

## Introduction to the special issue on the effects of sound on aquatic life

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### ABSTRACT:

The effects of anthropogenic (man-made) underwater sound on aquatic life have become an important environmental issue. One of the focal ways to present and to share knowledge on the topic has been the international conference on The Effects of Noise on Aquatic Life (“Aquatic Noise”). The conferences have brought together people from diverse interests and backgrounds to share information and ideas directed at understanding and solving the challenges of the potential effects of sound on aquatic life. The papers published here and in a related special issue of *Proceedings of Meetings on Acoustics* present a good overview of the many topics and ideas covered at the meeting. Indeed, the growth in studies on anthropogenic sound since the first meeting in 2007 reflects the increasing use of oceans, lakes, rivers, and other waterways by humans. However, there are still very substantial knowledge gaps about the effects of sound on all aquatic animals, and these gaps lead to there being a substantial need for a better understanding of the sounds produced by various sources and how these sounds may affect animals.

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## I. INTRODUCTION

This paper introduces the special issue of *The Journal of the Acoustical Society of America* (JASA) that deals with the very broad topic of effects of man-made sound on animals living in the aquatic environment. The idea for this special issue grew out of the fifth meeting on this topic that took place in Den Haag, The Netherlands, in July 2019.<sup>1</sup>

Over 200 papers were presented at the meeting, and while not all are published here or in the accompanying special issue of *Proceedings of Meetings on Acoustics* (POMA)<sup>2</sup> the combined published papers present a good overview of the many topics and ideas covered at that meeting. Those interested in learning more about the meeting itself, and its history, can find that in a summary paper by Erbe *et al.* (2019).

In addition to the papers that are here from the 2019 meeting, there is an extensive collection of papers from the four earlier meetings on The Effects of Noise on Aquatic Life. Papers from the fourth meeting 2016 in Dublin were published in POMA<sup>3</sup> (see Erbe *et al.*, 2016b), while papers from the third meeting in 2013 in Budapest, Hungary, were published in Popper and Hawkins (2016) and those from the second meeting in 2010 in Cork, Ireland, are found in Popper and Hawkins (2012). The first meeting, initiated by Arthur N. Popper, Anthony D. Hawkins, and Magnus Wahlberg, took place in Nyborg, Denmark, in 2007 and only had abstracts published (Hawkins *et al.*, 2008).

## II. PURPOSE OF THE MEETINGS AND SPECIAL ISSUE

The effects of sound on aquatic life is a complex scientific area, as can be seen by the diversity of papers in this special issue as well as in the papers from the previous meetings. While the focus of the meetings is on effects (and potential effects) on diverse animal species, understanding the animal-related issues, including behavior and physiology, requires understanding a variety of highly specialized disciplines that

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include, but certainly are not limited to, theoretical physics and acoustics (e.g., numerical modeling of sound waves), engineering management (e.g., development of mitigation measures), bioacoustics environmental policy, and ecology.

Generally, there is very little opportunity for individuals with interests in specific disciplines (e.g., underwater acoustics, animal physiology, and regulation) to meet and learn from one another since they often go to different scholarly meetings (though, importantly, meetings of the Acoustical Society of America, ASA, may be the one place for people from different disciplines to get to interact). Moreover, since those interested in various aspects of the effects of anthropogenic sound come from different disciplines, they publish in very different places. Thus (and again with JASA being a unique exception), it becomes rather difficult to really see and appreciate the breadth of interest in, and issues related to, the effects of man-made sound on aquatic life.

One of the hallmarks of each of the conferences is that participants can meet, hear, and learn about the issues confronting investigators, decision makers, aquatic industries, and environmental groups. This type of conference has led not only to better communication, but it has also helped investigators understand the kind(s) of research that would be most useful in finding solutions to regulatory and other applied science issues. Thus, the uniqueness of this meeting is that it brings together people interested in effects of sound on aquatic life from diverse interests and backgrounds and provides them with an environment where all can share information and ideas.

At the 2019 conference, a wide range of topics were discussed including the anthropogenic effects of underwater sound on aquatic animals such as those generated by explosions, ships, seismic exploration, offshore construction, sonars of various types, acoustic deterrent devices, wind farms, tide and wave generators, and of course sounds made by aquatic animals themselves. A number of these papers are published here and in the aforementioned POMA issue. These papers reflect the uniqueness of this topic in that they bring together work from diverse interests and backgrounds with the purpose of sharing information and ideas across disciplines. Indeed, the diversity of the papers highlight the need to make use of complementary knowledge and skills to resolve challenges regarding the effects of sound on aquatic life.

### III. OVERVIEW OF PAPERS

Sections A–E briefly describe the topics that were covered at the meeting and which are reflected in this special issue. Each section also lists the papers that cover the topic and reflects the Table of Contents (TOC) of the special issue of JASA. At the same time, it is important to understand that many of the papers at the meeting and in this issue overlap multiple areas, or may even cover topics that are not in the TOC. Thus, each reader may have their own perspective on how the papers should be organized. To reflect this

breadth of various papers, in each section, we not only mention the papers that we define as being there but related papers from other sections.

It is also useful to point out the taxonomic distribution of papers at the meeting and in this document. The proportion of taxa covered matches a general trend that we have encountered in all five of the meetings. In each case, the largest number of papers covered investigations on marine mammals, followed by studies on fishes and invertebrates (indeed, the first meeting had no papers on invertebrates). As Popper *et al.* (2020) recently pointed out, there is a need to increase the “share” of studies on fishes and invertebrates as these represent by far the largest proportion of the animal biomass in the world’s oceans and effects on each taxon could also lead to wider ecosystem impacts (e.g., impacts on the food chain).

#### A. Sound sources and soundscape

The *sound sources* and acoustic characteristics of all biotic and abiotic ambient sounds present in a particular location and time are collectively defined as the *soundscape* (ISO, 2017). The papers that fall under the *sound sources* and *soundscape* category deal with sources as diverse as impact pile driving, which is important in the context of offshore wind farm development (Stöber and Thomsen, 2019), ferries and other coastal maritime traffic, and tidal stream turbines (Amaral *et al.*, 2020; Parsons *et al.*, 2020; Magnier and Gervaise, 2020; Risch *et al.*, 2020; van Geel *et al.*, 2020). Papers in this category also include the analysis of soundscapes in large estuaries (the St. Lawrence river; Giard *et al.*, 2020), submarine canyons (Bolgan *et al.*, 2020), seamounts (Haver, 2020) and near a rocky shore (Jesus *et al.*, 2020). Two papers explore metrics for analyzing and managing soundscapes (Martin *et al.*, 2019; Müller *et al.*, 2020).

#### B. Sound production and communication

Marine animals use sound for a variety of purposes such as navigation, foraging, and communication. Thus, papers dealing with *sound production* and *communication* were an integral part of every aquatic noise meeting from the start. The papers presented in this issue cover a range of taxa including invertebrates (Moyano *et al.*, 2019), fishes (Hawkins and Picciulin, 2019; Riera *et al.*, 2020), and marine mammals (Guilment *et al.*, 2020; Holt *et al.*, 2019; Wei *et al.*, 2020).

#### C. Hearing and masking

Next are studies on *hearing* and *masking* (defined as the effect whereby an unwanted sound (the masker) decreases the ability to detect a wanted sound). The papers in this category include the provision of a best practice guidance on how to perform hearing studies in fishes (Popper *et al.*, 2019), the effects of sound stimuli on the hearing systems of harbor seals (Kastelein *et al.*, 2020) and dolphins (Finneran, 2020), and the spatial release from masking in bottlenose

dolphins (*Tursiops truncatus*) (Popov *et al.*, 2020). The latter describes the phenomenon when a decrease (release) from expected masking occurs when signal and noise sources are located at different positions (Erbe *et al.*, 2016a). Morrison *et al.* (2020) take the interesting approach to study how humans discriminate acoustically among bottlenose dolphin whistles with and without masking by boat noise to develop a hypothesis on whistle masking that can be tested further. The *hearing and masking* category also includes a paper analyzing how auditory masking can be addressed in marine environmental management (Pine *et al.*, 2020).

#### D. Effects

The section on *effects* comprises 14 papers and is the largest category in the special issue. Nine of the papers deal with marine mammals and include the categories of effects of sound as described by Hawkins and Popper (2016): the behavioral response to masking effects are addressed in two studies by Helble *et al.* (2020) and Thode *et al.* (2020) that describe the Lombard Effect where senders alter vocal behavior by changing calling parameters such as level, repetition rate, or frequency. The paper by Popov *et al.* (2020) from the masking section can also be placed here as spatial release is a behavioral reaction to masking. Other effects covered are behavioral response (other than the Lombard effect) (Caruso *et al.*, 2020; Trigg, 2020; Varghese *et al.*, 2020), impaired hearing (Schaffeld *et al.*, 2019; Schaffeld *et al.*, 2020; Whyte *et al.*, 2020), and physiological effects (Houser *et al.*, 2020), which are of importance as these have the potential to impact the health of an individual animal. Effects on fishes are covered by four investigations dealing with the behavioral response in Eurasian minnows (*Phoxinus phoxinus*) to tones of differing pulse repetition rate (Currie *et al.*, 2020), the effect of low-frequency noise on the behavior of juvenile Gilt-head seabream (*Sparus aurata*; Mauro *et al.*, 2020), physical effects of sound exposure from underwater explosions on Pacific sardines (*Sardinops sagax*; Dahl *et al.*, 2020), and molecular and cellular responses to long-term sound exposure in peled (*Coregonus peled*) (Sapozhnikova *et al.*, 2020). Only one paper covers the emerging issue of sound effects on invertebrates (Vazzana *et al.*, 2020).

#### E. Regulation, monitoring, and management

The category *regulation, monitoring, and management* includes papers covering automatic detection and classification of cetacean calls (Kirsebom *et al.*, 2020; Madhusudhana *et al.*, 2020) and a best practice for setting noise exposure criteria for fishes, a topic of particular importance for the management of anthropogenic sound (Hawkins *et al.*, 2020). This category also includes a study looking at techniques for distinguishing between impulsive and non-impulsive sound in the context of regulating sound exposure for marine mammals (Martin *et al.*, 2020) and another evaluating the predictive strength of underwater noise exposure criteria for marine mammals (Lucke *et al.*, 2020). Two

studies discuss and explain the international management and regulation of anthropogenic underwater sound (Colbert, 2020; Lewandowski and Staaterman, 2020). There are a variety of papers from other categories that are also relevant to this section (Bolgan *et al.*, 2020; Giard *et al.*, 2020; Martin *et al.*, 2019; Schaffeld *et al.*, 2019; Ainslie *et al.*, 2020; Parsons *et al.*, 2020; Pine *et al.*, 2020; Schaffeld *et al.*, 2020).

#### IV. CONCLUSIONS

As pointed out earlier in Sec. I, the papers presented in this special issue of JASA and the accompanying special issue of POMA, along with earlier publications from the past conferences on The Effects of Noise on Aquatic Life, represent a broad overview of a topic that is growing in interest world-wide. This growth reflects the increasing use of the oceans, lakes, rivers, and other waterways not only for exploration and production of energy, but also increased need for shipping, boating, and numerous other activities. However, as pointed out in several recent papers, there are very substantial gaps in our knowledge about the effects of sound on all aquatic animals, and also a very substantial need for better understanding of the sounds produced by various sources and how they may affect animals (e.g., Popper *et al.*, 2014, 2020; Southall *et al.*, 2019; Hawkins *et al.*, 2020).

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- <sup>1</sup>Information on the 2022 Effects of Noise on Aquatic Life Conference available at <https://an2022.org> (Last viewed August 5, 2020).
- <sup>2</sup>Accompanying special issue of POMA for the 2019 meeting available at <https://asa.scitation.org/toc/pma/37/1?size=all> (Last viewed August 5, 2020).
- <sup>3</sup>Papers from the 2016 meeting published in POMA available at <https://asa.scitation.org/toc/pma/27/1?size=all> (Last viewed August 5, 2020).
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