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ASA S3/SC1.4 TR-2014

Sound Exposure Guidelines for Fishes and Sea Turtles:

A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI

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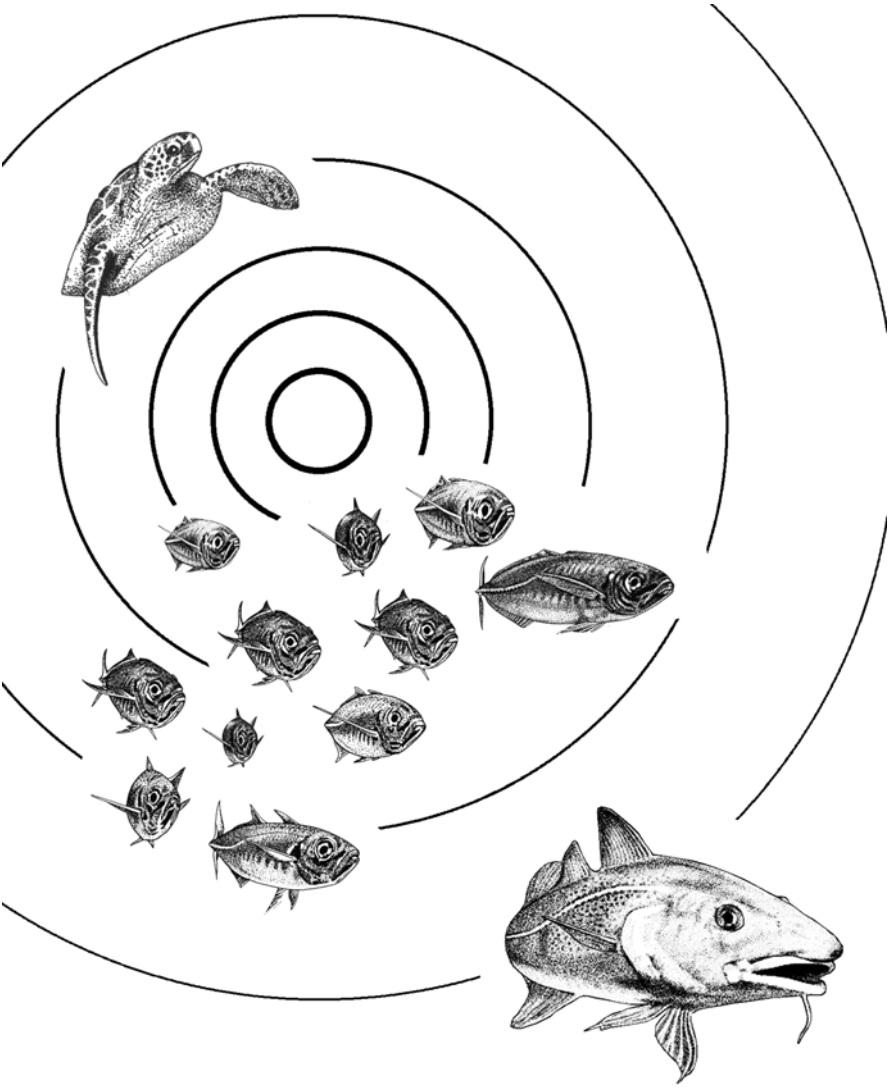
Acoustical Society of America

The mission of the **Acoustical Society of America** (www.acousticalsociety.org) is to increase and diffuse the knowledge of acoustics and promote its practical applications. The ASA is recognized as the world's premier international scientific society in acoustics, and counts among its more than 7,000 members professionals in the fields of bioacoustics, engineering, architecture, speech, music, oceanography, signal processing, sound and vibration, and noise control.

Since its first meeting in 1929, The Acoustical Society of America has enjoyed a healthy growth in membership and in stature. The present membership of approximately 7,000 includes leaders in acoustics in the United States of America and other countries. The Society has attracted members from various fields related to sound including engineering, physics, oceanography, life sciences, noise and noise control, architectural acoustics; psychological and physiological acoustics; applied acoustics; music and musical instruments; speech communication; ultrasonics, radiation, and scattering; mechanical vibrations and shock; underwater sound; aeroacoustics; macrosonics; acoustical signal processing; bioacoustics; and many more topics.

To assure adequate attention to these separate fields and to new ones that may develop, the Society establishes technical committees and technical groups charged with keeping abreast of developments and needs of the membership in their specialized fields. This diversity and the opportunity it provides for interchange of knowledge and points of view has become one of the strengths of the Society.

The Society's publishing program has historically included the *Journal of the Acoustical Society of America*, the magazine *Acoustics Today* (www.acousticstoday.org), a newsletter, and various books authored by its members across the many topical areas of acoustics. In addition, ASA members are involved in the development of acoustical standards concerned with terminology, measurement procedures, and criteria for determining the effects of noise and vibration.



Abstract

This Technical Report presents the outcome of a Working Group that was established to determine broadly applicable sound exposure guidelines for fishes and sea turtles. After consideration of the diversity of fish and sea turtles, guidelines were developed for broad groups of animals, defined by the way they detect sound. Different sound sources were considered in terms of their acoustic characteristics and appropriate metrics defined for measurement of the received levels. The resultant sound exposure guidelines are presented in a set of tables. In some cases numerical guidelines are provided, expressed in appropriate metrics. When there were insufficient data to support numerical values, the *relative* likelihood of effects occurring was evaluated, although the *actual* likelihood of effects depends on the received level. These sound exposure guidelines, which are based on the best scientific information at the time of writing, should be treated as interim. The expectation is that with more research, the guidelines can be refined and more cells in the tables completed. Recommendations are put forward defining the research requirements of highest priority for extending these interim exposure guidelines.

Foreword

[*This Foreword is for information only, and is not a part of the Technical Report ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles*.]

This Technical Report comprises a part of a group of definitions, standards, and specifications for use in animal bioacoustics. It was developed and approved by Accredited Standards Committee S3/SC 1 Animal Bioacoustics, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S3/SC 1 is as follows:

> Standards, specifications, methods of measurement and test, instrumentation, and terminology in the field of psychological and physiological acoustics, including aspects of general acoustics which pertain to biological safety, tolerance, and comfort of non-human animals, including both risk to individual animals and to the long-term viability of populations. Animals to be covered may potentially include commercially grown food animals; animals harvested for food in the wild; pets; laboratory animals; exotic species in zoos, oceanaria or aquariums; or free-ranging wild animals.

Publication of this Technical Report that has been registered with ANSI has been approved by the ANSI-Accredited Standards Committee S3/SC 1, Animal Bioacoustics. This document is registered as a Technical Report according to the Procedures for the Registration of Technical Reports with ANSI. This document is not an American National Standard and the material contained herein is not normative in nature. Comments on the content of this document should be sent to Standards Secretariat of the Acoustical Society of America, 1305 Walt Whitman Rd., Ste. 300 Melville, New York 11747-4300. Telephone: 631-390-0215; FAX: 631-923-2875; E-mail: asastds@aip.org.

As required by ASC S3/SC 1's operating procedures, this Technical Report will be subjected to periodic review by ASC S3/SC 1 at least every five years. However, it is possible that the committee will revise or withdraw it at any time. Users should check to confirm if a newer version is available.

The rationale for publishing this technical report is detailed in the Introduction.

At the time this Technical Report was submitted to Accredited Standards Committee S3/SC 1, Animal Bioacoustics, for approval the membership was as follows:

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Working Group S3/SC 1/WG 2, Effects of Sound on Fish and Turtles, which assisted Accredited Standards Committee S3/SC 1, Animal Bioacoustics, in the development of this Technical Report, had the following membership.

R.R. Fay, Co-Chair
A.N. Popper, Co-Chair

S. Bartol	R.L. Gentry	P.H. Rogers
T.J. Carlson	M.B. Halvorsen	B.L. Southall
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Keywords

Acoustics, Active Sonar, Anthropogenic, Airgun, Air-gun, Audiogram, Auditory Scene Analysis, Barotrauma, Behavior, Criteria, Ear, Eggs, Damage, Directional Hearing, Explosions, Explosives, Fitness, Frequency Weighting, Hearing, Injury, Intensity, Larvae, Lateral Line, Masking, Noise, Particle Motion, Peak, Pile Driving, Pressure, PTS, RMS, Scene Analysis, Seismic Airgun, Ship, Sonar, Sound Exposure Level, Swim Bladder, Threshold, Threshold Shift, TTS

Acknowledgements

The need for this panel was identified by Roger Gentry, then at NOAA in the U.S. Department of Commerce. He and Brandon L. Southall, also then at NOAA, identified the original panel members and allocated NOAA funds for its first three meetings. Subsequently, support for the meetings was provided by the National Science Foundation, the Office of Naval Research, and the Joint Industry Program (JIP) of the Oil and Gas Producers Association. Additional funds and support were provided by the Acoustical Society of America (ASA). We are grateful to all of these agencies for their support. Most of our meetings took place at the Mote Marine Laboratory in Sarasota, Florida. We want to thank the staff at Mote for their hospitality and their efforts to make the meetings comfortable and productive. We are grateful to members of the ANSI-Accredited Standards Committee S3/SC 1, Animal Bioacoustics, which is sponsored by the Acoustical Society of America, for their thorough and very useful review of this MS. Finally, we thank Dr. Peggy Edds-Walton for editing the final MS and Susan Blaeser of ASA for additional thoughtful suggestions.

Contents

Chapter 1
Introduction

1.1 Background

In many countries, legislation requires the assessment of sound-producing activities that may have an impact on animals in the aquatic environment (TNO 2011; Johnson 2012; Lewandowski et al. 2012; Tasker 2012, 2015; Dekeling et al. 2015; Gedamke et al. 2015). There is also often a requirement to prepare environmental assessments or statements that can lead to mitigation measures and/or restrictions for proposed activities. Because few scientific data are available regarding the effects of sound, particularly for fishes and sea turtles, assessment procedures and subsequent regulatory and mitigation measures are often severely limited in their relevance and efficacy. This creates uncertainty among all stakeholders as to how sound-producing exploration and operations should proceed.

In 1998 the U.S. National Oceanic and Atmospheric Administration (NOAA) convened an international panel of experts to prepare noise exposure guidelines for marine mammals. NOAA's intent was to provide its regulatory staff with the means of issuing permits on underwater noise production based on a set of organized principles and facts instead of on a case-by-case basis. The aim was to reduce regulatory uncertainty for all stakeholders by replacing precaution with scientific facts. The panel's initial guidelines appeared in a seminal paper (Southall et al. 2007).

In 2004, NOAA convened a similar panel to develop noise exposure criteria for fishes and turtles with the same goals in mind. It included three members of the marine mammal panel (WTE, RLG, and BLS) for continuity. When NOAA's support for this effort ended in 2006, the panel was organized as a Working Group (WG) under the ANSI-Accredited Standards Committee S3/SC 1, Animal Bioacoustics, which is sponsored by the Acoustical Society of America.

In addition, this Working Group, through its own efforts, obtained external funding for the project (see Acknowledgements). The Working Group met eight times between 2004 and 2010. It gathered and reviewed papers from both the peer-review and grey literature that presented data on the exposure of fish and sea turtles to

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