# Peer Review Report:

# National Oceanic and Atmospheric Administration Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals:

# Acoustic Threshold Levels for Onset of Permanent and Temporary Threshold Shifts

**Peer Reviewers**[1]


Klaus Lucke, Ph.D., Wageningen University and Research[2] (The Netherlands)

Paul Nachtigall, Ph.D., University of Hawaii

Doug Nowacek, Ph.D., Duke University

Aaron Thode, Ph.D., Scripps Institution of Oceanography


[Note: The original version of the Draft Acoustic Guidance sent to the peer reviewers included proposed behavioral thresholds for seismic activities. During the peer review, two peer reviewers raised substantial concerns with the proposed behavioral threshold methodology. In light of the reviewer comments, NOAA decided to re-evaluate our methodology for behavior and therefore included only threshold levels for permanent and temporary threshold shift in our Draft Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammals. Accordingly, we have not included peer reviewer comments on proposed behavioral thresholds in this peer review report.

NOAA is continuing our examination of the effects of noise on marine mammal behavior and will focus our work over the next year on developing guidance regarding the effects of anthropogenic sound on marine mammal behavior. Behavioral response is a complex question, and additional time is needed to research and appropriately address the issue. This guidance on behavior, when available, will also be subject to future peer review.]

**General Comments**[3]

REVIEWER 1

**Comment**: First, I appreciate the enormous amount of effort that has been put into this document. Having read it through, I realize that quite a literature search has been conducted, and the text is well-organized and well-written, which has helped me tremendously. Much of the science seems excellent to me, but I do have several major and minor concerns that I list in detail below.

[1] Note: Peer Reviewers' comments are presented as provided to NOAA. NOAA did not make any alterations (i.e., there may be spelling, grammatical, or other minor errors).

[2] Now at Curtin University (Australia).

[3] Reviewer identification numbers do not correspond to the order of reviewers above.

***Response***: Major and minor concerns are addressed in Specific Comments section below.

REVIEWER 2

**Comment**: Let me start by saying that I am thrilled that you have assembled this document and clearly put in a great deal of work and thought. These guidelines will be widely used and applied around the world, e.g.[4], [redacted] Along with the breadth of application and influence will also come broad scrutiny, and I think there are some aspects that will not 'review well'. Overall, my conclusion would be that these guidelines are not ready for broad distribution, but they are an excellent start and can be built upon to get a solid, useful set of standards.

> ***Response:*** Thanks for your comment. We have decided to move forward now only with the proposed temporary and permanent threshold shift thresholds and are delaying our guidance on behavioral impacts from sound in order to address it appropriately.

**Comment**: RE: Updating these levels through a systematic, transparent process. Excellent!

> ***Response:*** Thank you.

REVIEWER 3

No general comments were provided by this reviewer.

REVIEWER 4

**Comment**: As a general comment much has so far been written here about PTS with no qualifier that we have almost no data on PTS.

> ***Response:*** To further clarify, the following footnote (#6) was added:
> Note that since no direct data on marine mammal PTS exist, PTS onset thresholds have been extrapolated from marine mammal TTS data.

**Specific Comments (by Section)**

## I. INTRODUCTION

### 1.2.1 Assessment Framework

REVIEWER 4

**Comment:** Re: "The use of representative individuals/species is done as a matter of practicality (i.e., it is unlikely that adequate data will exist for the 125 marine mammal species found worldwide or be able to account for all sources of variability at an individual level) but is also scientifically based (i.e., taxonomy, functional hearing group, ecology). "

[4] The rest of the sentence has been redacted in order not to disclose REVIEWER 2's identity. Note: This general comment primarily relates to the proposed behavioral thresholds included in the version of the document provided to the peer reviewers.

Perhaps some comment that revisions will be undertaken when new data become available would be worthwhile here?

> ***Response***: The following sentence was added: "As new data become available for more species, this approach will be reevaluated."

**Comment:** Re: "NOAA must have an approach for updating our acoustic noise exposure levels and guidance (See Section III)."

Is this must also a 'will.'

> ***Response*****:** The sentence is changed to say: "As these new data become available, NOAA has an approach for updating our acoustic threshold levels (see Section IV)."

**Comment**: Re: "NOAA must have an approach for updating our acoustic noise exposure levels and guidance (See Section III[5])."

a simplistic approaches?

> ***Response***: The approach is fairly simplistic. It does not need to explicitly be stated. Additionally, the approach may change over time and with varying amounts of new data.

## II. NOAA'S ACOUSTIC THRESHOLD LEVELS FOR ONSET OF PERMANENT AND TEMPORARY THRESHOLD SHIFTS IN MARINE MAMMALS

REVIEWER 3

**Comment**: Re: As dual metrics NOAA considers that when either one of these two metrics is exceeded, PTS or TTS onset has occurred.

Dual metrics might not be the ideal – e.g. duration and interpulse interval (with associated recovery process) need to be considered as well.

> ***Response***: There are currently not enough data available to accurately account for recovery between pulses. When there are more data, this can be re-examined.
> Duration of exposure is taken into account via the $SEL_{cum}$ metric.

**Comment**: Re: Additionally, to account for the fact that different species groups use and hear sound differently, noise exposure levels are sub-divided into five broad functional hearing groups (i.e., low-, mid, and high-frequency cetaceans and phocid and otariid pinnipeds).

What about sirenia, mustelids, ursids and odobenids?

> ***Response***: The species groups mentioned are those that are not under NOAA's jurisdiction, which is why they are not addressed (under jurisdiction of U.S. Fish & Wildlife Service).

[5] Section III is now Section IV in the Draft Guidance for public comment (12-18-2013).

## 2.1 Marine Mammal Functional Hearing Groups

REVIEWER 4

**Comment**: Re: "Hearing has been directly measured in a multitude of odontocete and pinniped species (both in air and underwater) (see review in Southall et al. 2007)."

This implies we have lots of data on odontocete hearing in air. That is not true.

> ***Response***: The phrase "both in air and underwater" was referring just to pinnipeds, not odontocetes. This phrase has been added as a footnote (#7) to specifically indicate it applies only to pinnipeds.

**Comment**: Re: "Thus, hearing predictions for mysticetes are based on other methods (e.g., anatomical studies: Houser et al. 2001; Parks et al. 2007; vocalizations : see reviews in Richardson et al. 1995a; Wartzok and Ketten 1999; Au and Hastings 2008; taxonomy and behavioral responses to sound: Dahlheim and Ljungblad 1990; Frankel 2005; see review in Reichmuth 2007)."

Presumed hearing by assuming the animals hear only the sounds they make (but see Nachtigall et al 2007 polar bear work). Polar bears have a much wider hearing range than either their primary prey species or their own vocal range. New work by Colleen Reichmuth's lab shows similar results for the sea otter.

> ***Response***: Vocalizations were listed only as one means of estimating hearing ranges for mysticetes. It was not meant to be presumed as the only means. Other methods, like behavior and anatomy indicate that mysticetes (like most species, including humans) hear frequencies that extend beyond their vocal range.
>
> There is also a footnote (#8) with this sentence that says: "Studies in other species indicate that perception of frequencies may be broader than frequencies produced (e.g., Luther and Wiley 2009)."

## 2.2 Marine Mammal Auditory Weighting Functions

REVIEWER 1

**Comment**: Major concern: Mysticete auditory weighting function in Figure 2 (page 15[6]) is not consistent with references cited.

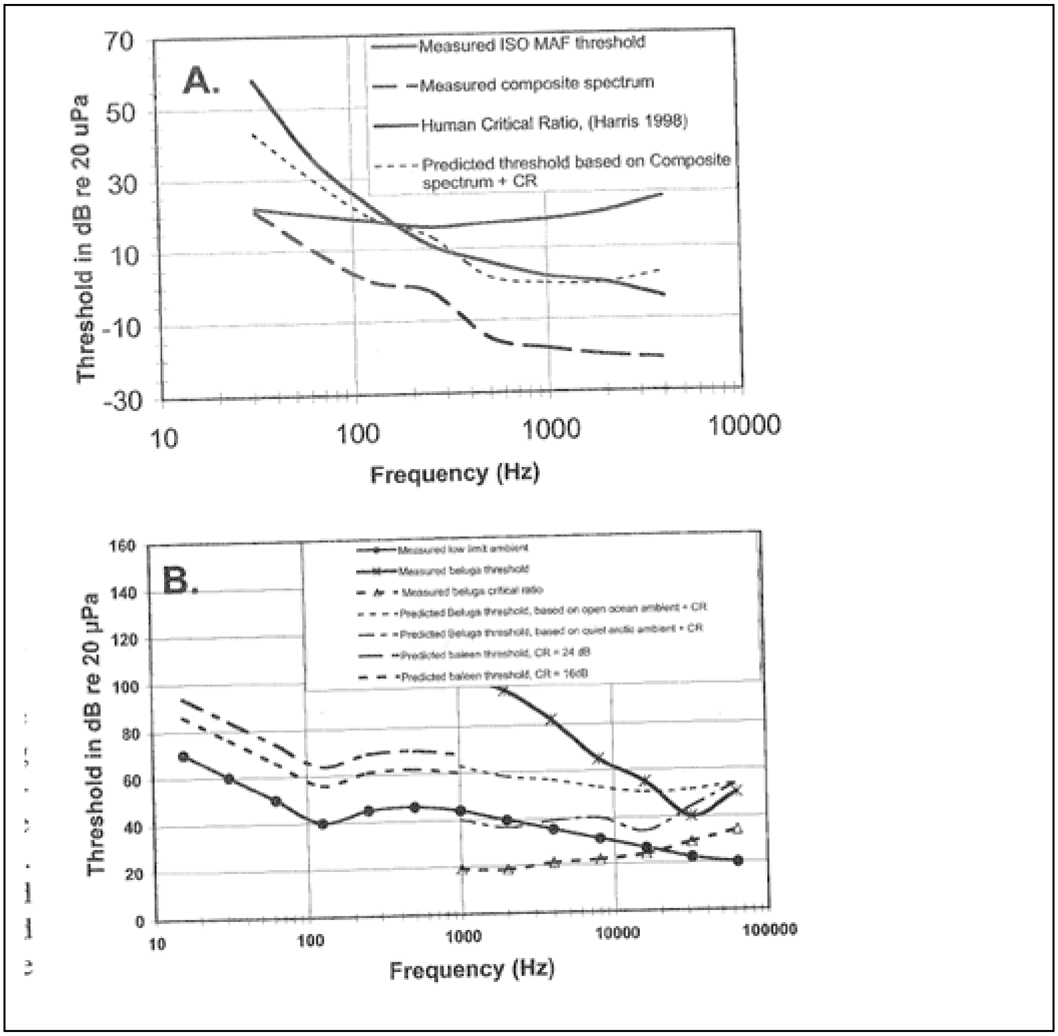
Recommended solution: make AWF only -20 dB at 10 Hz, not -50 dB.

I have specific concerns and recommendations about the low-frequency end of the proposed mysticete auditory weighting function (AWF) between 10 and 100 Hz, displayed in Figure 2 of section 2.2.1.2. This is a region of large economic consequence because seismic airguns typically have peak energy and power over this frequency range, so the question of baleen whale hearing sensitivity over this range will have a substantial impact on evaluations of the impact of seismic surveys on baleen whales.
My concern is that the dropoff in sensitivity by 50 dB from 100 Hz down to 10 Hz is inconsistent with both the sources cited and other independent sources. Instead, the dropoff should only be around 20 dB. The idea behind generating this curve is that the frequency-dependent hearing sensitivity of baleen whales should roughly match the frequency-dependent spectrum of ambient noise in the ocean (before substantial human contamination from shipping noise). This idea has been around a long time-- an interesting book section from Clark and Ellison 2004 (CE2004) is cited as the primary reference, who in turn state briefly that their data are derived from Urick (1983). David Bradley and Gerald D'Spain also

[6] Figure 2 is now found on page 9 of the Draft Guidance for public comment (12-18-2013).

gave a presentation on this idea in Dec 2001 at an Acoustical Society of America meeting as well, and I will be using one slide from their presentation to make my point.

Below is the Figure 73.6 from Clark and Ellison 2004 (CE2004) that Figure 2 seems to be based upon:




The figure shows the predicted hearing threshold of baleen whales (subplot B) increasing by roughly 40 dB as one descends from 100 to 10 Hz, based on the solid circle "low limit ambient" noise curve, which in turn is "based on the sum of measured lower ambient spectrum from Urick (1983)".  The problem is that neither Urick nor other references I find ever show the ambient noise levels increasing so rapidly with decreasing frequency.

For example, here are deep-water ambient noise plots from Urick (1983), third edition:

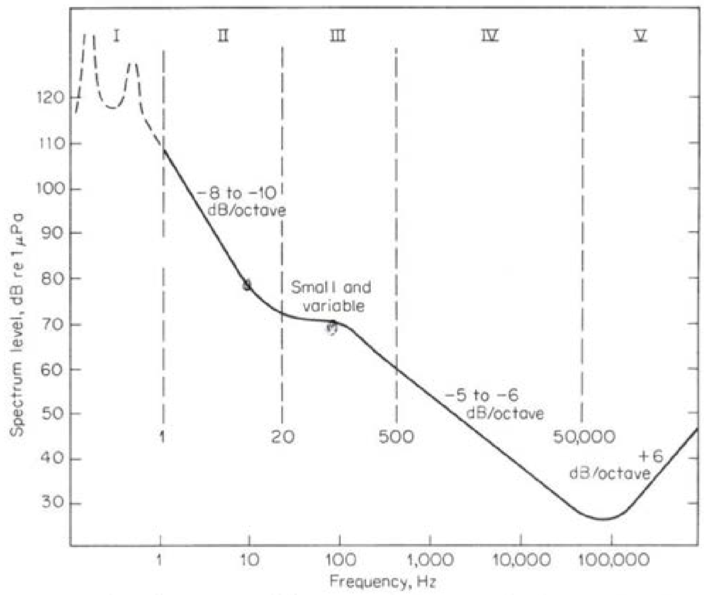



*fig. 7.4 Sample spectrum of deep-sea noise showing five frequency bands of differing spectral slopes. The slopes are given in decibels per octave of frequency.*

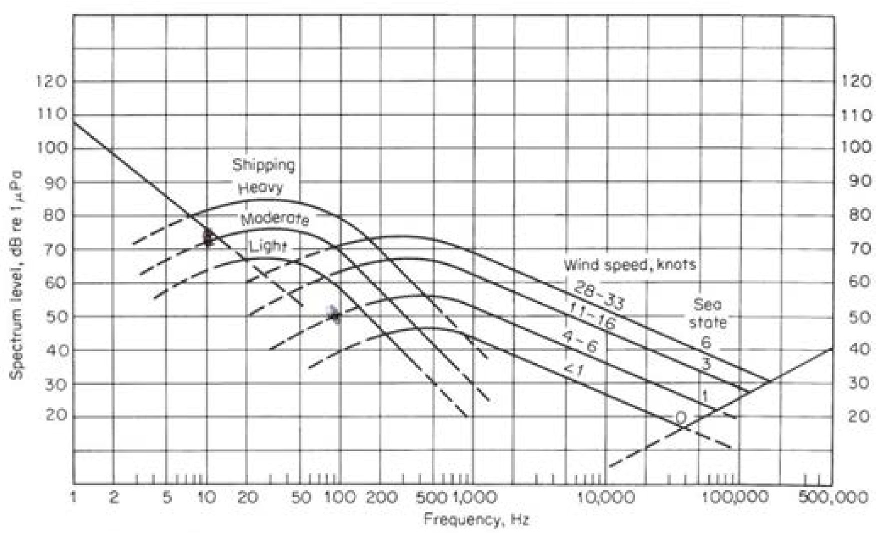
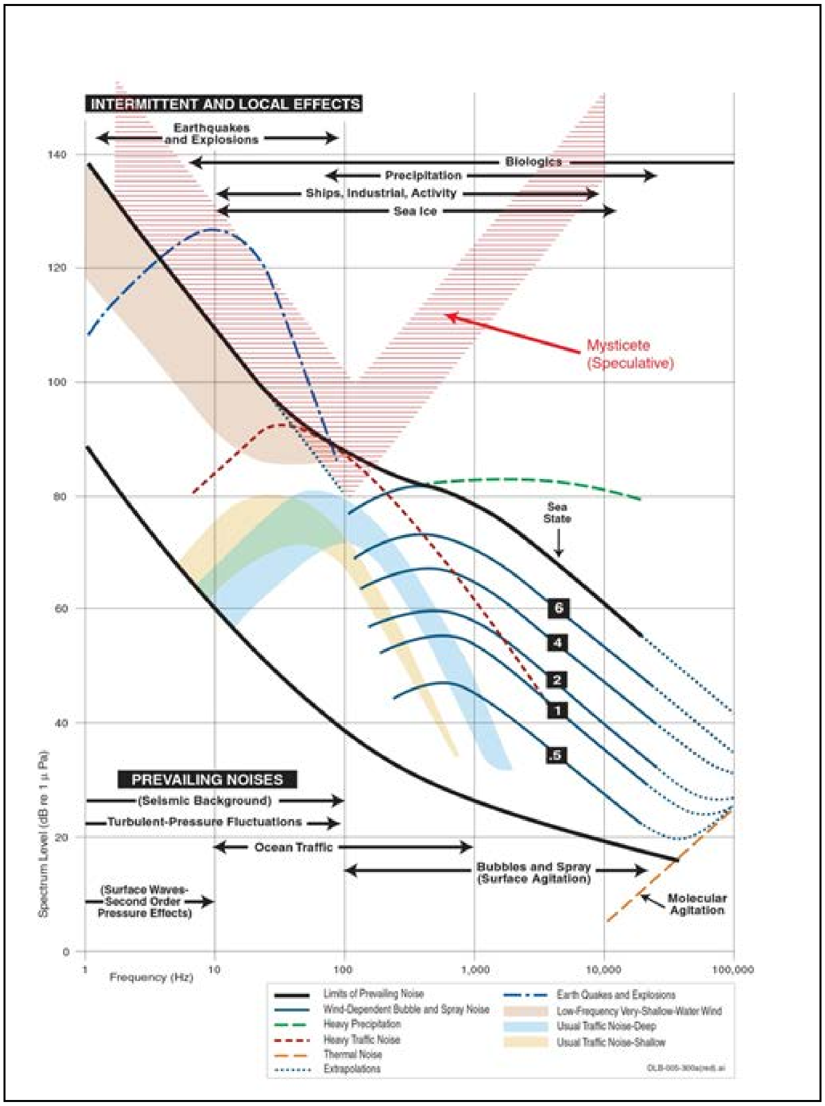



*fig. 7.5 Average deep-water ambient-noise spectra.*

(from Urick, 1983, Chapter 7).

Both figures show that ambient deep-water levels decrease by only 20 dB or so from 10 to 100 Hz, in the absence of shipping traffic. These results are consistent with the most famous study of ambient noise, Wenz (1963[7]) and the "Wenz" curves. Attached is a slide from Bradley's presentation[8] at the ASA that shows how these (peer-reviewed, standard) curves (and thus the mysticete AWF) should increase by at most 30 dB as one descends from 100 to 10 Hz, since the ambient noise levels increase by 20 dB over that range:




(from Bradley and D'Spain, 2001).

Finally, the CE2004 paper also seems to contradict itself on this topic. Below is Figure 73.4 from that paper, which is arguing that the vocalization frequencies of baleen whales occupy frequency bands of low ambient noise levels (before industrial activity). Although not explicitly mentioned in the text, the dashed lines represent the ambient noise levels. Note that the falloff for "coastal" environments (humpback, righ, bowhead) is only 20-25 dB between 10 and 100 Hz, and even less for "deep-water" environments shown for the blue and fin curves. Note the frequency axis typos in the left-hand column.

[7] NOAA believes the reviewer was referring to the Wenz 1962 Journal of the Acoustical Society of America publication (see literature cited).

[8] This same figure can be found in Bradley and Stern 2008.

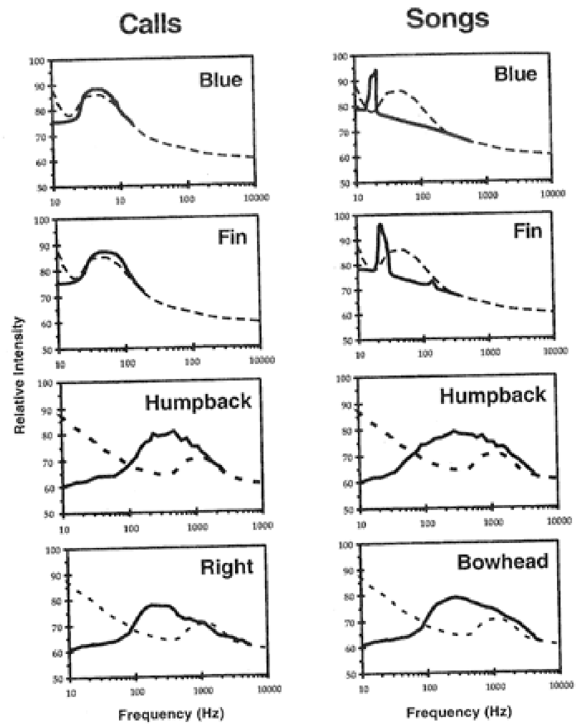



**Fig. 73.4.** *Left:* Average spectra for different species' calls coincident with the ambient noise for the pelagic (blue and fin whales) and coastal (humpback and right whales) environments. *Right:* Average spectra for different species' songs coincident with the ambient noise for the pelagic (blue and fin whales) and coastal (humpback and right whales) environments.

Thus all evidence from three sources suggests that the AWF for LF cetaceans should drop off to -30 or -20 dB at 10 Hz, not -50 dB, so Figure 2 (and thus the additional weighting subtraction in line 7, page 16).

> ***Response***: NOAA has revised the LF auditory weighting function in its latest Draft Guidance and removed any modifications based on ambient/background sound.
> Since this LF auditory weighting function derivation is new, NOAA anticipates there will be more comments/suggestions on this particular topic during the public comment period.

**Comment**: Minor concern: two functional hearing groups for LF cetaceans implied by cited reference. Solution: Insert a couple of sentences recognizing the challenges of using ambient noise spectra to estimate auditory weighting functions.

A close reading of CE2004 indicates that the authors believe that there are two distinct functional "acoustic" classes of mysticetes: "deep-water" and "coastal" species. The former tend to vocalize between 10 and 500 Hz, the latter between 100 and 1 kHz range. Given that the natural ambient noise spectra are quite different between the two environments, the logical conclusion of the paper is that the baleen whale species might have two AWF for "deep-water" and "shallow-water" species. That is the problem with using ambient noise to predict hearing sensitivity: the ambient noise spectrum varies considerably between different environments. I think a couple of sentences should be inserted into 2.2.1.2 that recognize this complexity.

> ***Response***: Since the revised LF auditory weighting function no longer includes modifications based on ambient/background sound, this comment is not directly addressed. Nevertheless, based on the already limited data available for LF cetaceans, it was deemed premature to create two different auditory weighting functions to account for potential differences between coastal and pelagic LF cetaceans.

REVIEWER 2

**Comment**: PTS/TTS weighting functions – I am not a hearing expert, so would likely defer to opinions of others, but I do not see enough support for going away from the m-weighted curve; the m-weighting is not a bad function. The MF and HF cetacean function is, to me, crazy…I find it very hard to believe that every dolphin is 20 dB less sensitive at 1-6 kHz than it is at ca. 50 kHz. Also, the mysticete curve seems to roll off very quickly.

> ***Response***: Finneran and Schlundt (2010) TTS data confirm that TTS onset occurs ~20 dB lower when animals are exposed at 20 kHz vs. 3 kHz. This trend also tracks well with equal loudness data available for this species. Thus, we are assuming these trends occur for other species as well.
>
> The mysticete curve rolled off more quickly because of the incorporation of ambient sound. In the latest version of the document, modifications based on ambient/background sound have been removed. Thus, the function does not roll off as quickly.

**Comment**: Re: NOAA recognizes that the implementation of marine mammal weighting functions represents a new and complicating factor for consideration, which may extend beyond the capabilities of some applicants. Thus, NOAA has developed alternative (default) noise exposure levels for those who cannot apply weighting functions (Table 6[9]). The use of these alternative noise exposure levels will typically result in higher exposures compared to those the incorporate weighting functions.

Wait, wait, wait…how can you say that you'll permit higher exposure to animals just because the humans are less capable?? I think this needs serious reconsideration.

> ***Response***: As explained later in the document, an applicant can choose to use simpler, alternative acoustic threshold levels, but these will result in an increased number of exposures compared to those not relying on the alternative acoustic threshold levels. The following explanatory sentence has been added to the document: "The use of these alternative acoustic threshold levels will typically result in a higher number of exposures compared to those that incorporate weighting functions." Thus, it is assumed an applicant would not choose to use alternative thresholds, unless they were incapable of incorporating more sophisticated exposure levels or auditory weighting functions. NOAA is also developing a User Guide (to be finalized with the Final Guidance), which could be used to illustrate this point.

REVIEWER 3

**Comment**: Re: There are other types of weightings for humans, as well [e.g., B, C, D] that deemphasize different frequencies to different extremes.

"A-weighting resembles the human auditory sensitivity curve, and is the most common weighting function prescribed in noise regulations. The C-weighting curve is flatter, subtracts less energy at the extreme high and low frequencies, and better matches human sensitivity to louder sounds."(Finneran & Jenkins 2012) What is NOAA's logic to use a weighting curve resembling the human A-weighting rather than a C-weighting?

> ***Response***: This specific sentence has been removed from the document. In actuality, the cetacean auditory weighting functions being proposed are actually more of a hybrid between human A- and C-weighting functions.

**Comment**: Re: Finneran and Jenkins (2012) developed auditory weighting functions specifically for cetaceans, including extrapolation procedures when no data were available.

[9] Table 6 is now Table 7in the Draft Guidance for public comment (12-18-2013).

The authors (i.e., Finneran and Jenkins) state: "Pile driving and seismic airguns, although impulsive sources, lack the potential for shock wave generation and are therefore not treated as explosives, but rather rely on unique criteria and thresholds agreed upon by Navy and NMFS. The criteria and thresholds for pile driving and airguns are therefore not included in this document."

NOAA's rationale to use their (Finneran and Jenkins') functions for all types of signals needs to be explained.

> ***Response***: The Finneran and Jenkins 2012 document updates criteria and weighting functions specifically for Navy sonar and explosives. NMFS has been using generic criteria (180/190 dB for auditory injury and 160/120 dB for behavioral harassment) for other non-Navy and non-explosive sound sources. These generic criteria will remain in use until replaced by updated threshold levels in future guidance.
>
> This Guidance document, updates PTS criteria for all sound sources (i.e., other activities will still rely on NMFS' generic criteria until they are updated in a formal manner via updated guidance). There was a footnote (#11) added to the Guidance document to explain the reason for this discrepancy in the Finneran and Jenkins 2012 document and what we are updating in the current Guidance document.

**Comment**: Re: These auditory weighting functions reflect frequencies within which these functional hearing groups are most sensitive to sound in terms of hearing and vulnerability to noise-induced threshold shifts.

What is the basis for the assumption that vulnerability to TTS can be derived from EQLs? This needs further explanation. [like e.g.: Finneran & Jenkins (2012 state: "In contrast to the onset of TTS, which represents an exposure threshold, the hazardousness of a noise exposure can also be described by the susceptibility of the listener, which represents the listener's sensitivity to noise. The relative susceptibility is obtained by negating the onset TTS levels (in dB), then normalizing these data at some frequency. High values of susceptibility therefore indicate frequencies where noise is more hazardous. The susceptibility data can be directly compared to auditory weighting functions, which preferentially emphasize (apply larger weight to) frequencies where noise is more hazardous and de-emphasize those frequencies where noise is less hazardous."

However, the supporting scientific evidence and rationale remains unclear at this point.

Finneran and Schlundt (2013) state: "The agreement between the weighting function derived from the 90-dB SPL equal loudness contour in TYH (Finneran and Schlundt, 2011) and the TTS onset data from both BLU and TYH [Fig. 4(b)] supports the use of this particular weighting function for dolphins, at least in the frequency range from ~3 kHz up to ~56 kHz (where the data exist). Below 3 kHz, the dolphin equal-loudness based weighting function predicts increasingly less susceptibility to noise; however, the equal loudness contours themselves do not extend below 2.5 kHz (Finneran and Schlundt, 2011), thus the shape of the weighting function at these frequencies is controlled by the functional form used and has not been directly validated. Therefore, additional data are needed below 2.5–3 kHz: equal loudness or equal latency contours and/or direct measurement of TTS onset at lower frequencies."

THIS seems to be the supporting evidence for applying EQL contours to assess the vulnerability of marine mammals to noise-induced TTS. ]

Another aspect that might be worth considering when applying weighting functions is that "marine mammals experience greatest TTS at a frequency ½-octave above the frequency of exposure when exposed to loud tones as has been shown in terrestrial mammals" (Southall et al. 2007).

Doesn't that imply that a similar 1/2 –octave shift must be applied to the weighting functions before using them for marine mammals?

***Response***: More justification for using equal loudness data has been added to the text. As for the incorporation of ½ octave shifts associated with noise-induced hearing loss, these are already taken into consideration by being incorporated into proposed TTS onset acoustic threshold levels, specifically for marine mammals (i.e., Finneran et al. 2007; Popov et al. 2011a; Popov et al. 2011b).

**Comment**: Re: Cetacean auditory weighting functions are a blend of the marine mammal or "M-weighting" functions proposed in Southall et al. 2007 below a certain inflection point.

Inflection point: from an evolutionary and (acoustically) ecological point of view it is not reasonable to apply this approach. More likely to use inverse audiogram or extrapolating Type II weighting functions to lf (and hf).

***Response***: The term "inflection point" has been removed from the document. The proposed cetacean auditory weighting functions are actually a hybrid between weighting functions ("hump") for frequencies that are more susceptible to noise (i.e., where we have data) and broader M-weighting functions for frequencies where there are less data (i.e., more uncertainty). Thus, they may not necessarily perfectly reflect acoustically how species hears sounds. However, they are more conservative than using inverse audiograms to solely derive auditory weighting functions and are considered more representative of the entire functional hearing group. Additionally, inverse audiograms cannot be used for LF cetaceans, since there are no direct measurements of hearing available and making further extrapolations would be going beyond the limits of the available science.

**Comment**: Re: The modification to the original Southall et al. 2007 auditory weighting functions reflects the frequency band of enhanced sensitivity, as far as hearing, as well as susceptibility to noise-induced threshold shifts.

Assumption re TTS not supported with data here, needs further explanation (see above).

***Response***: For example, Finneran and Schlundt (2010) does support that TTS onset occurs at a lower level in a bottlenose dolphin's best hearing range (i.e. 20 kHz) compared to TTS onset outside this best hearing range (i.e., 3 kHz). These data are used to extrapolate for other functional hearing groups where there are not data. Thus, the assumption is made that bottlenose dolphins represent a reasonable surrogate for what would be expected for other species.

**Comment**: Re: MF and HF cetacean auditory weighting functions

This seems like a drastic departure.

***Response***: These functions have previously been proposed in Finneran and Jenkins 2012 (i.e., this is not something new NOAA is proposing), but this is a topic where we hope to get further public comment.

**Comment**: Re: MF and HF cetacean auditory weighting functions (arrow indicate inflection points[10]; frequencies greater than inflection point represent the "hump" of best sensitivity).

Finneran & Jenkins (2012) state: "The M-weighting functions are nearly flat between the lower and upper cutoff frequencies (a and b, respectively) specified in Table 1. For this reason, they were believed to over-estimate the effects of noise at high and low frequencies and thus to be protective (Southall et al., 2007)."

[10] As indicated earlier, the term "inflection point" has been removed from the document. Thus, the arrow being referred to by the REVIEWER 3 is no longer found on Figure 1.

Does NOAA share the notion that M-weighting is too protective, especially in the low and high-frequencies? Applying the weighting curve type II as suggested by Finneran & Jenkins results in a reduction of ≥17 dB (MF cetaceans) and ≥20 dB (HF cetaceans) in the frequency range below 3 kHz.

Furthermore, Finneran & Jenkins state:

"At frequencies above 3 kHz, the dolphin susceptibility to TTS increases (the TTS onset is lower); however, the MF cetacean weighting function proposed by Southall et al. (2007) is flat between 3 and 20 kHz and does not reflect the dependence of TTS on exposure frequency. In contrast, the EQL weighting functions predict larger effects from noise than the MF cetacean M-weighting function above 3 kHz, and better match the susceptibility data."

Wouldn't that statement imply that M-weighting was not protective enough? Instead the Type II weighting curve is normalised to the maximum sensitivity in the 20-40 kHz region. This would be in accordance with Finneran & Schlundt (2011) stating:

"In other words, for the Southall et al. weighting function to truly be protective, the numeric thresholds would need to be based on the most susceptible frequency."

However, this is somehow contradictory to their statement:

"The present data, as well as the TTS onset data at 3 and 20 kHz, strongly suggest that the Southall et al. mid-frequency cetacean weighting function not only overestimates the impact of lower frequency sounds on dolphins, but also underestimates the effects of higher frequency sounds, since the weighting function was proposed for use with numeric thresholds obtained from TTS testing in the range of 3 to ~8 kHz, which is now known to be below the most susceptible frequencies in dolphins (Finneran and Schlundt, 2010)."

> ***Response***: NOAA believes that the auditory weighting functions presented in Finneran and Jenkins (2012) represent the most recent science regarding susceptibility to noise-induced hearing loss, especially at frequencies above 3 kHz for MF cetaceans (i.e., bottlenose dolphins). We do acknowledge that there are limited data currently available.

**Comment**: Re: The auditory weighting function, W(f), for all cetaceans, is represented by the following equation (Southall et al. 2007; Finneran and Jenkins 2012.

The equation given here is for the Type I weighting function while figure 1 shows the Type II weighting function. The correct mathematical definition would be:
$W_{II}(f) = \text{maximum}\,[G_1(f), G_2(f)]$

where $W_{II}(f)$ is the weighting function amplitude (dB) at the frequency f (Hz) (see Finneran & Jenkins 2012, also for further details – equation 6 and 7).

> ***Response***: The equation in the Guidance is correct. It looks different compared to Finneran and Jenkins 2012 because the K value depends on whether it is above or below the inflection point. Finneran and Jenkins 2012 just chose to express it as two different equations.

**Comment**: Re: Thus, based on these data, there does not seem to be justification to modify the "hump" for HF cetaceans as proposed by Finneran and Jenkins 2012.

But doesn't that at the same time contradict the approach of using equal loudness curves to derive a weighing function for HF cetaceans in general? Either the same approach can be applied to all species or it's not valid as such.

The results from Popov indicate that
a) the conclusion drawn here for HF cetaceans is not valid as there is a mismatch in the results and

b) extrapolating weighting functions from TTS susceptibility (as determined by Finneran and Schlundt for MF cetaceans) and EQLs is not valid for HF cetaceans.

Re: Based on what is known about the predominant vocal range of LF cetaceans, as well as hypothesized sensitivity to lower frequency sounds, the Finneran and Jenkins (2012) auditory weighting function was deemed not to reflect what is currently known about LF cetaceans' potential auditory capabilities. Thus, NOAA decided to develop an alternative LF cetacean auditory weighting function (Figure 2).

Another indicator that this approach might be valid for MF cetaceans, but should not be applied to other functional groups. The logic of doing so is not stringent.

> ***Response***: There are no equal loudness data available for any other species besides bottlenose dolphins[11], but TTS data was also used to support the location of the "hump." There are limited data to indicate that HF cetaceans are most susceptible to TTS within the range of frequencies that are currently being proposed for the "hump" (Popov et al. 2011a; Popov et al. 2013). Finneran and Schlundt (2013) found TTS susceptibility might not necessarily directly reflect hearing sensitivity.
>
> What is the suggested alternative for HF cetaceans? M-weighting from Southall et al. 2007?

**Comment**: Re: Based on what is known about the predominant vocal range of LF cetaceans, as well as hypothesized sensitivity to lower frequency sounds, the Finneran and Jenkins (2012) auditory weighting function was deemed not to reflect what is currently known about LF cetaceans' potential auditory capabilities. Thus, NOAA decided to develop an alternative LF cetacean auditory weighting function (Figure 2).

> ***Response***: This particular topic was identified as one where NOAA would appreciate more input during the public comment period.

**Comment**: Re: This information was specifically used to modify further the LF cetacean auditory weighting functions at frequencies at and below 100 Hz to represent relative impact of ambient noise on hearing ability and susceptibility to noise-induced hearing loss.

The logic of using a masked perception threshold (i.e. a physical constraint) as a criterion for TTS susceptibility is not convincing/stringent without further elaboration on the available relevant scientific data.

> ***Response***: In the updated version of the Guidance, any modification of the LF cetacean auditory weighting function based on background/ambient sound has been removed.

**Comment**: Re: Below 100 Hz modifications were made to weighting function based on ambient noise levels (Clark and Ellison 2004).

This weighting function is flat from 100 Hz – 1 kHz, thus (e.g.) fin or blue whale vocalisation is not regarded in this context? Their best sensitivity might/ is likely to be much lower than that of e.g. humpback whales.

> ***Response***: Based on limited data available for LF cetaceans, it was deemed premature to derive separate auditory weighting functions for blue or fin whales, separate from other mysticetes. The LF cetacean auditory weighting function was identified as one where NOAA would appreciate more input during the public comment period.

[11] We are aware that equal loudness studies are currently underway for harbor porpoises in the laboratory of Dr. Ron Kastelein.

**Comment**: Re: Additionally, from the available TTS datasets, none indicate that pinnipeds are more susceptible to noise-induced threshold shifts within a certain portion of their auditory range.

Are they as comprehensive as the ones done for cetaceans, i.e. is it already valid to make such a statement – or is premature?

> ***Response***: NOAA recognizes this point. There have been fewer studies completed on pinniped TTS compared to cetaceans. A footnote (#14) has been added to acknowledge this.
>
> Nevertheless, with currently available data, there are no justifications to make any modifications from the more simple M-weighting auditory weighting functions.

**Comment**: Re: Establishment of numerical noise exposure levels for PTS and TTS onset (cSEL metric threshold; the peak pressure metric threshold is not weighted), which is NOAA's responsibility; and

This is important, should be mentioned earlier in the document.

> ***Response***: Information has been added earlier in the document to address where auditory weighting functions are applicable ($SEL_{cum}$) and where they are not (i.e., $dB_{peak}$).

**Comment**: Re: If a sound produced is within the auditory frequency range of a marine mammal but approaches the boundary of that range (i.e., outside frequency range of maximum sensitivity), the marine mammal is believed to be less able to hear that sound and believed less susceptible to noise-induced hearing loss (i.e., TTS or PTS onset).

This assumption is not backed up sufficiently by scientific data for LF and HF cetaceans.

> ***Response***: NOAA does not have data on hearing, let alone TTS in LF cetaceans and would appreciate a suggested alternative.

**Comment**: Re: Essentially, auditory weighting functions act as a "filter" that reduces the energy associated either with a physiological response or with isopleths, with weighting functions never resulting in larger isopleths.

It is appropriate to weight impulse sound sources, particularly with dominant low frequency content. However, data used to calculate the threshold for impact need to be similarly weighted, i.e. it is inappropriate to compare a weighted exposure to an un-weighted threshold.

> ***Response***: NOAA agrees that weighting acoustic threshold levels should only be used with weighted exposures. At the end of the paragraph, the document says if NOAA proposed marine mammal auditory weighting functions are used to model isopleths, they should be used in conjunction with corresponding NOAA PTS and TTS onset acoustic threshold levels that have also been derived using auditory weighting functions.

**Comment:** Re: If NOAA proposed marine mammal auditory weighting functions are used to model isopleths, they should be used in conjunction with corresponding NOAA PTS and TTS onset noise exposure levels that have also been derived using auditory weighting functions.

This is an important point – see comment before.

Also, it needs to be made clearer what the benefit is of applying weighting to both the exposure level AND the TTS/PTS onset noise exposure levels?

> ***Response***: The benefits are that they more realistically reflect currently available data. This clarification has been added to the text of the Guidance. NOAA has developed alternative acoustic threshold levels for those who cannot directly account for auditory weighting functions.

REVIEWER 4

**Comment**: Re: “A similar extrapolation was proposed for LF cetaceans, but NOAA decided to derive LF cetacean auditory weighting functions in a slightly different manner.”

Why?

> ***Response***: The reason is further explained in Section 2.2.1.2 Generalized Auditory Weighting Functions for Low-Frequency Cetaceans. The reader is referred to this section for more information.

**Comment**: Re: “Thus, based on auditory anatomy and vocalizations, it would seem that HF cetaceans would be more sensitive to higher frequencies compared to MF cetaceans.”

Would it be worth your while to take a look at critical bands/critical ratios of the different groups at high frequencies to discern differences? We have more data on those.

> ***Response***: This could be further explored but based off of current TTS data (e.g., Finneran and Schlundt 2013), it seems that susceptibility to noise-induced hearing loss may not necessarily reflect hearing sensitivity. As more data become available, this can and will be reevaluated

**Comment**: Re: “However, LF cetaceans are predicted to have good sensitivity from 20 Hz to 2 kHz (Ketten 1998), with some species like humpback (Houser et al. 2001) and minke whales (Tubelli et al. 2012b) predicted to have an expanded best hearing range (i.e., up to 6 to 7.5 kHz).”

I think minke's are predicted to hear much higher frequencies than that in the Tubelli et al work. Ketten's students predict over 30 kHz hearing.

> ***Response***: NOAA agrees. This is reflected in the explanation as to why the upper frequency range of LF cetaceans was extended to 30 kHz (compared to 22 kHz, which was proposed in Southall et al. 2007).
>
> The sentence the reviewer identifies specifically refers to the “best hearing range.” Best hearing range is not meant to reflect the entire auditory range.

**Comment**: If the animals have evolved hearing low frequencies in that environment why would they be noise rather than threshold limited?

> ***Response***: In the updated version of the Guidance, any modification of the LF cetacean auditory weighting function based on background/ambient sound has been removed.

**Comment**: It is increasingly obvious that empirical measures of mysticete hearing are necessary. The technology exists to tackle that issue.

> ***Response***: NOAA agrees.

**Comment**: Re: “Additionally, from the available TTS datasets, none indicate that pinnipeds are more susceptible to noise-induced threshold shifts within a certain portion of their auditory range.”

Unfortunately we do not have empirical equal loudness curves for pinnipeds like we have for at least one odontocete. It is important to indicate how thin the assuptions of the Southall et al data are when it comes to equal loudness curves. The reaction time data seem very promising in that direction.

> ***Response***: The sentence before indicates: Equal loudness measurements have not been obtained for any pinniped species.

NOAA acknowledges that pinniped auditory weighting functions are more simplistic than what is being proposed for cetaceans. This is because there are not currently enough data to support any modifications.

**Comment**: Still no information to the reader that we have essentially no data on PTS onset in marine mammals. It is imperative to point out in this document what we do not know, and what we must therefore assume. Conclusions based on assumptions must be particularly made obvious to the reader and user.

***Response***: As per previous comment on this issue, a footnote (#6) was added earlier in explaining this. Moreover, when one looks at the proposed PTS onset acoustic threshold levels (i.e., Table 6[12]), there is additional detail provided regarding data used to derive acoustic threshold levels, including when there were data available and when there were not data available (e.g., indicates that all PTS threshold levels were extrapolations based on terrestrial data).

**Comment**: Re: "Thus, NOAA has developed alternative (default) noise exposure levels for those who cannot apply weighting functions (Table 6[7]). The use of these alternative noise exposure levels will typically result in higher exposures compared to those the incorporate weighting functions."

choose not to apply?

***Response***: As explained later in the document, an applicant can choose to use simpler, alternative acoustic threshold levels, but these will result in an overestimate in the number of exposures. The following explanatory sentence has been added to the document: "The use of these alternative acoustic threshold levels will typically result in a higher number of exposures compared to those that incorporate weighting functions." Thus, it is assumed an applicant would not choose to use alternative thresholds, unless they were incapable of incorporating more sophisticated exposure levels or auditory weighting functions. NOAA is also developing a User Guide (to be finalized with the Final Guidance), which could be used to illustrate this point.

## 2.3 TTS and PTS Onset Acoustic Threshold Levels

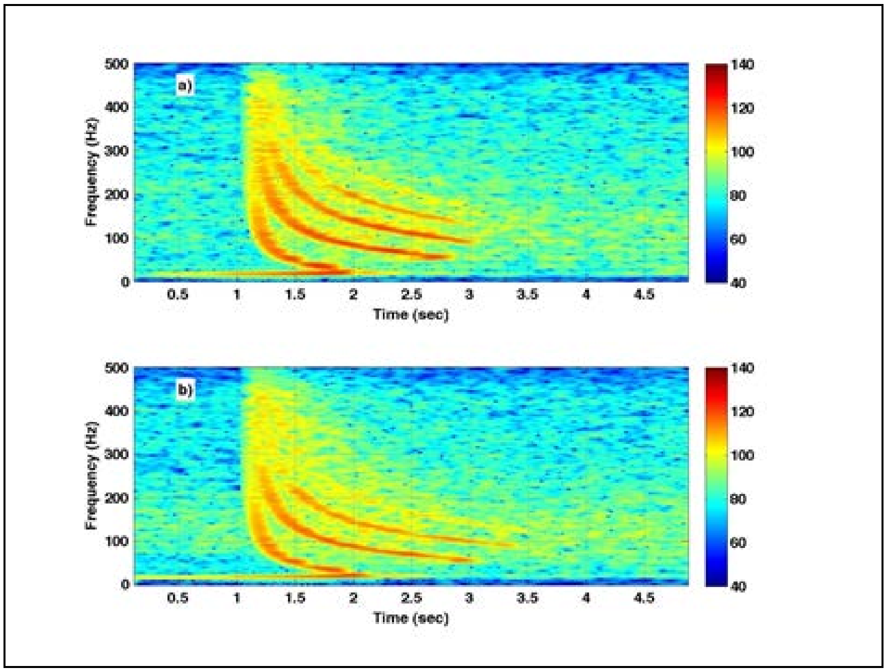
REVIEWER 1

**Comment**: Major concern: practical definition of an "impulsive" in dispersive propagation environments for pulses 1 s or less:
Solution: provide explicit definition of an impulsive event that defines duration as being measured at the source location.

"Studies were summarized by dividing them into the following categories: Impulsive (transient, brief [less than 1 second], broadband, and typically consist of high peak pressure with rapid rise time and rapid decay [ANSI 1986; NIOSH 1998; ANSI 2005]) vs. Non-impulsive sources (can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically do not have a high peak pressure with rapid rise time [typically only small fluctuations in dB level] that impulsive signals do ([ANSI 1995; NIOSH 1998])."

These quotations were the only points in the document where the practical definition of an impulsive is defined, and it seems to require the pulse to be less than 1 sec. This may lead to practical problems in applying the proposed TTS and PTS thresholds to sounds like airguns in dispersive propagation environments.

[12] Table 6 is now Table 7in the Draft Guidance for public comment (12-18-2013).




The figure above shows how a seismic airgun pulse appears after traveling several kilometers in shallow waters in the Beaufort Sea.  As you can see, the duration of all components of the pulse are greater than one second.  In addition, the presence of mulitpath as intense as the first arrival extends the duration of the signal further.  Are these signals impulsive (187 dB cSEL PTS) or non-impulsive (198 dB cSEL PTS)?  I think an explicit definition of what constitutes a "Impulsive" category should be present much earlier than page 21 in the document, and if the definition includes a signal duration, it should have a statement that the signal duration should be 1 sec or less when generated at the source, not measured at the receiver.

> ***Response***: NOAA agrees with indicating that definitions apply to characteristics at the source and not the receiver. This has been clarified within the Guidance document. These definitions are also included in the Glossary. A footnote (#18) has been added to the first time the word "impulsive" is used noting that these definitions are based on characteristics at the source and not at the receiver.

**Comment**: Major concern:  defining cSEL to be measured over 24 hours for a continuous activity leads to inconsistencies with the behavioral criteria.

Proposed solution:  Redefine cSEL time to be three hours for situations where migration/travel is dominant behavior, roughly consistent with exposure time for migrating animals.

In section 2.3.1.1. it states that 24 hours is a conservative estimate for the time needed to integrate the cSEL, and roughly covers a diurnal cycle (and thus most short-term behavioral states).
If used by default, a single airgun survey, firing at 10 s intervals, generates 8640 pulses/day -> 40 dB increase in cSEL over the SEL of a single pulse.  That is, a survey generating "only" 132 dB received SEL pulses (roughly 132 dB re 1upa rms for 1 s pulses in Arctic environments) will exceed the impulsive TTS cSEL criteria for LF cetaceans (172 dB).

I feel the report has so many caveats on this subject as to render this definition worthless:
"The 24-h baseline accumulation period is generally considered a conservative baseline for accumulation time under most situations. However, flexibility may be required. For example, if specific information on residence time of individuals, likely swim speeds for transient species, more specific details on the sound-producing activity (e.g., specific times when activity temporarily ceases),"

Just about every oil and gas industry survey is going to try to reduce this period of time to the time it takes for a migrating animal to swim past a spatially compact activity.

I think a sentence should be added that if the primary behavior of marine mammals in the area is migration, the cSEL duration can be restricted to three hours. Areas that cover feeding and mating should remain at 24 hours. This is much simpler than requiring an applicant to estimate swimming speed, swimming depth, whether animals is assumed to deviate or avoid course, etc. Restricting duration to 3 hours also makes the behavioral and TTS criteria more consistent.

> ***Response***: NOAA appreciates your input on this particular topic and anticipate there will be additional comments provided during the public comment period. The proposed 24-h accumulation period may not be appropriate for certain sound sources or species. We are planning to call particular attention to this topic during the public comment period. Additionally, your comments seem to focus strictly on seismic activities. However, the proposed accumulation period is for all PTS onset acoustic threshold levels for various sources (e.g., sonar, pile driving, drilling, etc.). Thus, there are multiple considerations needed based on whether a source is stationary or mobile and based on the species and specific context of exposure. Finally, in inconsistencies with future behavioral thresholds will be considered. It is not an issue at this time as references to behavioral thresholds have been removed from the Guidance.

**Comment**: Moderate concern: how define cSEL when multiple activities present?

Proposed solution: Provide specific guidelines whether cSEL covers only proposed activities or whether it covers all independent activities (including shipping) during that time. State whether NOAA will reduce the cSEL threshold if multiple permits working in the same area are received.

Another issue with defining cSEL duration to be 24 hours is what to do when multiple uncoordinated activities are present. For example, multiple seismic surveys? Shipping vessel transits? NOAA should also state intentions what it plans to do if multiple organizations submit requests to operate in the same region, with each showing individual cSELs below TTS, but cumulative cSEL from all operations exceed TTS.

> ***Response***: Currently, the PTS onset acoustic threshold levels are being proposed for discrete activities and not multiple activities occurring in a single area. This will be clarified in the text (footnote #15).

**Comment**: Major concern: Determining dolphin hearing sensitivity below 150 Hz.

Solution: W(f) should be extended below 150 Hz to -90 dB cutoff frequency, and recommend further studies to test MF capability below 150 Hz.

Figure 1 shows that below 150 Hz MF cetacean sensitivity is below -50 dB, and is set to zero. My concern with this issue is that airgun signals have large intensities below 150 Hz, so even if dolphins have low sensitivity to these sounds (-90 dB?) over three hours of close-range exposure could yield a non-negligible cSEL. I believe that the oft-cited fact that dolphins bowride on active seismic vessels is not definite proof that these animals are not sensitive to these sounds-- these observations are consistent with the expectation that the transmission loss of low-frequency sound at a pressure-release surface is near zero--so these observations do not prove nor disprove that dolphins have no hearing sensitivity below 150 Hz, or wouldn't be affected if foraging or breeding within a few kilometers of the vessel.

> ***Response***: The lower hearing limit for MF cetaceans is based off the recommendations from Southall et al. 2007. They say "Based on the combined available data, mid-frequency species are estimated to have lower and upper frequency "limits" of nominal hearing at approximately 150 Hz and 160 kHz, respectively."

We (NOAA) relied on the lower and upper hearing limits for all marine mammal functional hearing groups proposed in Southall et al. 2007, unless otherwise mentioned (i.e., did make some minor changes, see Table 1). Thus, until new data are available, it is considered premature to make any further adjustments.

Additionally, the functional hearing limits proposed in Southall et al. 2007 are meant to be a composite hearing range for the entire group of species within the functional hearing group. Thus, it doesn't mean that every species within that functional hearing group can hear over the entire functional hearing range (i.e., individual species' hearing range is not as broad as the functional hearing group).

**Comment**: Minor suggestion: Beyond the equal energy hypothesis.

While slightly beyond the scope of NOAA's charge, I'm intrigued by what violations of the EEH imply. It seems like a next model beyond the EEH would be a simple resonator model (mass, dashpot, spring; inductor, resistor, capacitor, etc.) with a possible active feedback element. Such a system can absorb and dissipate energy at different rates, and may display some of the behaviors being observed: that longer-duration exposures lead to higher TTS; that TTS can increase after exposure is finished, etc.

***Response***: Thanks for the suggestion. This is something that could be explored for updated guidance.

**Comment**: Minor suggestion: use "peak-to-peak" instead of "peak" criteria for PTS and TTS tables. Peak-to-peak would seem to be a more appropriate measure of mechanical damage, but I am not a expert on this topic. The switch would change values by about a factor of 6 dB.

***Response***: The peak pressure metric was recommended in Southall et al. 2007 as an appropriate metric for PTS and TTS. They say "Peak pressure is a useful metric for either pulse or nonpulse sounds, but it is particularly important for characterizing pulses (ANSI, 1986; Harris, 1998, Chapter 12)." They also go on to say "Mammalian hearing is most readily damaged by transient sounds with rapid rise-time, high peak pressures, and sustained duration relative to rise-time (for humans: Thiery & Meyer-Bisch, 1988; for chinchillas [*Chinchilla lanigera*], Dunn et al., 1991)." Thus, peak pressure is considered a more appropriate metric to use compared to peak-to-peak pressure.

Additionally, converting all the current TTS data from the peak to peak-to-peak pressure metric would be difficult (i.e., conversion factor you mentioned may not be appropriate for all sound sources).

<u>REVIEWER 2</u>

**Comment**: Re: The 24-h baseline accumulation period is generally considered a conservative baseline for accumulation time under most situations. However, flexibility may be required.

I agree that this flexibility is needed, particularly when considering aggregate and cumulative effects.

***Response***: The baseline accumulation period is meant to be used on an activity-by-activity basis, not necessarily to calculate cumulative effects from multiple activities occurring over a particular space or over a particular time period (see footnote #15). That is beyond the scope of this document.

**Comment**: Re: Finally, in situations where there is a resident population in a confined area (e.g., Cook Inlet belugas) and/or there is the potential animals could be exposed for more than 24 h, a modification to this baseline accumulation period should be considered, along with activity-, site-, and species-specific factors (i.e., case-by-case scenario).

And what about sequential and/or parallel activities? If you have two seismic surveys being conducted within 'auditory footprint' of each other, how do you account for this additional accumulation?

> ***Response***: The baseline accumulation period is meant to be used on an activity-by-activity basis, not necessarily to calculate cumulative effects from multiple activities occurring over a particular space or over a particular time period (see footnote #15). That is beyond the scope of this document.

**Comment:** Aggregate and cumulative exposure are not addressed, and a logical place to do it is with the accumulation baseline and cSEL in Section 2.3.1.1. You state that you need to retain flexibility, and I understand that, but in a discussion of how to calculate an acceptable dose period, seems to me you should use that opportunity to discuss aggregate and cumulative exposure.
Also in this section, you discuss application of weighting functions…not sure why you're saying you'll allow higher doses to the animals just because the humans are not capable of applying weighting functions? Seems like a slippery slope…upon whom do you impose the requirement of using the weighting functions?

> ***Response***: The baseline accumulation period is meant to be used on an activity-by-activity basis, not necessarily to calculate cumulative effects from multiple activities (cumulative or aggregate) occurring over a particular space or over a particular time period. That is beyond the scope of this document.
>
> As explained later in the document, an applicant can choose to use simpler, alternative acoustic threshold levels, but these will result in an overestimate in the number exposures. Thus, it is assumed an applicant would not choose to use alternative thresholds, unless they were incapable of incorporating more sophisticated exposure levels or auditory weighting functions.

**Comment**: Re: Sound exposure containing transient components (e.g., short duration and high amplitude; impulsive sounds) can create a greater risk of causing direct mechanical fatigue (as opposed to strictly metabolic) to the inner ear compared to sounds that are strictly non-impulsive (Henderson and Hamernik 1986; Levine et al. 1998; Henderson et al. 2008).

Long term exposure, in addition to peak pressures, cause mechanical fatigue…

> ***Response***: NOAA agrees. That is why the $SEL_{cum}$ is also being proposed within a set of dual acoustic threshold levels.

**Comment**: Re: Cell with non-impulsive TTS onset noise exposure levels for narrowband sources above 6 kHz for LF cetaceans.
I know this is above the inflection point, but 195 cSEL is high, e.g., consider humpbacks can produce fundamental frequencies at 2 kHz or higher, so the first or second harmonic would be subjected to this…they can certainly hear and are likely sensitive to these frequencies

> ***Response***: This was the acoustic threshold level initially proposed in Southall et al. 2007. Also, note that since the LF cetacean auditory weighting function has been modified, 6 kHz has been changed to 10 kHz.

<u>REVIEWER 3</u>

**Comment**: Re: Factors like level (e.g., overall level, sensation level, or level above background), duration, repetition rate (intermittent versus continuous exposure), number of transient components (short duration and high amplitude), and/or frequency (especially in relation to hearing sensitivity) often are also important factors associated with threshold shifts

... and associated with that the recovery between successive impulses.

***Response***: The potential for recovery between intermittent periods has been added here. NOAA agrees that the other factors mentioned by the reviewer are also important. However, for most situations, there are not enough data available to integrate these factors into our acoustic threshold levels. As more data become available, this will be further considered.

**Comment**: Evaluation and summary of currently available, published data (24 studies, as of 30 April 2013) on hearing loss associated with noise exposure in marine mammals.
Peer-reviewed?

***Response***: Yes, all studies evaluated for TTS onset had to be peer reviewed. This has now been added to the table listing all the studies to indicate that they are all peer reviewed.

**Comment**: Re: TTS onset, Impulsive, HF cetaceans: 165 dB cSEL

If these data are unweighted and the TTS onset level is based on Lucke et al. (2009) how has this data point been derived? The level measured by Lucke et al. (2009) was 164 dB SELp-p.

**Response**: For the alternative acoustic thresholds level for HF cetaceans exposed to impulsive sounds, this value was derived from the weighted value (146 dB $SEL_{cum}$ plus the K value from Table 2, which is 19.4). This results in 165 dB $SEL_{cum}$.

Looking back at Lucke et al. 2009, the unweighted value provided in this paper for TTS onset was164.3 dB SEL. So, 164 dB $SEL_{cum}$ is more appropriate to use because it comes directly from the data instead of the extrapolated 165 dB $SEL_{cum}$. This change has been made.

REVIEWER 4

**Comment:** A short but technically correct definition of cSEL might be valuable for the reader here.

***Response***: NOAA agrees. The following definition has been added:
Level of acoustic energy accumulated over a given period of time or event (EPA 1982) or specifically, ten times the logarithm to the base ten of the ratio of a given time integral of squared instantaneous frequency-weighted sound pressure over a stated time interval or event to the squared reference pressure (ANSI 1994, 1995).

This was done for peak pressure: Greatest absolute instantaneous sound pressure within a specified time interval (ANSI 1986; ANSI 1994).
These definitions also appear in the Glossary.

**Comment:** Re: "Since currently no published data exist on PTS in marine mammals, TTS data were evaluated and summarized to extrapolate to PTS onset"
using the assumption from......

***Response:*** How extrapolations were done is described in Step 6 (a few lines down):
Extrapolation for PTS onset (both in peak pressure and $SEL_{cum}$ metrics) based on data from humans and terrestrial mammals.

**Comment**: HMMM, does this mean that the dolphins measured and published by Au (1980) producing 230 dB peak to peak echolocation clicks are deafening themselves? How about the sperm whales with their 240 dB peak to peak clicks? Are both species deafening their neighbors? Is this issue addressed at all?

***Response:*** This issue isn't addressed because the Guidance document is restricted to covering exposure to anthropogenic sounds. Additionally, the proposed TTS and PTS acoustic threshold levels are for the onset of TTS or PTS (i.e., proposed acoustic threshold levels are likely conservative). In some situations, marine mammals have been exposed to levels exceeding proposed PTS onset acoustic threshold levels and have still recovered often within 24 h or less (i.e., Kastak et al. 2005; Nachtigall et al. 2003; Nachtigall et al. 2004; Finneran et al. 2010a; Popov et al. 2011a; the exception is Finneran et al. 2007 that saw recovery within four days after exposure).

Animals that echolocate have mechanisms to protect their own hearing during vocalizations. Additionally, frequencies used for echolocation are high, which means they attenuate rather quickly. Thus, the likelihood of animals deafening themselves or conspecific neighbors is considered highly unlikely.

## III. REGULATORY CONTEXT FOR AUDITORY IMPACT ACOUSTIC THRESHOLD LEVELS FOR MARINE MAMMALS

[Note: This section was not included for peer review. The intent of the peer review process is to focus is on the technical aspects of the document. It is not for comment on any potential policy or legal implications of the application of the guidance document, or on the amount of uncertainty that is acceptable or the amount of precaution that should be embedded in any regulatory analysis of impact (OMB 2005).]

## IV. UPDATE OF ACOUSTIC GUIDANCE AND ACOUSTIC THRESHOLD LEVELS

REVIEWER 4

**Comment**: Re: "NOAA will establish a small internal, cross-agency team, consisting of staff from our various offices, regions, and science centers, to re-evaluate and update acoustic noise exposure levels with new data every three to five years or more frequently, if deemed necessary."

Given that much of the data has been generated outside of NOAA, would it not be valuable to reach outside of the agency for expertise and advice? Why only make the group small and internal?

***Response***: NOAA's internal review group will be used for initial vetting prior to proposing and seeking public comment on any major changes to the Guidance.

## APPENDIX A: MARINE MAMMAL AUDITORY WEIGHTING FUNCTION AMPLITUDES

There were no peer reviewer comments made on this section of the document.

## APPENDIX B: DEVELOPMENT OF ACOUSTIC THRESHOLD LEVELS FOR ONSET OF PERMANENT AND TEMPORARY THREHSOLD SHIFT

REVIEWER 1

**Comment**: Complement: I like B7, and a plan for incorporating future research in general.
Just wanted to show I can say positive things, too!

***Response***: NOAA agrees that having a plan to incorporate future research is essential.

REVIEWER 3

**Comment**: Re: However, NOAA recognizes that the implementation of marine mammal weighting functions represents a new, relatively complex factor for consideration, which may extend beyond the capabilities of some.
How will this be determined? As these alternative levels are different it provides applicants with the opportunity to choose the values which are most beneficial for them.

> ***Response***: NOAA disagrees. Alternative acoustic threshold levels, although simpler, typically result in higher exposure levels because the alternative levels do not incorporate as many factors in the analysis. Thus, these alternative levels end up predicting more individuals will experience TTS or PTS than if they were not used. There is no advantage of using alternative levels, but this is ultimately the choice of the applicant.

**Comment**: Re: If a sound is above the inflection point, the functional hearing group has enhanced hearing sensitivity and susceptibility to noise-induced hearing loss (i.e., PTS or TTS)
See earlier comment: this wording suggests that the default exposure levels (Type II) are more protective than the Type I weighting curve suggested by Southall et al. (2007) while in fact they are not. The default Type II weighting curves have their highest sensitivity at 20-40 kHz (MF and HF cetaceans) and strongly reduced levels at frequencies below the inflection point.

> ***Response***: NOAA believes that the auditory weighting functions presented in Finneran and Jenkins represents the most recent science regarding susceptibility to noise-induced hearing loss, especially at frequencies above 3 kHz for MF cetaceans (i.e., bottlenose dolphins). NOAA acknowledges that there are limited data currently available. Also note, the term inflection point has been removed from the document.

**Comment**: Re: If there is an impulsive or a non-impulsive, broadband source with the majority of its sound pressure level above 3 kHz (for MF and HF cetaceans) or 6 kHz (for LF cetaceans), then proposed default criteria would need to be modified (case-by-case basis)

Following which principle approach? Whose authority is it to determine the criteria on a case-by-case basis?

> **Response**: It would be NOAA's authority (i.e., not the applicant). Also note, in the updated version of the document 6 kHz has been changed to 10 kHz.

**Comment**: Re: Popov et al. 2011a found that, in general, the lower the frequency range of exposure, the larger the amount of TTS. This result was reported as unexpected, since this species is more sensitive to higher frequencies. It also took longer for these lower frequencies to recover. They also reported exposures of higher level and shorter duration resulted in higher levels of TTS compared to exposures of lower level and longer duration, which is contrary to what has been found in other studies (e.g., Kastak et al. 2005; Kastak et al. 2007; Mooney et al. 2009b; Finneran et al. 2010a; Kastelein et al. 2012a; Kastelein et al. 2012b).

Which indicates that there might be again a substantial difference between these two functional hearing groups.

> ***Response***: NOAA agrees that there could be differences between these functional hearing groups, but current data indicate, as far as auditory weighting functions, that both MF and HF are most susceptible in a similar frequency range. For PTS onset acoustic threshold levels, HF cetaceans have a lower onset compared to MF cetaceans, indicating that they are more sensitive. As more data become available, both auditory weighting functions and acoustic threshold levels can be further refined.

## APPENDIX C: PEER REVIEW PROCESS

There were no peer reviewer comments made on this section of the document.

## APPENDIX D: GLOSSARY

This appendix was not included in the version reviewed by the peer reviewers.

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