antarctic Research

## Summary<sup>2</sup>

Scientific knowledge regarding the effect of noise on marine wildlife continues to advance, based almost exclusively on studies outside the Antarctic region. Despite these advances in knowledge, the state-of-knowledge regarding the spatial and temporal distribution of sound sources, the real-world characteristics and distribution of anthropogenic noise and the environmental factors that determine its effects on receptor organisms and/or populations, is judged by experts to be fair to good. How marine wildlife will respond to exposures to noise remains largely unknown with no information for many important species. While there is improved knowledge of the effects of noise on several cetacean species, there remains a lack of research on marine species endemic to Antarctica, including little knowledge of population level effects and variations in effects with life stage. Due to the lack of fundamental knowledge, current approaches to mitigation and management remain largely unverified as to effectiveness in avoiding and/or reducing detrimental effects. Expanded monitoring of natural ambient and anthropogenic sound in Antarctic marine environments is needed to fully assess real-world noise exposure scenarios. While at an early stage, identification of “sound-sensitive” Antarctic species, potential “sound hotspots” in Antarctica and cumulative effects are beginning to emerge. Further studies of the responses of Antarctic species and populations to anthropogenic noise are essential to advancing evidence-based policies that are practicable while achieving conservation goals.

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<sup>1</sup>This paper utilizes the definitions established by the International Organization of Standards (ISO) 18405:2017 <https://www.iso.org/standard/62406.html> which defines terms and expressions used in the field of underwater acoustics, including natural, biological and anthropogenic (i.e. man-made) sound. In particular, the distinction between the usage of ‘sound’ and ‘noise’:

**3.1.1.1 sound**, alteration in pressure, stress or material displacement propagated via the action of elastic stresses in an elastic medium and that involves local compression and expansion of the medium, or the superposition of such propagated alterations

- Note 1 to entry: The medium in which the sound exists is often indicated by an appropriate adjective, e.g. airborne, water-borne, or structure-borne.
- Note 2 to entry: In the remainder of this document, the medium is assumed to be a compressible fluid.
- Note 3 to entry: A sound wave is a realization of sound.
- Note 4 to entry: The word “sound” may also be used as part of a compound noun, in which case, it is a synonym of “acoustic”. For example, “acoustic pressure” and “acoustic power” are synonyms of sound pressure (3.1.2.1) and sound power (3.1.3.14).

**3.1.1.2 ambient sound**, sound (3.1.1.1) that would be present in the absence of a specified activity

- Note 1 to entry: Ambient sound is location-specific and time-specific.
- Note 2 to entry: In the absence of a specified activity, all sound is ambient sound.
- Note 3 to entry: Ambient sound includes ambient noise (3.1.5.11).
- Note 4 to entry: Examples of specified activity include the act of measuring the underwater sound and the radiation of sound by specified sound sources.
- Note 5 to entry: Ambient sound can be anthropogenic (e.g. shipping) or natural (e.g. wind, biota).

**3.1.5.9 noise**, time-varying electric current, voltage, sound pressure (3.1.2.1), sound particle displacement (3.1.2.9), or other field quantity except the signal (3.1.5.8) or signals

<sup>2</sup> From ATCM XLI, IP 28 (2018) - The focus of SCAR's review is anthropogenic noise. To any potential receiver (i.e., an individual of a species or a population) there are three categories of acoustic energy of interest: i) ambient sound, ii) biological sound – self-generated signals (e.g., vocalizations) or signals from potential predators or prey; and iii) noise - sound energy generated by human activities that is known to cause negative effects in the receiver. Noise as a term is ubiquitous in the scientific literature documenting the occurrence of impacts, or the lack thereof, in the presence of unwanted acoustic energy.

## **Introduction<sup>3</sup>**

This Working Paper (WP) reviews what is known about sound in Antarctic marine environments. It then outlines what is known about the impacts of anthropogenic sound on marine wildlife, and looks at emerging research on ‘sound sensitive’ species and sound hotspots. Finally it discusses in detail the gaps in the current state of knowledge and how they can be addressed.

This WP is provided in response to a request from CEP XVII (2014) that SCAR update information on anthropogenic sound in the Southern Ocean since ATCM XXXV Information Paper 21 (SCAR, 2012). In this process, SCAR first commissioned a comprehensive literature review in the 2016/17 intersessional period. SCAR then convened a committee of experts, overseen by an independent Chair in late 2017 to provide further advice on this issue, and bring all relevant information together. This information is provided in Background Paper (BP) 3, which supports this WP. Further details of the consultation process are provided in ATCM XLI Information Paper 28.

Peer-reviewed publications are solely considered in this update. From 2012 to 2018, several reviews examined sound sources and characteristics and the potential for impacts on marine wildlife. A comprehensive review was recently published detailing the current state of knowledge on underwater noise in the Arctic<sup>4</sup> and the findings are broadly consistent with those outlined in this update.

Since 2012, progress has been made in describing and measuring real-world acoustic environments. Evidence that anthropogenic noise can affect marine life continues to accumulate. Research is improving assessments of the biological significance of observed responses to sound, and understanding of the potential for population level and cumulative impacts, but much remains unknown. Understanding of the sources and types of anthropogenic sound present in Antarctic marine waters, as assessed by the expert panel (see BP 3 2019) is fair to good but often lacking completeness and important details. The state-of-knowledge of potential impacts for: 1) cetaceans (and marine mammals in general) is fair to good, 2) pinnipeds is poor to fair, 3) seabirds is poor, 4) fishes is fair and 5) invertebrates is poor – with a notable lack of knowledge about sounds’ impacts on species endemic to the Antarctic region. The state-of-knowledge regarding the effectiveness of mitigation and management approaches is poor to fair. Few studies quantify the effectiveness of mitigation and/or management efforts in meeting conservation goals.

## **Natural Ambient Sound**

Natural ambient sound in Antarctic marine environments is comparable to sound in other parts of the ocean. There is more spatial and seasonal variability in natural sounds in Antarctic waters than at lower latitudes due to the presence of and changes in ice in its many forms. The levels of natural ambient sound remain incompletely quantified in Antarctic marine environments.

## **Anthropogenic Sound**

Sources of anthropogenic sound found in Antarctic marine environments include ships, scientific seismic surveys and echosounders (for navigation, biomass estimation, current profiling, depth sounding, and sub-bottom profiling). Anthropogenic sound source types and characteristics in the Antarctic are reasonably well known though spatial and temporal variability is not well characterized.

<sup>3</sup> From ATCM XLI, IP 28 (2018) – “Experts advised SCAR that within the audiology and auditory physiology communities, noise is defined as “an aperiodic signal that interferes with the perception of sound...” For noise exposures a distinction is made between sound as a physical phenomenon and noise as an unwanted sound that is dependent upon the perception of a receiver. The anthropogenic sounds of interest to policy makers are the signals that are corruptive to ecological processes, communication, perception, and/or behavior. Not all signals produced by human activities can be perceived by all species and responses are species and environmental setting specific. A signal is a sound that becomes noise only and when a receiver determines it to be disturbing, unwanted, or stressful.

<sup>4</sup> PAME (2019) Underwater Noise in the Arctic: A State of Knowledge Report, Rovaniemi, May 2019. Protection of the Arctic Marine Environment (PAME) Secretariat, Akureyri

The numbers and density of ships navigating Antarctic waters is low compared with other regions of the world's ocean. Fishing activities in Antarctic waters are far lower than those conducted in other regions of the world's oceans. A more complete understanding of Antarctic regional sound sources must consider all types of activities and associated sound producing sources.

### ***Marine Wildlife and Anthropogenic Sound***

Variations in methodologies amongst studies makes comparisons challenging. Caution should be used when extrapolating findings from other regions of the world's oceans to Antarctic marine environments and species. Some studies of wild populations either occur (or have closely related taxa occurring) in Antarctic waters and these are more applicable.

#### **Cetaceans**

Cetaceans are the most studied aquatic mammals and the state-of-knowledge of responses to sound exposures is fair to good. Whale responses to anthropogenic sound are variable depending on the species, sound source characteristics and source-animal distance. Anthropogenic sound interferes with hearing, can cause marine mammals to interrupt their feeding, alter their vocalizations, or leave important habitat, among other behavioural and physiological responses. Data on sound-induced threshold shifts in marine mammals are available for only a few species and questions remain about extrapolating these results to other species. Cetaceans are a likely priority for mitigation/management attention due to their iconic nature and research indicating the potential for impacts.

#### **Pinnipeds**

The state-of-knowledge of potential impacts of anthropogenic sound on pinnipeds is poor to fair. Much of the research on pinnipeds and sound has focused on effects on hearing.

#### **Fish**

The state-of-knowledge of potential impacts of anthropogenic sound on fish is fair. Studies of fishes, while limited, have indicated possible hearing, physiological and behavioural responses to anthropogenic noise exposures. Some of the observed responses may have implications for population/fisheries-level impacts. Differences in methodologies make comparisons difficult. There are no studies on the effects of anthropogenic sounds on Antarctic fishes. It is uncertain how, or if, the observed responses, or the lack of responses, in non-Antarctic fishes might be expressed in Antarctic fish species.

#### **Invertebrates**

The state-of-knowledge of potential impacts of anthropogenic sound on invertebrates is poor. There is a lack of consensus over how results obtained from experimental and/or laboratory studies translate to real-world sound exposure scenarios. Understanding the role particle motion plays in sound exposure responses in invertebrates is limited but it may be important. There is little knowledge about how individual invertebrate responses translate to community or population-level effects. Understanding of how sound exposure affects early life-stages of invertebrates is limited, with some indications that it may be significant.

#### **Seabirds**

The state-of-knowledge of potential impacts of anthropogenic sound on seabirds is poor. There is little data on the effect of underwater sounds on Antarctic diving birds.

### ***Sound-Sensitive Antarctic Species and Sound "Hotspots"***

Evidence identifying which Antarctic species may be most vulnerable to anthropogenic sound exposure is incomplete, however early results point to candidate species. Some cetacean species are a

likely high priority group for protection due to their iconic status and the availability of research indicating potential impacts. Identification of areas of concentrated anthropogenic noise (sound “hotspots”) and species judged to be sensitive to sound exposure (“sound-sensitive species”) would inform policy by providing an indication of the juxtaposition of areas of greatest exposure risk with distributions of the most vulnerable species. Although at an early stage, predictions of where high-risk noise exposure areas intersect with the locations of sound sensitive species could help target mitigation and management efforts.

### ***Cumulative Impacts***

Cumulative effects of anthropogenic sound on animal populations may result from repeated interruptions of feeding, displacement from breeding areas, elevated levels of stress hormones, masking of communications, masking of predator sounds and changes to migration tracks. These effects may be particularly detrimental to small, endangered populations.

### ***Mitigation and Management***

The state-of-knowledge regarding the effectiveness of mitigation and management of anthropogenic sound in the oceans is poor to fair with few studies that quantify the success of mitigation and/or management efforts. For sources such as seismic or sonar, operational mitigation to date has largely focused on limiting exposure. Reducing the power of the source, or shutting it down if vulnerable species are close, is commonly used to attempt to reduce the risk of injury. The most commonly-used marine mammal sound mitigation regime includes Marine Mammal Observers (MMO) or Passive Acoustic Monitoring (PAM) to detect animals close to the source. There is a lack of evidence-based assessments of the effectiveness of mitigation and management protocols in accomplishing explicit conservation/protection goals. There are no studies in the Antarctic region or for Antarctic species. No single monitoring method is likely to detect all animals in all conditions and environments, therefore a combination of methods will improve the effectiveness of impact risk reduction.

### ***Concluding Remarks***

There are significant gaps in scientific knowledge essential to advancing evidence-based policy-making regarding the impacts of noise in Antarctic marine environments. Addressing these gaps will require:

- Expanding the scope of studies of species and taxonomic groups’ exposure-response to anthropogenic noise.
- Standardizing methodologies, experimental approaches and metrics of effectiveness.
- Improving knowledge of the spatial and temporal scales of natural ambient and anthropogenic sound in Antarctic waters.
- Conducting risk assessments that determine the likelihood that individuals and populations will be exposed to harmful levels of sound.
- Facilitating accessibility to all types of data and encouraging data sharing.
- Improving mitigation and management solutions.
- Continuing to monitor developments in regard to anthropogenic sound in the Southern Ocean.
- Fostering a collaborative relationship between all stakeholders.

Anthropogenic noise in the world’s ocean will continue to be of interest for the foreseeable future. Formulation of robust mitigation and management actions require a more complete understanding of a diverse set of factors. Better definition of the vulnerabilities of species and life stages, and when anthropogenic sounds become noise, will be essential for effective mitigation and management

strategies. A better understanding of how organisms, populations and ecosystems respond to anthropogenic noise in the context of complex and multiple environmental pressures will be critical.

***Recommendations***

SCAR recommends that the CEP:

- 1) Encourages the development of research and other activities, which are outlined in the concluding remarks above, to address gaps in the evidence-base needed to support the development of decision-making and policy regarding the impacts of noise in the Antarctic environment.