Peer Review Report

Follow-Up Review to:
U.S. Navy Technical Report: Auditory Weighting Functions and TTS/PTS Exposure Functions for TAP Phase 3 Acoustic Effects Analyses

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Review of:
Document Containing Proposed Changes To:
National Oceanic and Atmospheric Administration Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts

Peer Reviewers[1]

Whitlow Au, Ph.D., University of Hawaii
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Klaus Lucke, Ph.D., Curtin University (Australia)
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As NOAA worked to address comments it received during the first and second public comment periods and finalize the Acoustic Guidance, the U.S. Navy's methodology (Appendix A of 2015 July Draft Guidance, NOAA 2015a) was further evaluated internally (within NOAA), as well as by the Navy (SPAWAR Systems Center Pacific). As a result, several recommendations/modifications were suggested. Upon consideration, NOAA updated portions of the Draft Guidance to reflect these suggested modifications and solicited public comment on the proposed changes via a focused14-day public comment period in March 2016 (NOAA 2016a). Concurrent with this third public comment period, NOAA requested that the peer reviewers of the Navy's methodology review the proposed changes to the Draft Guidance and indicate whether the revisions would significantly alter any of the

[1] Note: Reviewer identification numbers do not correspond to the order of reviewers above but do correspond to the same identification number from the original review (NOAA 2015b). Peer Reviewers' comments are presented as provided to NOAA. Generally, NOAA did not make any alterations (i.e., there may be spelling, grammatical, or other minor errors). If alterations were made, they were done for clarity and are indicated by brackets.

[2] During initial peer review, Dr. Le Prell was associated with the University of Florida.

comments made during their original review[3] (NOAA 2015b). This document summarizes those comments received by the peer review during this follow-up review and NOAA's response to those comments.

The proposed changes to the Draft Guidance were organized into six sections:

- Section 1. Low-Frequency (LF) Cetaceans: Modification of the methodology for predicting a composite audiogram and acoustic threshold levels for LF cetaceans
- Section 2. Mid-Frequency (MF) Cetaceans: Placement of white-beaked dolphins from the MF cetacean to the high-frequency (HF) cetacean functional hearing group
- Section 3. High-Frequency (HF) Cetaceans: Inclusion of an additional audiogram from a harbor porpoise based on recently published data
- Section 4. Phocid (PW) Pinniped: Removal of datasets with individuals having hearing loss and/or non-representative hearing from the PW pinniped functional hearing group
- Section 5. Peak Sound Pressure Level (PK) Acoustic Threshold Levels: Removal of PK acoustic threshold levels for non-impulsive sounds for all functional hearing groups and use of dynamic range methodology to derive PK thresholds for functional hearing groups with no direct data
- Section 6. Summary of Proposed Changes: Summarized proposed changes to the 2015 July Draft Guidance (NOAA 2015a) via tables and figures

NOAA was responsible for conducting this follow-up peer review. The intent of this follow-up peer review report is to address only how NOAA plans to consider the peer reviewers' comments in the Final Acoustic Guidance. Peer reviewers' follow-up comments were also provided to the Navy to consider in their "TAP Phase 3" analyses. This report does not to address how the Navy will incorporate or consider this review.

[3] Note: During the follow-up peer reviewer, reviewers were only asked to review the document containing proposed changes and consider comments in the context of their original review in NOAA 2015b (i.e., They were not asked to review any version of NOAA's Acoustic Guidance). More information about the follow-up peer review, including peer review charge, can be found at: http://www.cio.noaa.gov/services_programs/prplans/ID43.html.

General Comments

REVIEWER 1

Comment 1: I have carefully reviewed the March 2016 Guidance document containing proposed changes to: National Oceanic and Atmospheric Administration Draft Guidance for assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts. To assess the impact of the changes, I have re-reviewed the original text, figures, and tables that were part of the Draft Guidance previously released to the public for comments on July 23, 2015.

I have also reread all of the comments that I provided previously as part of the second peer review team, and the Peer Review Report: US Navy Technical Report: Auditory Weighting Functions and TTS/PTS Exposure Functions for TAP Phase 3 Acoustic Effects Analyses (February 2015).

All of the above were used to allow me to fully assess the impact of the updates with respect to my previous review and any substantive changes as a consequence of the revisions.

In response to the general directive, I note here that that none of the revisions to the document substantially change any of the comments provided during my review.

***Response*:** NOAA thanks the reviewer for their follow-up review.

REVIEWER 2

Comment 2: I have reviewed the document related to underwater acoustic threshold levels for onset of permanent and temporary threshold shifts (March 2016) and my previous comments on the Finneran 2015 report.

As per Dr. N.R. LeBoeufs letter/e-mail of 11 March 2016, I have focussed my review on determining if the updates would substantially change any of my comments on my review of the Navy's methodology. I have reviewed my comments and I do not have any changes to make. In cases where I had a misunderstanding or thought that errors had occurred etc., the NOAA and Navy responses[4] have provided information which clarifies or explains the issues.

***Response*:** NOAA thanks the reviewer for their follow-up review.

[4] Referring to responses provided in NOAA 2015b.

Specific Comments (by Section)

1. LOW-FREQUENCY (LF) CETACEANS

REVIEWER 1

Comment 3: Changes to the methodology for predicting composite audiograms and acoustic thresholds for low-frequency cetaceans (section 1) are clearly described and are well justified, given previously and appropriately acknowledged uncertainty.

***Response*:** NOAA thanks the reviewer for their comment.

REVIEWER 2

Comment 4: With respect to the recent document, there is a typographical error in Table PC2, page 11. The "Difference" values for phocids underwater should be 128 dB (not 133) and for otariids underwater 133 dB (not 128).

Response: NOAA agrees. This error will be corrected it in the Final Acoustic Guidance.

REVIEWER 3

Comment 5: My comments focus mainly on the composite audiogram and weighting function for LF cetaceans. In this context I applaud NOAA aiming to better account for uncertainty associated with the functional hearing group of LF cetaceans. Several "*modifications were made to the original methodology (NOAA 2015a) for deriving a predicted composite audiogram/auditory weighting function and acoustic threshold levels.*" However, I recommend to revisit these changes for the following reasons:

In chapter 1.1.1 (Discussion, p.4) it is stated that "*Upon re-evaluation, the Navy recommended and NOAA concurred that preliminary data relating to predicted audiograms for LF cetaceans should not be included at this time (e.g., Ketten and Mountain 2009; Ketten 2014; Ketten and Mountain 2014).*"

NOAA's previous Draft Guidance seemed to be balanced between the two approaches used to derive information on hearing in low-frequency cetaceans (modelled biomechanical data for the inner ear and modelled data on sound transmission in the auditory periphery). The rationale that "*these data currently lack a complete description of methodology used to derive predicted audiograms, with the data in Ketten 2014 and Ketten and Mountain 2014 only available in the format of a slide associated with a presentation*" has important implications for NOAA's Guidance on LF cetaceans. While, sadly enough, one of the lead authors of the studies mentioned died recently, I'm wondering if NOAA approached the other author on this issue to publish the data or provide them for peer-review? NOAA made the decision to omit not only the modelled biomechanical data for the inner ear, but also the remaining modelled data on sound transmission in the auditory periphery. In comparison to the previous version of this document, this is a substantial change with important effects on the composite audiogram and weighting function. Given the importance of the modelled data (both approaches), it would seem

justifiable to me to delay the revision of the NOAA Guidance in order to achieve peer-reviewed publication of those data.

> ***Response:*** The decision to remove preliminary data from consideration (e.g., Ketten and Mountain 2009; Ketten 2014; Ketten and Mountain 2014) was not an easy decision or one made without careful deliberation. However, there was much uncertainty as to if/when these data would be published in a format that allowed for critical evaluation. NOAA decided that further delaying the Final Guidance for an undetermined amount of time for these data was not justified. When these data are published, because of the inherent lack of data for this functional hearing group, NOAA will re-evaluate its current approach and make changes, if deemed necessary.
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> In reference to the data provided in Cranford and Krysl 2015, despite NOAA not directly incorporating the predicted audiogram from this paper into the updated methodology, they are included for comparative purposes in NOAA 2016b (Figure PC1). The resulting updated predicted LF cetacean audiogram is much broader than that presented in Cranford and Krysl (2015).

Comment 6: Instead, NOAA has taken a different approach by applying previously published model predictions of LF cetacean hearing. By doing so, NOAA comes to the conclusion that "*these previously published model of LF cetacean hearing broadly suggest best sensitivity (in terms of parameter T') from ~1 to 8 kHz, with thresholds within ~40 dB of best sensitivity as low as ~30 Hz and up to ~25 kHz).*" The best fit parameters for the LF cetacean composite audiogram and the LF cetacean weighting function are based on this broad assumption. From my point of view, the most critical aspect in this context seems to be the frequency of best hearing and the low-frequency cut-off (f_1) [F_1] of the best hearing range. Some of the studies cited in the Draft Guidance in this context refer to much lower frequencies and dominant parts of the vocalisations of baleen whales can be found in the ten Hz - low hundred Hz range (see Clark and Ellison, 2004). Nevertheless, in NOAA's Draft Guidance the frequency band is cut off at 410 Hz and the frequency of best hearing is determined to be at 5.6 kHz. Clark and Ellison (2004) assume that "*the frequency band of lowest hearing threshold includes the frequency band of sound production*" and base this assumption on the logic that "*evolutionary pressure would select for the most efficient use of the dynamic range experienced by the auditory mechanism.*" (Clark and Ellison, 2004). They come to the conclusion that right whales (e.g.) would have their best hearing in the 200-400 Hz band with an estimated hearing threshold of 60-70 dB re 1 µPa. Moreover, there is information on the sounds emitted by other baleen whales, such as the blue and fin whale. Fin whales emit characteristic 1 s FM down-sweeps from 30 to 15 Hz, commonly called the 20-Hz signal (Edds, 1988; Goldbogen et al., 2014; Schevill et al., 1964). Antarctic blue whales make so-called 'Z-calls' (also as song) which sweeps from 28 to 18 Hz (Rankin et al., 2005; Samaran et al., 2010; Sirovic et al., 2007; Sirovic et al., 2004; Stafford et al., 2004). There is no significant vocal activity emitted by these species at higher frequencies. Consequently, the estimated frequency of best hearing in baleen whales and/or the low-frequency cut-off frequency should be shifted towards lower frequencies. By applying NOAA's current weighting function for LF cetaceans the corrected (weighted) threshold are centred at 5.6 kHz and cut-off at frequencies below 410 Hz. Following the logic and modelling by Clark & Ellison (2004) this would result in underestimated threshold by >20 dB which, in turn, would lead to an increased risk of negatively affecting LF cetaceans through impulsive and continuous low-frequency sounds. NOAA discusses Clark and Ellison's predicted

frequency range, frequency of best hearing and thresholds (p.10), but the argument for not using the data by Clark and Ellison (2004) is merely a reference to their own prediction, without a scientifically valid discussion of why the data by Clark and Ellison (2004) were not considered: "*However, the July 2015 Draft Guidance's predicted audiogram for LF cetaceans indicates this functional hearing group has best hearing sensitivity at higher frequencies (i.e., NOAA 2015a: 3.5 kHz; updated to 5.6 kHz in Section 1.1.1.1 of this document) rather than the 200-400 Hz range where Clark and Ellison (2004) provided an expected threshold. Accordingly, it is not appropriate to use the Clark and Ellison (2004) threshold recommendation with the best hearing range from the predicted audiogram in the Draft Guidance.*" This is a circular argument and doesn't add any credibility to the approach chosen by NOAA.

> ***Response:*** NOAA understands the inherent uncertainty associated with having to derive audiogram parameters for this functional hearing group. However, we believe it is important to focus on the resulting predicted composite audiogram (threshold within 1 dB of lowest thresholds from ~1.8 to 11 kHz and within 3 dB of the lowest threshold from ~0.75 to 14 kHz) and weighting function (weighting function amplitude of < -1 dB at 500 Hz and < -7 dB at 100 Hz), which are broader (i.e., more conservative) than what was previously proposed in NOAA 2015a. It should also be noted that this functional hearing group's weighting/exposure functions are broader than any other functional hearing group (i.e., resulting in a greater frequency range of susceptibility). Additionally, the PTS onset thresholds (both metrics) for LF cetaceans has been reduced in NOAA 2016b compared to NOAA 2015a.
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> Regarding the ultra-low-frequency vocalizations of fin and blue whales, if one uses Figure 73.6 from Clark and Ellison (2004)[5] to estimate a hearing threshold for these species, it would result in threshold much higher than the 54 dB thresholds proposed in NOAA 2016b. Furthermore, compared to NOAA 2015a, our most recent proposal results in an 18-dB more conservative weighting function amplitude at 20 Hz (NOAA 2016b).
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> With the F_1 parameter, it should be noted that the value derived in NOAA 2016b (i.e., 0.41 kHz) results in a wider predicted audiogram, in term of low frequencies, than what was presented in NOAA 2015a (i.e., 0.594 kHz in Appendix A: Table 4), which included preliminary data sets (e.g., Ketten and Mountain 2009; Ketten 2014; Ketten and Mountain 2014). Thus, when these preliminary data sets do become published, NOAA anticipates they could result in a narrower (less conservative) predicted audiogram compared to what NOAA in proposing for the Final Guidance.

Comment 7: The uncertainty in determining the parameters for f_2 [F_2] is even larger and taken to an extreme by using other in-water marine mammal functional hearing groups as surrogates. The

[5] Note: NOAA received public comments from both the authors of the Clark and Ellison (2004) paper who discussed how NOAA's proposed LF cetacean weighting function (NOAA 2016b) compares to the predicted hearing sensitivity based on ambient noise levels from Clark and Ellison (2004). They indicated, "The general pattern of LF cetacean hearing sensitivity being bound by low ambient noise levels supports the derived composite audiogram curve and should be added to the draft guidance to strengthen its scientific justification." These comments can be found at: https://www.regulations.gov/#!documentDetail;D=NOAA-NMFS-2013-0177-0155.

overall uncertainty which is inherent to this entire process of developing guidance in so many ways (number of samples, extrapolation from one subject to a species and entire functional hearing groups) should be weighed heavier than it currently is the case. The decision to omit important data rather than delaying the process and seeking a peer-review makes the NOAA Guidance for LF cetaceans questionable and less reliable.

> ***Response:*** NOAA acknowledges the uncertainty in having to estimate the audiogram parameters for LF cetaceans. However, NOAA believes that using other in-water marine mammal functional hearing groups' data as a surrogate means to derive this parameter is justifiable (i.e., assuming that if actual data were available for LF cetaceans that they would fall within the bounds of other in-water marine mammal functional hearing groups).
>
> Specifically, with the F_2 parameter, it should be noted that the value derived in NOAA 2016b (i.e., 9.4 kHz) results in a much wider predicted audiogram, in terms of high frequencies, than what was presented in NOAA 2015a (i.e., 3.11 kHz in Appendix A: Table 4), which included preliminary data sets (e.g., Ketten and Mountain 2009; Ketten 2014; Ketten and Mountain 2014). Thus, if/when these preliminary data sets do become published, NOAA anticipates they could result in a narrower (less conservative) predicted audiogram compared to what NOAA in proposing for the Final Guidance.

Comment 8: NOAA acknowledges the discrepancy between frequency of social calls of some LF cetaceans (such as blue whales, p.8), but supports their own approach by referring to other low-frequency species (seals and elephants) whose social calls contain energy shifted below their region of best hearing. In the light of the huge uncertainties this might be scientifically justifiable, but the result certainly doesn't represent a conservative approach. A scientifically and ecologically more viable approach (besides seeking peer-review of existing information) would be a separation of the LF cetacean functional hearing group in at least two groups – those which are known or likely to emit social calls at frequencies in the low hundreds or tens of Hz (blue whale, fin whale e.g.) and those emitting signals in the higher frequency range (such as humpback whale).

> ***Response:*** NOAA believes the approach presented in NOAA 2016b is conservative, especially in light of what was proposed in the July 2015 Draft Guidance (NOAA 2015a), which relied on preliminary data (e.g., Ketten and Mountain 2009; Ketten 2014; Ketten and Mountain 2014). NOAA understands that as data becomes available for LF cetaceans, it may be justified to subdivide this functional hearing group into multiple subdivisions. However, at this time, NOAA does not believe there are enough data to support further LF cetacean divisions and subsequent auditory weighting functions, especially since so little direct information on hearing is available for this functional hearing group.

Comment 9: A note (p.2) says: "*NOAA is aware that the authors of Southall et al. (2007) are in the process of updating their original publication and recognizes that when this updated publication becomes available, it may suggest alternative means for predicting an auditory weighting function and acoustic threshold levels for this functional hearing group. NOAA may re-evaluate our methodology for LF cetaceans when this updated Southall et al. publication becomes available.*"

Once again, it would seem to me (as a non-US reviewer) that it would be worthwhile delaying the new NOAA Guidance until this group of experts publish their results. It would certainly be more efficient and provide greater validity to any guidance if based on scientifically widely accepted data and approaches, rather than re-assessing the NOAA Guidance in the near future. Moreover, there is a discrepancy between the above statement that NOAA may re-evaluate its methodology when the updated recommendations become available and the statement found in 3.1 (Discussion on HF cetaceans, p.12) that "*NOAA may not update the Guidance's composite audiograms and associated weighting functions each time new data become available (i.e., Guidance has an established a schedule to re-evaluate all new data every 3 to 5 years.*" Clarification on the rationale behind the (seemingly) different approaches to LF and other data sets seems necessary. If a re-evaluation of the NOAA Guidance would commence in 3 to 5 years after the publication (in 2016 or 2017) of the ongoing revision and would take again 3 to 4 years, it would result in Guidance for LF cetaceans remaining to be based at a scientifically questionable status until 2022-2026.

> ***Response:*** NOAA declines to delay further the Guidance to incorporate the updates to the Southall et al. 2007 publication. The author of the Navy's methodology that we incorporated into our Guidance (Finneran) is also a member of the panel updating Southall et al. 2007. Thus, NOAA anticipates that the update to Southall et al. 2007 will be very similar to what is presented in our Final Guidance.
>
> NOAA will continue to monitor and evaluate new data as they become available and update the Guidance as appropriate (anticipating updates to occur periodically on a three to five year cycle but also allowing for more accelerated updates when circumstances warrant (e.g., LF cetacean data)).

REVIEWER 4

Comment 10: As a scientist and a rational person, I have essentially no confidence in table PC1. Considering lines 21-29, these numbers should be shifted to the left to lower frequencies, based on the characteristics of the call of these baleen whales. For example, fin whales typically emit "20 Hz" tone burses that are well described in the literature. The also emit FM down sweep from about 40 Hz to about 20 Hz. According to the "predicted" audiogram of Cranford and Krysl 2015, fin whales would have a hard time hearing what they regularly emit. This doesn't make sense at all. The best frequency of hearing in Cranford-Krysl model is 1 kHz, about 5 octave away from a typical fin whale call at 40 Hz. Something must be fundamentally flawed with the model. The dominant frequency of humpback whale calls and songs are between 200 and 400 Hz. The predicted curve by Houser (2001) should be shifted to lower frequencies by about an octave if the best sensitivity of the humpback whale hearing is close to the dominant frequencies of their calls and song units.

In line 33 of page 28 it stated that "A general pattern of some social calls containing energy shifted below the region of best hearing sensitivity is well-documented in other low-frequency species including many phocid seals (see Wartzok and Ketten 1999) and some terrestrial mammals, notably the Indian elephant (Heffner and Heffner 1982)." This general principle is useful, however, by how much below the best hearing sensitivity would be constitute a reasonable guess for baleen whales?

***Response*:** NOAA believes that the resulting predicted LF cetacean audiogram from the estimated parameters in Table PC1 and the associated weight/exposure functions are reflective of what is predicted in terms of mysticete hearing and what is known about their vocalizations. As stated in NOAA (2016b), it is important to remember that the resulting weighting function is wider than the composite audiogram. For example, the weighting function (See Section 6: Figure PC3 of NOAA 2016b) associated with the updated composite audiogram in Figure PC1, has a weighting function amplitude of < -1 dB at 500 Hz and < -7 dB at 100 Hz. It should also be noted that the LF functional hearing group has a broader weighting/exposure function than any other marine mammal functional hearing group (i.e., indicates that this functional hearing group has a wider frequency range of susceptibility to noise-induced hearing loss) to account for inherent uncertainty associated with mysticete hearing.

Comment 11: On Page 10 "Clark and Ellison (2004) provided a predicted hearing threshold (i.e., 60 to 70 dB) for LF cetaceans based on ambient noise levels between 200 and 400 Hz." I question this statement since most odontocetes hearing threshold tend to about 50 dB and I see no reason why baleen whales would be any different even if ambient noise is higher at low frequencies. To be conservative I would stick with the lower estimate of 60 dB.

***Response*:** NOAA believes that LF cetaceans hearing thresholds are predicted be higher (i.e., poorer sensitivity) compared to MF cetaceans (Southall et al. 2007). However, the methodology used to estimate hearing thresholds for LF cetaceans in the Acoustic Guidance was based on using data from other in-water functional hearing groups and is consistent with how other surrogate values/parameters were derived. This method predicts a threshold of 54 dB, which happens to be identical to that of MF cetaceans.

Comment 12: I am confused by the term fo [f_0] on PC2. Is it the frequency of best hearing? It can't be since *Tursiop truncates* is about 50 kHz, and if so it would be classify [classified] as a mid-frequency animal. In my opinion It should be the upper limit of hearing, which is about 150 kHz for *Tursiops,* so I would classify TT as a HF animal. If the upper limit of hearing is used than I don't think there is a debate on whether beaked whales belong in the HF group on page 11, line 13 since measurements by Pacini et al 2011 show best frequency of hearing at 55 kHz and upper limit about 80 kHz for a beached Blansville [Blainville] beaked whale.

***Response*:** The parameter f_0 represents the frequency of best hearing associated with a functional hearing groups' composite audiogram. For MF cetaceans, which bottlenose dolphins (*Tursiops truncatus*) are a member, the composite audiogram has frequency of best hearing at 55 kHz. The upper limit of hearing, mentioned by the peer reviewer, is considered in defining the functional hearing range of MF cetaceans (i.e., 160 kHz). NOAA believes that both the bottlenose dolphin's and the beaked whale's best hearing frequency and auditory range are representative of species within MF cetaceans functional hearing group

(i.e., there is no justification to move[6] either species to the HF cetacean functional hearing group; Southall et al. 2007).

2. MID-FREQUENCY CETACEANS (MF) CETACEANS

REVIEWER 1

Comment 13: Shifting of the white-beaked dolphins from the mid-frequency to the high-frequency cetacean functional hearing group (section 2) is data based, and appropriately justified.

***Response*:** NOAA thanks the reviewer for their comment.

3. HIGH-FREQUENCY (HF) CETACEANS

REVIEWER 1

Comment 14: After careful comparison of the previous figure and modified figure to incorporate an additional harbor porpoise audiogram (section 3), this is reasonable and appropriate given that other changes were being made simultaneously.

***Response*:** NOAA thanks the reviewer for their comment.

4. PHOCID (PW) PINNIPEDS

REVIEWER 1

Comment 15: Removal of pinnipeds with existing hearing loss is clearly appropriate and is a positive change (section 4).

***Response*:** NOAA thanks the reviewer for their comment.

REVIEWER 4

Comment 16: Since I worked mainly with odontocetes I will excuse myself from comments on Pinnipeds.

***Response*:** NOAA acknowledges comment.

[6] Note: The peer reviewer's comment refers to page 11, line 13 of the document available during the Draft Acoustic Guidance's third public comment period (NOAA 2016b), which refers to moving white-beaked dolphins from the MF to the HF cetacean functional hearing group.

5. PEAK SOUND PRESSURE LEVEL (PK) ACOUSTIC THRESHOLD LEVELS

REVIEWER 1

Comment 17: Changes to the methodology in section 5, specifically, use of dynamic range methodology in place of PK threshold levels where there are no direct data was well described and a clear rationale is provided.

***Response*:** NOAA thanks the reviewer for their comment.

REVIEWER 2

Comment 18: One important issue, (my comment 57[7] relating to the use of dynamic range) still stands. Although some of the values associated with calculating the Peak PTS levels have changed, I feel that the issue I raised is still valid. The dynamic ranges for impulsive sounds for the onset of PTS for the various species groups range from 154 dB (HF cetaceans) to 176 dB (MF cetaceans) (Lpk,flat values of Table PC4 minus the auditory threshold values of Table PC2).

***Response*:** NOAA notes that the dynamic ranges provided by the Reviewer are 6 dB higher than what appears in NOAA 2016b (i.e., Thresholds in Table PC4 represents PTS onset and not TTS onset, which was used to derive a surrogate dynamic range for functional hearing groups where no data are available). NOAA believes the updated dynamic range methodology is the most appropriate means for deriving surrogate peak sound pressure (PK) thresholds for functional hearing groups where no data currently exist and these derived thresholds are not unrealistic. The PK thresholds for MF and HF cetaceans were obtained from direct measurements, which seem to support a larger dynamic range than what has been observed in terrestrial mammals (148 to 170 dB for marine mammals vs. 140 dB for humans).

6. SUMMARY OF PROPOSED CHANGES

REVIEWER 1

Comment 19: The summary in section 6 is clearly written and was helpful.

Based on all of the above, I have no substantive changes to suggest and I commend the authors of this report for integrating a large amount of data from marine and terrestrial animals to derive recommended functions.

***Response*:** NOAA thanks the reviewer for their comment.

[7] From NOAA 2015b, the peer reviewer was advocating for the use of 140 dB dynamic range from human studies (Starck et al. 2003) as a conservative surrogate value.

Literature Cited (as referenced within Peer Review Report)

Clark, C.W., and W.T. Ellison. 2004. Potential use of low-frequency sound by baleen whales for probing the environment: Evidence from models and empirical measurements. Pages 564-581 in J.A. Thomas, C.F. Moss, and M. Vater, eds. Echolocation in Bats and Dolphins. Chicago: University of Chicago Press.

Cranford, T.W., and P. Krysl. 2015. Fin whale sound reception mechanisms: Skull vibration enables low-frequency hearing. PLOS ONE 10(3): e0122298.

Edds, P. L. 1988. Characteristics of finback *Balaenoptera physalus* vocalizations in the St. Lawrence Estuary. Bioacoustics 1:131-149.

Finneran, J.J. 2015a. U.S. Navy Technical Report: Auditory Weighting Functions and TTS/PTS Exposure Functions for TAP Phase 3 Acoustic Effects Analyses (February 2015). San Diego, California: SPAWAR Systems Center Pacific (SSC PAC).

Finneran, J.J. 2015b. Auditory weighting functions and TTS/PTS exposure functions for cetaceans and marine carnivores. July 2015. San Diego: SSC Pacific.

Goldbogen, J. A., A.K. Stimpert, S.L. Deruiter, J. Calambokidis, A.S. Friedlaender, G.S. Schorr, G., D.J. Moretti, P.L. Tyack, P. L., and B.L. Southall. 2014. Using accelerometers to determine the calling behavior of tagged baleen whales. Journal of Experimental Biology 217:2449-2455.

Heffner, R.S. and H.E. Heffner. 1982. Hearing in the elephant (*Elephas maximus*): Absolute sensitivity, frequency discrimination, and sound localization. Journal of Comparative and Physiological Psychology 96:926-944.

Houser, D.S., D.A. Helweg, and P.W.B. Moore. 2001. A bandpass filter-bank model of auditory sensitivity in the humpback whale. Aquatic Mammals 27:82-91.

Ketten, D.R. 2014. Expert evidence: Chatham Rock Phosphate Ltd Application for Marine Consent. New Zealand: Environmental Protection Agency. Available at: http://www.epa.govt.nz/EEZ/EEZ000006/EEZ000006_13_04_PowerPoint_Ketten.pdf.

Ketten, D.R., and D.C. Mountain 2009. Modeling Minke Whale Hearing. United Kingdom: Joint Industry Programme.

Ketten, D.R., and Mountain, D.C. 2014. Inner ear frequency maps: First stage audiograms of low to infrasonic hearing in mysticetes. Presentation at ESOMM 2014, Amsterdam, Netherlands.

NOAA (National Oceanic and Atmospheric Administration). 2015a. National Oceanic and Atmospheric Administration Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Threshold Levels for Onset Permanent and Temporary Threshold Shifts. July 2015. Silver Spring, Maryland: NMFS Office of Protected Resources.

NOAA (National Oceanic and Atmospheric Administration). 2015b. NOAA's peer review report for Navy technical report. Silver Spring, Maryland: NMFS Office of Protected Resources.

NOAA (National Oceanic and Atmospheric Administration). 2016a. Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing—Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts. Federal Register 81(51): 14095-14096.

NOAA (National Oceanic and Atmospheric Administration). 2016b. Document Containing Proposed Changes To: National Oceanic and Atmospheric Administration Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Threshold Levels for Onset Permanent and Temporary Threshold Shifts. Silver Spring, Maryland: NMFS Office of Protected Resources.

Pacini, A.F., P.E. Nachtigall, C.T. Quinots, T.D. Schofiled, D.A. Look, G.A. Levine, and J.P. Turner. 2011. Audiogram of a stranded Blainville's beaked whale (*Mesoplodon densirostris*) measured using auditory evoked potentials. The Journal of Experimental Biology 214: 2409-2415.

Rankin, S., D. Ljungblad, C.W. Clark, and H. Kato. 2005. Vocalisations of Antarctic blue whales, *Balaenoptera musculus intermedia*, recorded during the 2001/2002 and 2002/2003 IWC/SOWER circumpolar cruises, Area V, Antarctica. Journal of Cetacean Research and Management 7:13-20.

Samaran, F., C. Guinet, O. Adam, J.F. Motsch, and Y. Cansi. 2010. Source level estimation of two blue whale subspecies in southwestern Indian Ocean. Journal of the Acoustical Society of America 127:3800-3808.

Schevill, W. E., W.A. Watkins, and R.H. Backus. 1964. The 20- cycle signals and Balaenoptera (fin whales). Marine Bio-Acoustics 45:147-152.

Sirovic, A., J.A. Hildebrand, and S.M. Wiggins. 2007. Blue and fin whale call source levels and propagation range in the Southern Ocean. Journal of the Acoustical Society of America 122:1208-1215.

Sirovic, A., J.A. Hildebrand, S.M. Wiggins, M.A. McDonald, S.E. Moore, and D. Thiele. 2004. Seasonality of blue and fin whale calls and the influence of sea lee in the Western Antarctic Peninsula. Deep-Sea Research Part II-Topical Studies in Oceanography 51:2327-2344.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas, and P.L. Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals 33:411-521.

Stafford, K. M., D.R. Bohnenstiehl, M. Tolstoy, E. Chapp, D.K. Mellinger, and S.E. Moore. 2004. Antarctic-type blue whale calls recorded at low latitudes in the Indian and eastern Pacific Oceans. Deep-Sea Research Part I-Oceanographic Research Papers, 51:1337-1346.

Starck, J., E. Toppila, and I. Pyykko. 2003. Impulse noise and risk criteria. Noise and Health, 5:63-73.

Wartzok, D., and D.R. Ketten. 1999. Marine mammal sensory systems. Pages 117-175 in J.E. Reynolds III and S.A. Rommel, eds. Biology of Marine Mammals. Washington, D.C.: Smithsonian Institution Press.