Progress since the 2016 National Marine Fisheries Service’s Marine Mammal Technical Guidance

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Progress since the 2016 National Marine Fisheries Service’s Marine Mammal Technical Guidance

Amy R. Scholik-Schlomer

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In July 2016, the National Oceanic and Atmospheric Administration’s National Marine Fisheries Service (NMFS) published Technical Guidance for assessing the effects of underwater sound on marine mammal hearing (i.e., thresholds for the onset of permanent and temporary threshold shifts). Since 2016, NMFS continues to work to refine this document, its underlying assumptions, and associated user tools.

On April 28, 2017, Presidential Executive Order (EO) 13795 was issued. Section 10 specifically called for the review of the Technical Guidance by the Secretary of Commerce to determine if it was appropriate to rescind or revise this document. To assist the Secretary of Commerce, in 2017, NMFS held a 45-day public comment period and an in-person meeting with other federal agencies to obtain feedback on the Technical Guidance. The EO 13795 review process provided NMFS with the opportunity to acquire valuable feedback from the public/stakeholders and federal agencies on the Technical Guidance since its finalization. Three key topics were raised: 1) the limited scientific data on mysticete hearing; 2) the appropriate accumulation period for assessing sound exposure on marine mammals; and 3) the need for improvements to the Technical Guidance’s optional user tools. Based on this input and per approval of the Secretary of Commerce, in June 2018, NMFS issued a Revised Technical Guidance and an updated optional User Spreadsheet tool that included a new instruction manual. The Revised Technical Guidance also summarized and evaluated relevant scientific literature published since the 2016 Technical Guidance. Furthermore, NMFS committed to convening two working groups to address outstanding technical and implementation issues raised: 1) mysticete hearing and 2) the default maximum 24-hour accumulation period. Finally, in late 2018, NMFS conducted an additional 45-day public comment period on the optional User Spreadsheet tool, which will result in further refinements based on feedback from stakeholders, including the development of a more user-friendly web-based calculator tool.
1. INTRODUCTION

In July 2016, the National Atmospheric and Oceanic Administration’s National Marine Fisheries Service (NOAA NMFS) issued its Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts (Technical Guidance) as a NOAA Technical Memorandum (NMFS-OPR-55). In addition to this document, NMFS published a complementary Federal Register (FR) Notice, which provided the regulatory context for implementing the Technical Guidance under the U.S.’ Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and National Marine Sanctuaries Act (NMSA) and addressed substantive comments received during three separate public comment periods. NMFS also produced an optional companion User Spreadsheet to serve as a tool for applying the Technical Guidance’s updated thresholds and marine mammal auditory weighting functions. Furthermore, before finalization, the Technical Guidance underwent several stages of independent peer review.

Upon issuance of the Technical Guidance, NMFS assisted action proponents/applicants and agency personnel transition to the Technical Guidance and apply their more complex thresholds to real-world applications.

Subsequently, on April 28, 2017, Presidential Executive Order (EO) 13795, titled Implementing an America-First Offshore Energy Strategy, was issued. Section 10 of EO 13795 required a review of the Technical Guidance by the Secretary of Commerce and directed the Secretary to either rescind or revise it. To assist the Secretary with the review, NMFS provided another opportunity for public comment via a new 45-day public comment period and hosted an Interagency Consultation meeting with representatives from ten U.S. federal agencies. In response to the feedback received during that public comment period and the Interagency Consultation meeting, the Secretary decided to revise the Technical Guidance rather than rescind it, and directed NMFS to issue a 2018 Revised Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts (2018 Revised Technical Guidance) (NOAA Technical Memorandum NMFS-OPR-59) (June 21, 2018). The 2018 Revised Technical Guidance retained the thresholds and auditory weighting functions presented in the original 2016 Technical Guidance document. However, with the issuance of the 2018 Revised Technical Guidance, NMFS committed to further addressing outstanding scientific and implementation issues.

2. 2016 TECHNICAL GUIDANCE

The 2016 Technical Guidance updates thresholds for assessing the potential impacts of anthropogenic sound on marine mammal hearing, via marine mammal hearing groups, in terms of temporary (TTS) and permanent threshold shifts (PTS) (Tables 1-2; Figures 1-2). Prior to the Technical Guidance, NMFS primarily relied on two generic thresholds for assessing auditory impacts (PTS onset) for most underwater sound sources: one for cetaceans (root mean square sound pressured level, RMS SPL: 180 dB), and one for pinnipeds (root mean square sound pressured level: 190 dB). These generic thresholds, developed in the late 1990s, were based on the best information available at the time and applied to most sound sources. However, specific sound sources, like tactical sonar and underwater explosives, reflected more recently developed thresholds. Since the adoption of these original generic thresholds, scientific understanding of the physical characteristics of a sound source contributing to noise-induced hearing loss and of the effects of sound on marine mammal hearing has greatly advanced, making it necessary to examine more comprehensively the previous generic thresholds in light of the current state of science.

To develop the Technical Guidance, NMFS compiled, interpreted, and synthesized scientific literature on the impacts of sound on marine mammal hearing, including a recent U.S. Navy Technical Report, to produce updated thresholds. The Technical Guidance represented the first ever effort by NMFS to present this type of information in a single, comprehensive document. The intended users include analysts/managers and other relevant stakeholders, including U.S. federal agencies, when seeking to
determine whether and how activities could result in potential auditory impacts to marine mammals via acoustic exposure.

**Table 1. Technical Guidance’s marine mammal hearing groups.**

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>Generalized Hearing Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-frequency (LF) cetaceans (baleen whales)</td>
<td>7 Hz to 35 kHz</td>
</tr>
<tr>
<td>Mid-frequency (MF) cetaceans (dolphins, toothed whales, beaked whales, bottlenose whales)</td>
<td>150 Hz to 160 kHz</td>
</tr>
<tr>
<td>High-frequency (HF) cetaceans (true porpoises, <em>Kogia</em>, river dolphins, cephalorhynchid, <em>Lagenorhynchus cruciger</em> &amp; <em>L. australis</em>)</td>
<td>275 Hz to 160 kHz</td>
</tr>
<tr>
<td>Phocid pinnipeds (PW) (underwater) (true seals)</td>
<td>50 Hz to 86 kHz</td>
</tr>
<tr>
<td>Otariid pinnipeds (OW) (underwater) (sea lions and fur seals)</td>
<td>60 Hz to 39 kHz</td>
</tr>
</tbody>
</table>

**Table 2. Summary of Technical Guidance’s Permanent Threshold Shift (PTS) onset thresholds.**

<table>
<thead>
<tr>
<th>Hearing Group</th>
<th>PTS Onset Thresholds* (Received Level)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-Frequency (LF) Cetaceans</strong></td>
<td>( L_{p,0-pk,flat} : 219 \text{ dB} )</td>
<td>( L_{E,p,LF,24h} : 183 \text{ dB} )</td>
</tr>
<tr>
<td><strong>Mid-Frequency (MF) Cetaceans</strong></td>
<td>( L_{p,0-pk,flat} : 230 \text{ dB} )</td>
<td>( L_{E,p,MF,24h} : 185 \text{ dB} )</td>
</tr>
<tr>
<td><strong>High-Frequency (HF) Cetaceans</strong></td>
<td>( L_{p,0-pk,flat} : 202 \text{ dB} )</td>
<td>( L_{E,p,24h} : 155 \text{ dB} )</td>
</tr>
<tr>
<td><strong>Phocid Pinnipeds (PW) (Underwater)</strong></td>
<td>( L_{p,0-pk,flat} : 218 \text{ dB} )</td>
<td>( L_{E,p,PW,24h} : 185 \text{ dB} )</td>
</tr>
<tr>
<td><strong>Otariid Pinnipeds (OW) (Underwater)</strong></td>
<td>( L_{p,0-pk,flat} : 232 \text{ dB} )</td>
<td>( L_{E,p,OW,24h} : 203 \text{ dB} )</td>
</tr>
</tbody>
</table>

* Dual metric thresholds for impulsive sounds: Use whichever results in the largest isopleth for calculating PTS onset.

**Note:** Peak sound pressure level \((L_p,0-pk)\) has a reference value of 1 \(\mu Pa\), and weighted cumulative sound exposure level \((L_{E,p})\) has a reference value of 1 \(\mu Pa\)²/s. In this Table, thresholds are abbreviated to be more reflective of International Organization for Standardization standards. The subscript “flat” is being included to indicate peak sound pressure are flat weighted or unweighted within the generalized hearing range of marine mammals (i.e., 7 Hz to 160 kHz). The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function (LF, MF, and HF cetaceans, and PW and OW pinnipeds) and that the recommended default accumulation period is 24 hours.
Figure 1. Technical Guidance’s auditory weighting functions for low-frequency (LF), mid-frequency (MF), and high-frequency (HF) cetaceans.

Figure 2. Technical Guidance’s underwater auditory weighting functions for otariid (OW) and phocid (PW) pinnipeds.

The Technical Guidance serves as an important tool to help evaluate the potential effects of anthropogenic sound on marine mammal hearing but is not the entirety of an effects analysis under either
the MMPA or ESA. Moreover, the Technical Guidance may inform decisions on mitigation and monitoring requirements in connection with any permits/authorizations issued by NMFS but does not mandate any specific mitigation requirements. Furthermore, the Technical Guidance only pertains to marine mammals and does not include thresholds for other NMFS' protected species, such as fishes or sea turtles. Nevertheless, we recognize the need for updated guidance and thresholds for these other taxa and are working on separate guidance documents to address them.

3. TECHNICAL GUIDANCE REVIEW UNDER EO 13795

To assist the Secretary of Commerce in carrying out the directive under section 10 of EO 13795, NMFS first held a new 45-day public comment period to solicit additional comments on the 2016 Technical Guidance for consistency with the EO’s policy (the fourth public comment opportunity on the Technical Guidance since 2013). Additionally, NMFS conducted a federal interagency consultation effort that included inviting representatives from 15 U.S. federal agencies to participate in an in-person meeting at NMFS Headquarters in Silver Spring, Maryland, to serve as a formal forum to discuss the Technical Guidance and provide additional comments.

A. 2017 PUBLIC COMMENT PERIOD

During the 45-day public comment period (May 31-July 17, 2017; 82 FR 24950), NMFS received 62 comments related to the 2016 Technical Guidance. Comments were submitted by a broad group of stakeholders, including U.S. federal agencies (Bureau of Ocean Energy Management, U.S. Navy, Marine Mammal Commission), oil and gas industry representatives, Members of Congress, subject matter experts, nongovernmental organizations, a foreign statutory advisory group, a regulatory advocacy group, and members of the public (Table 3).

<table>
<thead>
<tr>
<th>Commenter Category</th>
<th>Specific Commenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. federal agencies</td>
<td>Bureau of Ocean Energy Management; Marine Mammal Commission; U.S. Navy</td>
</tr>
<tr>
<td>Members of Congress</td>
<td>22 members</td>
</tr>
<tr>
<td>Oil and gas industry</td>
<td>American Petroleum Institute/International Association of Geophysical Contractors/Alaska Oil and Gas Association/National Ocean Industries Association</td>
</tr>
<tr>
<td>Non-Governmental Organization</td>
<td>Natural Resources Defense Council/The Human Society of the US/Whale and Dolphin Conservation; Ocean Conservation Research</td>
</tr>
<tr>
<td>Regulatory advocacy group</td>
<td>Center for Regulatory Effectiveness</td>
</tr>
<tr>
<td>Foreign statutory advisor Group</td>
<td>Joint Nature Conservation Committee</td>
</tr>
<tr>
<td>Subject matter experts</td>
<td>Marine scientist/mammologist; Geophysicist/Geochemist; Acoustician</td>
</tr>
<tr>
<td>General public</td>
<td>47 individuals</td>
</tr>
</tbody>
</table>

Most of the comments (85%) recommended no changes to the Technical Guidance. More importantly, no public commenter suggested rescinding the Technical Guidance. The U.S. Navy, Marine Mammal Commission, Members of Congress, and subject matter experts expressed support for the Technical Guidance’s thresholds and auditory weighting functions as reflecting the best available science. The remaining comments (15%) focused on additional scientific publications for consideration or recommended revisions to improve implementation of the Technical Guidance.

All public comments received during this review can be found at: [https://www.regulations.gov/docket?D=NOAA-NMFS-2013-0177](https://www.regulations.gov/docket?D=NOAA-NMFS-2013-0177)
B. 2017 FEDERAL INTERAGENCY CONSULTATION MEETING

Of the 15 invited U.S. federal agencies, ten participated in the federal interagency consultation meeting on September 25, 2017 (Table 4).

None of the attending agencies recommended rescinding the Technical Guidance. Overall, the federal agencies were supportive of the Technical Guidance’s thresholds and auditory weighting functions and the science behind their derivation and were appreciative of the opportunity to provide input. Comments received at the meeting focused on improvements to implementation of the Technical Guidance and recommendations for working groups to address implementation of the Technical Guidance or any new scientific information as it becomes available.

<table>
<thead>
<tr>
<th>Bureau of Ocean Energy Management</th>
<th>National Science Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of State</td>
<td>U.S. Air Force</td>
</tr>
<tr>
<td>Federal Highway Administration</td>
<td>U.S. Army Corps of Engineers</td>
</tr>
<tr>
<td>Marine Mammal Commission</td>
<td>U.S. Geological Survey</td>
</tr>
<tr>
<td>National Park Service</td>
<td>U.S. Navy</td>
</tr>
</tbody>
</table>

4. 2018 REVISED TECHNICAL GUIDANCE

During both the public comment period and the federal interagency consultation meeting, three key topics were raised: 1) the limited scientific data on the impacts of sound on LF cetacean hearing; 2) the need to determine the appropriate accumulation period for all species of marine mammals and sound sources; and 3) the need to improve the 2016 Technical Guidance’s optional User Spreadsheet tool. Commenters encouraged the agency to establish working groups to address these data gaps and future needs.

The comments received during this process affirmed that the Technical Guidance is based on the best available science. Nevertheless, based on consideration of comments received and per the approval of the Secretary of Commerce, NMFS issued a revised version of the Technical Guidance8 that retained the thresholds and auditory weighing functions from the 2016 Technical Guidance and updated the optional User Spreadsheet tool to improve implementation and facilitate its use by action proponents/applicants. Additionally, NMFS committed to: 1) soliciting additional public comment on our User Manual and associated optional User Spreadsheet tool; 2) convening a Working Group (WG) to re-evaluate the default maximum 24-hour accumulation period; and 3) convening a WG to understand further the impacts of sound on LF cetacean hearing.

A. 2018 PUBLIC COMMENT PERIOD ON OPTIONAL USER TOOLS

To get additional feedback on improvements that could be made to the optional User Spreadsheet tool, NMFS solicited stakeholder feedback via 45-day public comment period (September 24-November 8, 2018; 83 FR 48291).19 During this public comment period, NMFS received four comments from oil and gas industry representatives, individual members of the public, and environmental consultants.

NMFS is in the process of incorporating recommendations received into an updated version of the optional User Spreadsheet tool and associated User Manual (e.g., ensuring consistent terminology; exploring ways for tool to provide more accurate results). Additionally, NMFS is producing a web-based version of the optional User Spreadsheet that will improve usability.

The intent with our optional user tools is that they remain “living documents,” capable of being updated as better information on implementation of the Technical Guidance becomes available (i.e., user tools can be updated faster and more easily than Technical Guidance, which a formal process for updates). Note: adjustments/updates to the user tools do not refer to adjustments to the Technical Guidance’s thresholds/auditory weighting function but rather factors that would result in the calculation of more accurate isopleths.
(i.e., the distance from the source within which an animal is likely to exceed the PTS onset threshold) using the thresholds/auditory weighting functions (i.e., the focus is on implementation not the science supporting the thresholds/auditory weighting functions).

B. WORKING GROUP ON “24-HOUR ACCUMULATION TIME”

Under NMFS’ previous generic PTS onset thresholds (i.e., RMS SPL 180 dB for cetaceans and 190 dB for pinnipeds), once a marine mammal (receiver) entered the predicted isopleth, the threshold was exceeded and the receiver was considered to experience PTS onset. In other words, duration of exposure was not a consideration (i.e., once receiver entered the predicted isopleth, it exceeded the PTS onset threshold no matter whether it stayed there for 24 seconds or for 24 hours).

However, with the Technical Guidance’s cumulative sound exposure level (SEL_{cum}) metric, since there is a time (duration of exposure) component inherently included, the threshold is more realistic. The potential a receiver has for exceeding the PTS onset threshold depends on how long it is exposed and at what level, based on how close it is to the sound source (Figure 3). To account for those factors in the estimation of the accumulated sound at the exposed animal, in order to assess against the Technical Guidance thresholds, the relative movement of the animal and the source need to be modeled. However, in situations where this type of modeling is not available, using the isopleth calculated by the optional User Spreadsheet tool with the current recommended 24-hour accumulation time as an input likely can result in an overestimate of the number of animals exceeding the PTS onset threshold, because standard calculations only consider the number of animals likely to be inside an isopleth, but not how long they are there. The optional User Spreadsheet tool also considers animals to be stationary and receiving all sound exposure within the 24 hour period, even though this is unlikely in most situations.

Thus, in late 2018, NMFS established an internal Working Group consisting of members from our Headquarters Offices (both Protected Resources and the Office of Science & Technology), Regional Offices, and Science Centers to explore further the default 24-hour accumulation period (24-Hour WG). The 24-Hour WG has focused their discussions on stationary sources, specifically those involving coastal/nearshore impact and vibratory pile driving given that those are the activities where the default 24-
hour accumulation period often leads to the most conservative results (e.g., for impact pile driving activities each subsequent strike makes the isopleth larger, including the assumption that a marine mammal is exposed to all strikes within a 24-hour period) and for which action proponents/applicants often rely on the optional User Spreadsheet tool to assess the potential for PTS onset.

NMFS acknowledges that describing sound exposure in terms of the source is much easier than predicting sound exposure to marine mammals in free-ranging situations. For example, an exposure scenario for a stationary source would be drastically different for a group of transient delphinids swimming past the source versus a group of resident pinnipeds hauled-out near the source. Thus, a basic understanding of how the sound source overlaps with marine mammals over space and time is essential to understanding actual exposure but is often difficult to predict. Additionally, the behavioral context of the animal during exposure (e.g., migrating, feeding, breeding20) and the likelihood an individual will stay near a source and be exposed (e.g., fight vs. flight21 or social context22), as opposed to avoiding the source (which could have separate consequences23), determines what the animal accumulates in terms of level and duration of exposure. Thus, there is a need for better information/modeling to predict accurately free-ranging marine mammal exposures under complicated real-world scenarios. NMFS is currently examining how these various factors can be better incorporated in our current Technical Guidance (e.g., via animat modeling, such as Marine Mammal Movement and Behavior, 3MB24).

Once NMFS develops an alternate methodology, it will be shared via a tiered approach (Figure 4). NMFS will first reach out to other interested federal agencies to get input on our approach before sharing it more broadly with the public, academia, and other stakeholders.

Figure 4: NMFS’ tiered approach for working groups.

C. WORKING GROUP ON “LOW-FREQUENCY CETACEANS”

Throughout the development of the Technical Guidance, LF cetaceans were identified as the marine mammal hearing group with the most uncertain thresholds due to limited direct measurements of hearing for this group.25 Hearing predictions for mysticetes are currently based on other methods including: anatomical studies and modeling;26,27,28,29 vocalizations;30,31,32 taxonomy; and behavioral responses to sound.33,34

The LF cetacean hearing group also is of particular interest because the majority of species in this hearing group are designated as endangered or threatened under the ESA,35 and many anthropogenic sound sources produce low-frequency sounds believed to be in this hearing group’s most susceptible hearing range.15,30

As of 2019, NMFS has not yet convened this working group. From a practical standpoint, as with the 24-WG, NMFS would start by convening an internal working group and many of the members of the LF cetacean working group (LFC WG) would be the same as those participating in the 24-hour WG.

Furthermore, the Subcommittee on Ocean Science and Technology (SOST),36 which is a partnership between the Office of Naval Research, Chief of Naval Operations, the Bureau of Ocean Energy Management, NOAA, and the Marine Mammal Commission, is directly funding research pertaining to the development of audiograms for mysticetes. The SOST specifically solicited proposals in July 2018 to improve the understanding and measurement of auditory capabilities and sensitivities of LF cetaceans to
anthropogenic sound. In mid-2019, the SOST made their decision on to fund three proposals.\textsuperscript{37} Thus, NMFS believes it will be prudent to await the outcome of this new research before convening this WG.

When the LFC WG commences, the focus will be on approaches for addressing this hearing group in future versions of the Technical Guidance. Additionally, the LFC WG will follow the same tiered approach as the 24-hour WG (Figure 4). Nevertheless, at this point, there is still a lot left to be determined regarding the most appropriate path forward for this WG.

5. RELATION TO SOUTHALL ET AL. 2019

Via a parallel process, a similar methodology used for the NMFS 2018 Revised Technical Guidance was adopted in the recent scientific recommendations of Southall et al. 2019.\textsuperscript{15} However, Southall et al. 2019 adopts an updated and slightly modified approach for segregating marine mammals into hearing groups, as well as naming these hearing groups (i.e., essentially species formerly classified as MF cetaceans\textsuperscript{12} are now classified as HF cetaceans, and species formerly classified as HF cetaceans\textsuperscript{12} are now classified as Very High-Frequency cetaceans; Table 5).

NMFS will continue to rely upon the marine mammal hearing group categorizations provided in the 2018 Revised Technical Guidance, until a subsequent revision to this document is appropriate. In the interim, NMFS recommends that any reference to a marine mammal hearing group also specify the relevant publication referred to for that hearing group label.

Table 5: Comparison of marine mammal hearing group categorization between recent scientific recommendations and Revised 2018 Technical Guidance.

<table>
<thead>
<tr>
<th>Family/Genera/Species Included</th>
<th>Southall et al. 2019 Hearing Group</th>
<th>NOAA 2018 Hearing Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balenidae; Balaenopteridae; Neobalenidae; Eschrichtiidae</td>
<td>LF cetaceans</td>
<td>LF Cetacean</td>
</tr>
<tr>
<td>Delphinidae; Monodontidae; Ziphiidae; Physeteridae; Plantanistidae</td>
<td>HF Cetaceans</td>
<td>MF Cetaceans</td>
</tr>
<tr>
<td>Phocoenidae; Iniidae; Kogiidae, Lipotidae; Pontoporiidae; Cephalorhynchus spp.; Lagenorhynchus cruciger; Lagenorhynchus australis</td>
<td>Very High-Frequency Cetaceans</td>
<td>HF Cetaceans</td>
</tr>
<tr>
<td>Phocidae</td>
<td>Phocid Carnivores in Water</td>
<td>PW Pinnipeds</td>
</tr>
<tr>
<td>Otariida</td>
<td>Other Marine Carnivores in Water</td>
<td>OW Pinnipeds</td>
</tr>
</tbody>
</table>

6. WHAT IS NEXT?

NMFS plans to conduct regular internal and external “check-ins” with users to gather feedback on the Technical Guidance and the optional user tools. Thus, suggestions are always welcome and appreciated.

Research on the effects of anthropogenic sound on marine mammal hearing has increased dramatically in the last decade and will likely continue to increase in the future. NMFS will continue to monitor and evaluate new data as they become available and plans to update the Technical Guidance as appropriate.
(anticipating a three to five year cycle to regularly evaluate newly available data and determine if updates are necessary).

ACKNOWLEDGMENTS
The author would like to thank Deborah Ben-David, Jolie Harrison, and Trevor Spradlin of NMFS, for reviewing and providing helpful comments on this manuscript.

REFERENCES


35 https://www.fisheries.noaa.gov/species-directory/threatened-endangered
